REPUBLIC OF KENYA

LEARNING GUIDE

FOR

COMMON COMPETENCIES

FOR

ELECTRICAL, ELECTRONICS AND MECHANICAL ENGINEERING SECTORS

LEVEL 6

TVET CDACC
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FOREWORD

The provision of quality education and training is fundamental to the Government's overall strategy for social economic development. Quality education and training will contribute to achievement of Kenya's development blue print and sustainable development goals. This can only be addressed if the current skill gap in the world of work is critically taken into consideration.

Reforms in the education sector are necessary for the achievement of Kenya Vision 2030 and meeting the provisions of the Constitution of Kenya 2010. The education sector has to be aligned to the Constitution and this has triggered the formulation of the Policy Framework for Reforming Education and Training (Sessional Paper No. 4 of 2016). A key provision of this policy is the radical change in the design and delivery of the TVET training which is the key to unlocking the country's potential in industrialization. This policy document requires that training in TVET be Competency Based, Curriculum development be industry led, certification be based on demonstration and mastery of competence and mode of delivery allows for multiple entry and exit in TVET programs.

These reforms demand that industry takes a leading role in TVET curriculum development to ensure the curriculum addresses and responds to its competence needs. The learning guide in common competencies for this sector enhances a harmonized delivery the competency-based curriculum for Electrical, Electronics and Mechanical sectors level 6.

It is my conviction that this learning guide will play a critical role towards supporting the development of competent human resource for the Electrical, Electronics and Mechanical sectors' growth and sustainable development.

PRINCIPAL SECRETARY, VOCATIONAL AND TECHNICAL TRAINING
MINISTRY OF EDUCATION

PREFACE

Kenya Vision 2030 is anticipated to transform the country into a newly industrializing, "middle-income country providing a high-quality life to all its citizens by the year 2030". The Sustainable Development Goals (SDGs) further affirm that the manufacturing sector is an important driver to economic development. The SDG nine that focuses on Building resilient infrastructures, promoting sustainable industrialization and innovation can only be attained if the curriculum focuses on skill acquisition and mastery. Kenya intends to create a globally competitive and adaptive human resource base to meet the requirements of a rapidly industrializing economy through life-long education and training. TVET has a responsibility of facilitating the process of inculcating knowledge, skills and attitudes necessary for catapulting the nation to a globally competitive country, hence the paradigm shift to embrace Competency Based Education and Training (CBET). The Technical and Vocational Education and Training Act No. 29 of 2013 and the Sessional Paper No. 4 of 2016 on Reforming Education and Training in Kenya, emphasized the need to reform curriculum development, assessment and certification to respond to the unique needs of the industry. This called for shift to CBET to address the mismatch between skills acquired through training and skills needed by industry as well as increase the global competitiveness of Kenyan labor force.

The TVET Curriculum Development, Assessment and Certification Council (TVET CDACC), in conjunction industry/sector developed the Occupational Standards which was the basis of developing competency-based curriculum and assessment of an individual for common competencies for an Electrical, Electronics and Mechanical sectors' level 6. The learning guide is geared towards promoting efficiency in delivery of curriculum. The learning guide is designed and organized with clear and interactive learning activities for each learning outcome of a unit of competency. The guide further provides information sheet, self-assessment, tools, equipment's, supplies, and materials and references.

I am grateful to the Council Members, Council Secretariat, Electrical, Electronics and Mechanical sectors' experts and all those who participated in the development of this learning guide.

Prof. CHARLES M. M. ONDIEKI, PhD, FIET (K), Con. EngTech.
CHAIRMAN, TVET CDACC

ACKNOWLEDGEMENT

This learning guide has been designed to support and enhance uniformity, standardization and coherence in implementing TVET Competency Based Education and training in Kenya. In developing the learning guide, significant involvement and support was received from various organizations.

I recognize with appreciation the critical role of the participants drawn from technical training institutes, universities and private sector in ensuring that this learning guide is in-line with the competencies required by the industry as stipulated in the occupational standards and curriculum. I also thank all stakeholders in the Electrical, Electronics and Mechanical sectors for their valuable input and all those who participated in the process of developing this learning guide.

I am convinced that this learning guide will go a long way in ensuring that workers in Electrical, Electronics and Mechanical sectors acquire competencies that will enable them to perform their work more efficiently and make them enjoy competitive advantage in the world of work

DR. LAWRENCE GUANTAI M'ITONGA, PhD
COUNCIL SECRETARY/CEO
TVET CDACC

ACRONYMNS AND ABBREVIATIONS

CAD	Computer Aided Design
CCTV	Closed Circuit Tele Vision
CDACC	Curriculum Development, Assessment and Certification Council
EHS	Environment Health and Safety
IEE	Institute of Electrical Engineers
HVAC	Heating Ventilation and Air Conditioning
IBMS	Integrated Building Management System
K.C.S. E	Kenya Certificate of Secondary Education
KNQA	Kenya National Qualification Authority
KNQF	Kenya National Qualification Framework
KEBS	Kenya Bureau of Standards
KPLC	Kenya Power and Lighting Company
NCA	National Construction Authority
NEMA	National Environment Management Authority
OSHA	Occupational Safety and Health Act
PPE	Personal Protective Equipment
PV	Photo Voltaic
TVET	Technical and Vocational Education and Training
WIBA	Work Injury Benefits Act
CPU	Control Powering Unit
CR	Core Competency
DTI	Dial test indicator
ENG	Engineering
FOT	Fixed orifice tube
GPS	Global positioning system
IBL	Industrial Based Learning
ICT	Information and Communication Technology
IT	Information Technology
KPI	King Pin inclination
MPE	Mechanical Plant Engineering
MPT	Mechanical Plant Technician
OBD	On-board diagnostics
OS	Occupational Standards
PPE	Personal protective equipment
SI	Spark ignition
SOP	Standard Operating Procedures
TVET	Technical and Vocational Education and Training
TQM	Total Quality Management

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LIST OF TABLES AND FIGURES

CHAPTER 1: INTRODUCTION

1.1. Background Information

This learning guide has been developed in line with the functions of TVET CDACC as stipulated in Article 45 (1a) of the Technical and Vocational Education and Training (TVET) Act No. 29 of 2013, the Sessional Paper No. 2 of 2015 that embraces Competency Based Education and Training (CBET) system. It is therefore, the sole intent of this document to provide guidelines for a Competency-Based Common Competencies for Electrical and Electronics Engineering, and Mechanical Engineering Sectors for level 6

This learning guide consists of interactive learning activities, content, self assessment and relevant and related references that enhances implementing of the Engineering courses for level 6 qualification. It enables the trainee to acquire the competencies that enable him/her to undertake the various processes in Electrical, Electronics and Mechanical Engineering Sectors. The Guide further provides illustration, web links, case studies, exmaples and resources on how to implement all the learning outcomes/elements described in the Curriculum and occupational standards with a particular focus to a trainee.

1.2. The Purpose of Developing the Trainee Guide

Electrical Engineering (Power option) Level 6 curriculum development process was initiated using the DACUM methodology where jobs/occupations were identified. Further, job analysis charts and occupational standards were generated in collaboration with the industry players under the guidance of TVET CDACC (Curriculum Development Assessment and Certification council). The result of the process was an Electrical, Electronics and Mechanical Engineering level 6 common units. The common units were further broken down to end up with units of learning. To effectively implement common units, learning guides are required to provide training content and guide the learner and trainers on the learning process aimed at imparting g the relevant knowledge, requisite skills and the right attitude the industry. Learning guides are part of the raining materials

1.3. Layout of the Trainee Guide

The learning guide is organized as per chapters. Chapter one presents the background information, and purpose of developing the trainee guide. Each of the units of learning/unit of competency is presented as a chapter on its own. Each chapter presents the introduction of the unit of learning/unit of competency, performance standard and list of the learning outcome/elements in the occupational standards.

Learning Activities

For each learning outcome, the learning activities are presented covering the performance criteria statements and trainees demonstration of knowledge in relation to the range in the occupational standard and content in the curriculum.

Information Sheet
The information sheet is section under each learning outcome that provides the subject matter in relation to definition of key terms, method, processes/procedures/guidelines, content, illustrations (photographs, pictures, video, charts, plans, digital content, and simulation) and case studies.

Self-Assessment
Self-assessment based on the performance criteria, required knowledge, skills and the range as stated in the occupational standards. The section further provides questions and assignments in which trainees demonstrate that they have acquired the required competences and an opportunity to reflect on what they have acquired. It is expected that the trainer keeps a record of their plans, their progress and the problems they encountered which will go in trainee's portfolio. A portfolio assessment consists of a selection of evidence that meets the pre-defined requirements of complexity, authenticity and reliability. The portfolio starts at the beginning of the training and will be the evidence for the development and acquisition of the competence (summative and formative) by the student. It is important to note that Portfolio assessment is highly emphasized in the learning guide

Finally the guide presents tools, equipment's, supplies and materials for each learning outcome as guided by the performance criteria in occupational standards and content in curriculum. References, relevant links and addendums are provided for further reading. The units of competency comprising this qualification include the following common and units of learning:

This course is designed to equip learners with the competencies required to apply engineering mathematics, perform workshop processes, apply electrical principles, prepare and interpret technical drawings, apply mechanical science principles, apply thermodynamic principles, apply fluid mechanics principles and apply material science and perform metallurgical processes.

Common Units of Learning

Table 1: Common Units of Learning

Unit Code	Unit Title	Duration in Hours	Credit Factors
ENG/CU/PO/CC/01/6	Engineering Mathematics	110	11
ENG/CU/PO/CC/02/6	Electrical principles	240	24
ENG/CU/PO/CC/03/6	Workshop Technology	60	6
ENG/CU/PO/CC/04/6	Technical Drawing	130	13
ENG/CU/PO/CC/05/6	Mechanical Science Principles	75	7.5
ENG/CU/PO/CC/06/6	Thermodynamic Principles	40	4.0
ENG/CU/PO/CC/07/6	Fluid Mechanic Principles	75	7.5

ENG/CU/PO/CC/08/6	Material Science & Metallurgical Processes	70	7.5
Total		800	80.0

CHAPTER 2: ENGINEERING MATHEMATICS /APPLY ENGINEERING MATHEMATICS

2.1. Introduction of the Unit of Learning / Unit of Competency

This unit describes the competencies required by a technician in order to apply algebra, apply trigonometry and hyperbolic functions, apply complex numbers, apply coordinate geometry, carry out binomial expansion, apply calculus, solve ordinary differential equations, solve Laplace transforms ,apply power series, apply statistics, apply numerical methods, apply vector theory apply matrix, apply Fourier series and numerical methods.

2.2. Performance Standard

The trainee will apply algebra, trigonometry and hyperbolic functions, complex numbers, coordinate geometry, carryout binomial expansion, calculus ordinary differential equations, Laplace transforms, power series, statistics Fourier series, vector theory, matrix and numerical methods in solving engineering problems.

2.3. Learning Outcomes

2.3.1. List of Learning Outcomes

a) Apply Algebra
b) Apply Trigonometry and hyperbolic functions
c) Apply complex numbers
d) Apply coordinate geometry
e) Carry out Binomial Expansion
f) Apply Calculus
g) Solve ordinary differential equations
h) Apply Laplace transforms
i) Apply power series
j) Apply statistics
k) Apply Fourier series
l) Apply vector theory
m) Apply matrix
n) Numerical methods

2.3.2. Learning Outcome No. 1. Apply Algebra

2.3.2.1 Learning Activities.

Learning Outcome No. 1. Apply Algebra	
Learning Activities	Special Instructions
• Perform calculations involving indices as per the concept • Perform calculations involving logarithms as per the concept • Solving simultaneous as per the rules • Solving quadratic equations as per the concept	

2.3.2.2. Information Sheet No.2/ LO1.

Algebra is used throughout engineering, but it is most commonly used in mechanical, electrical, and civil branches due to the variety of obstacles they face. Engineers need to find dimensions, slopes, and ways to efficiently create any structure or object.

Definitions

Algebra is the study of mathematical symbols and the rules for manipulating these symbols; it is a unifying thread of almost all of mathematics. It includes everything from elementary equation solving to the study of abstractions such as groups, rings, and fields.

Content

Indices

An index number is a number which is raised to a power. The power, also known as the index, tells you how many times you have to multiply the number by itself. For example, 2^5 means that you have to multiply 2 by itself five times = 2×2×2×2×2 = 32

Laws of indices

(i) $x^0 = 1$

(ii) $x^{-n} = \frac{1}{x^n}$

(iii) $x^n.x^m = x^{n+m}$

(iv) $x^n - x^m = x^{n-m}$

(v) $(x^n)^m = x^{m.n}$

(vi) $x^{\frac{n}{m}} = \sqrt[m]{x^n}$

Application of rules of indices in solving problems.

- $y^a \times y^b = y^{a+b}$

Examples

$2^4 \times 2^8 = 2^{12}$

$5^4 \times 5^{-2} = 5^2$

- $y^a \div y^b = y^{a-b}$

Examples

$2-3 \ = \ 1/23 \ = \ 1/8$

$3^{-1}=1/3$

- $ym/n \ = \ (n\sqrt{}y)m$

Examples

$16^{1/2} = \sqrt{16} = 4$

$8^{2/3} = (\sqrt[3]{8})^2 = 4$

- $(y^n)^m = y^{nm}$

Example

$2^5 + 8^4$

$= 2^5 + (2^3)^4$

$= 2^5 + 2^{12}$

$y^0 = 1$

Example

$5^0 = 1$

Logarithms

If a is a positive real number other than 1, then the logarithm of x with base a is defined by:

$y = \log_a x$ or $x = a^y$

Laws of logarithms

(i) $log_a(xy) = log_a x + log_a y$

(ii) $log_a\left(\frac{x}{y}\right) = log_a x + log_a y$

(iii) $log_a(x^n) = nlog_a x$ for every real number

Simultaneous equations with three unknown

Simultaneous equations are equations which have to be solved together to find the unique values of the unknown quantities which are time for each of the equations. Two methods of solving simultaneous equations analytically are:

(i) By substitution

(ii) By elimination

Examples

Solve the following simultaneous equation by substitution methods

$3x - 2y + = 1 \ldots\ldots\ldots..(\text{i})$

$x - 3y + 2z = 13 \ldots\ldots.(ii)$

$4x - 2y + 3z = 17 \ldots\ldots\ldots(iii)$

From equation (ii) $x = 13 + 3y - 2z$

Substituting these expression $(13 + 3y - 2z \quad for\ x\ \ gives)$

$3(13 + 3y - 2z) + 2y + z = 1$

$39 + 9y - 6z + 2y + x = 1$

$11y - 5z = -38 \ldots\ldots\ldots\ldots\ldots..(iv)$

$4(13 + 3y - 2z) + 3z - 2y = 17$

$52 + 12y - 8z + 3z - 2y = 17$

$10y - 5z = -35 \ldots..(v)$

Solve equation (iv) and (v) in the usual way,

From equations (iv) $5z = 11y + 38; z = \frac{11y+38}{5}$

Substituting this in equation (v) gives

$$10y - 5\left(\frac{11y + 38}{5}\right) = -35$$

$$10y - 11y - 38 = -35$$

$$-y = -35 + 38 = 3$$

$$y = -3$$

$$z = \frac{11y + 38}{5} = \frac{-33 + 38}{5} = \frac{5}{5} = 1$$

But $x = 13 + 3y - 2z$

$x = 13 + 3(-3) - 2(1)$

$= 13 - 9 - 2$

$= 2$

Therefore, $x = 2,\ y = -3\ \ and\ z = 1$ is the required solution

For more worked examples on substitution and elimination method refer to Engineering Mathematics by A.K Stroud.

Quadratic Equations

Quadratic equation is one in which the highest power of the unknown quantity is 2. For example $2x^2 - 3x - 5 = 0$ is a quadratic equation? The general form of a quadratic equation is $ax^2 + bx + c = 0, where\ a, b\ and\ c$ are constants and $a \neq 0\ of\ solving\ quadratic\ equations$.

a. By factorization (where possible)
b. By completing the square
c. By using quadratic formula
d. Graphically

Example

Solve the quadratic equation $x^2 - 4x + 4 = 0$ by factorization method

Solution

$$x^2 - 4x + 4 = 0$$
$$x^2 - 2x - 2x + 4 = 0$$
$$x(x-2) - 2(x-2) = 0$$
$$(x-2)(x-2) = 0$$

i.e $x - 2 = 0\ \ or\ x - 2 = 0$

$x = 2\ \ or\ x = 2$

i.e. the solution is $x = 2$(twice)

For more worked examples on how to solve quadratic equations using, factorization, completing the square, quadratic formula refer to basic engineering mathematics by J.O Bird, Engineering mathematical by K.A STROUD etc

2.3.2.3. Self-Assessment

This section must be related with the Performance Criteria, Required Knowledge and Skills and the Range as stated in the Occupational Standards.

Q1. (a) Solve the following by factorization

(i) $x^2 + 8x + 7 = 0$

(ii) $x^2 - 2x + 1 = 0$

(b) Solve by completing the square the following quadratic equations

(i) $2x^2 + 3x - 6$

(ii) $3x^2 - x - 6 = 0$

Q.2 Simplify as far as possible

(i) $log(x^2 + 4x - 3) - log(x + 1)$

(ii) $2log(x - 1) - log(x^2 - 1)$

Q.3 Solve the following simultaneous equations by the method of substitution

$$x + 3y - z = 2$$
$$2x - 2y + 2z = 2$$
$$4x - 3y + 5z = 5$$

Q.4 Simplify the following

$$F = (2_{x}^{\frac{1}{2}} y^{\frac{1}{4}})^4 \div \sqrt{\frac{1}{9}}x^2y^6 \ x \ (4\sqrt{x^2y^4})^{-1/2}$$

Describe quadratic equations.

Differentiate between the two methods of solving simultaneous equations

(i) By substitution

(ii) By elimination

Indices is the study of mathematical symbols and the rules for manipulating these symbols. True or false?

Quadratic equation is one in which the highest power of the unknown quantity is 2. True or false

2.3.2.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Calculator
- Writing materials

2.3.2.5. References

- Basic Engineering Mathematics by J.O Bird
- Engineering Mathematics by K.A STROUD
- Technical mathematics book 2 by J.O bird

2.3.3. Learning Outcome No. 2. Apply trigonometry and hyperbolic functions

2.3.3.1. Learning Activities

Learning Outcome No. 2. Apply Trigonometry And Hyperbolic Functions	
Learning Activities	Special Instructions
• Perform calculations using trigonometric rules • Perform calculations using hyperbolic functions	

2.3.3.2. Information Sheet No 2/LO2.

Trigonometry is the branch of mathematics which deals with the measurement of sides and angles of triangles and their relationship with each other. Two common units used for measuring angles are degrees and radians.

Trigonometric ratios

The three trigonometric ratios derived from a right - angled triangle are the same, cosine and tangent refer to basic engineering mathematics by J.0 Bird to read move about trigonometry ratios.

Solution of right-angled triangles

To solve a triangle means to find the unknown sides and angles, this is achieved by using the theorem of Pythagoras and or using trigonometric ratios.

Example

In a triangle PQR shown below find the length of PQ and PR

$$t\ on\ 38^0 = \frac{PQ}{QR} = \frac{PQ}{7.5}$$

Hence

$$\begin{aligned} PQ &= 7.5\ X\ \tan 38^0 \\ &= 7.5\ x\ 0.7813 \\ &= 5.86\ cm \end{aligned}$$

$$\cos 38^0 = \frac{QR}{PR} = \frac{7.5}{PR}$$

$PR = \frac{7.5}{cos 38^0} = \frac{7.5}{0.7880}$ =9.518cm

For more worked examples refer to basic engineering mathematics by J.) Bird. Also use it to learn about angles of elevation and depression.

Compound angle formulae

Sin $(A \pm B) = Sin\ A \cos B \pm Cos\ A \sin B$

$$Cos(A \pm B) = Cos\ Acos\ B \mp Sin\ A\ Sin\ B$$

$$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \; tanB}$$

Refer to technician mathematics book 3 by J.O Bird and learn more about compound angle formulae

Conversion of a coswt + bsinwt into the general form $R\ Sin(wt + 2)$

Let a Coswt + bSinwt = $R\ Sin(wt{+}\propto)$

Expanding the right hand side using the compound angle formulae gives

Acoswt + bSinwt = $R(Sinwt\ Cos \propto\ +coswt\ sin \propto)$

$=R \cos \propto\ |Sinwt + R\ Sin\ \propto Coswt$

Equating the coefficients of Coswt on both sides gives.

$a = R\ Sin \propto i.e\ Sin\ \propto = \dfrac{a}{R}$

Equating the coefficients of Sinwt on both sides gives

$b = R\ cos \propto\ \ i.e\ Cos\ \propto = \dfrac{b}{R}$

If the values of $a\ and\ b$ are known, the values of $R\ and\ \alpha$ can be calculated.

From Pythagoras theorem.

Diagram

$R = \sqrt{a^2} + b^2$

And from trigonometric ratios,

$\propto = tan^{-1}(\dfrac{a}{b})$

Example

Express 3 $Sin\ \theta + 4\ Cos\theta$ in the general form $R\ Sin(\theta + \alpha)$

Let 3 $Sin\ \theta + 4\ Cos\ \theta = R\ Sin\ (\theta + \alpha)$

Expanding the right hand side using the compound angle formulae gives

$3\ Sin\ \theta + 4\ Cos\ \theta = R\ [Sin\theta\ Cos\alpha + Cos\ \theta\ Sin\alpha\ ]$

$= R\ cos\alpha\ Sin\ \theta + R\ Sin\ \alpha\ Cos\ \theta$

Equating the coefficient of:

$Cos\theta; == R\ Sin\ \alpha\ i.e\ Sin\ \alpha = \dfrac{4}{R}$

Sin θ : $3 = R\ Cos\ \alpha\ \ i.e\ \ Cos\ \alpha = \frac{3}{R}$

This the values of $R\ and\ \alpha$ can be evaluated.

Diagram

$$R = \sqrt{4^2 + 3^2 = 5}$$

$$\alpha = tan^{-1}\frac{4}{3} = 53.13^0 or\ \ 233.13^0$$

Since both $Sin\ \alpha\ and\ Cos\ \alpha$ are positive, r lies in the first quadrant where all are positive, Hence 233.13^0 is neglected.

Hence

$3\ Sin\theta + 4\ Cos\ \theta = 5\ Sin\ (\theta + 53.13^0)$

Example

Solve the equation $3\ Sin\ \theta + 4\ Cos\ \theta = 2$ for values of θ between 0^0 and 360^0 inclusive

Soln:

From the example above

$3\ Sin\theta + 4\ Cos\ \theta = 5\ Sin\ (\theta + 53.13^0)$

Thus

$5\ Sin(\alpha + 53.13^0) = 2$

$Sin(\theta + 53.13^0) = \dfrac{2}{5}$

$\theta + \ 53.13^0 = Sin^{-1}\ 2/5$

$\theta + \ 53.13^0 = \ 23.58^0$ or 156.42^0

$\theta = \ 23.58^0 - \ 53.13^0 = -29.55^0$

$=330.45^0$

OR $\theta = 156.42^0 - 53.13^0$

$=103.29^0$

Therefore the roots of the above equation are 103.29^0 *or* 330.45^0

For more worked examples refer to Technician mathematics book 3 by J.) Bird.

Double /multiple angles
For double and multiple angles refer to Technician mathematics by J.O Bird

Factor Formulae
For worked exampled refer to Technic mathematics book 3 by J. O Bird, Pure mathematics by backhouse and Engineering mathematics by KA Stroud.

Half –angle formulae
Refer to pure mathematics by backhouse and Engineering mathematics by K.A STROUD

Hyperbolic functions
Definition of hyperbolic functions, $Sinhx\ cosh\ x\ and\ tanh\ x$

- Evaluation of hyperbolic functions
- Hyperbolic identifies
- Osborne's Rule
- Solve hyperbolic equations of the form a $coshx + bSinhx = C$

For all the above refer, to Engineering mathematics by K.A STROUD

2.3.3.3. Self-Assessment
Q1. A surveyor measures the angle of elevation of the top of a perpendicular building as19^0. He moves 120m nearer the building and measures the angle of elevation as47^0. Calculate the height of the building to the nearest meter.

Q2. Solve the equation $5\cos\theta + 4\ Sin\ \theta = 3$ for values of θ between 0^0 and 360^0
Inclusive.

Q3. Prove there identifies

$(i)\ Cash\ 2x = cash^2x + Sinh^2x$

$(ii) Sinh(x + y) Sinh\ Coshy\ + coshy\ Sinhx$

Q.4 Solve the equation
$3\ Sin\ hx + 4\ Coshx = 5$
Define trigonometry

5. Describe trigonometric ratios
6. Differentiate various hyperbolic functions
7. Perform calculations on various hyperbolic functions
8. Trigonometry is the branch of mathematics which deals with the measurement of sides and angles of triangles and their relationship with each other. True or false?
9. Hyperbolic function is in the form sinX, TanX. True or False?

2.3.3.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

Writing materials

Geometrical set

Calculator

2.3.3.5. References

- Basic engineering mathematics by J.O Bird
- Technical mathematics book 3 by J.O Bird
- Pure mathematics book 1 by Backhouse
- Engineering mathematics by K a Stroud

2.3.4. Learning Outcome No.3 Apply Complex Number

2.3.4.1. Learning Activities

Learning Outcome No. 3. Apply Complex Number	
Learning Activities	Special Instructions
• Preparing complex numbers using ARgand diagrams • Performing operations involving complex number • Performing calculations involving complex number using De Moirés theorem	

2.3.4.2. Information Sheet chapter 2/LO3

Apply Complex Number

A number of the form $a + ib$ is called complex number where $a \; and \; b$ are real numbers and $i = \sqrt{-1}$ we call $'a'$ the real part and 'b' the imaginary part of the complex $a + ib$ if $a = o$ then ib is said to be purely imaginary, if $b = 0$ the number is real.

Pair of complex number $a + ib$ are said to be conjugate of each other.

Addition and subtraction of complex numbers

Addition and subtraction of complex numbers is achieved by adding or subtracting the real parts and the imaginary parts.

Example 1

$(4 + j5) + (3 - j2)$

$(4 + j5) + (3 - j2)$=$4 + j5 + 3 - j2$

=$(4 + 3) + j(5 - 2)$

=$7 + j3$

Example 2

$$(4 + j7) - (2 - js) = 4 + j7 - 2 + js = (4 - 2) + j(7 + 5)$$
$$= 2 \; + j12$$

Multiplication of complex numbers

Example 1

$(3 + j4)(2 + j5)$

$6 + j8 + j15 + j^2 20$

$6 + j23 - 20 \; (since j^2 = -1)$

=$-14 + j^{23}$

Examples 2

$(5 + j8)(5 - j8)$

$(5 + j8)(5 - j8) = 25 + j40 - j40 - j^2 64$

$= 25 + 64$

=89

A pair of complex numbers are called conjugate complex numbers and the product of two conjugate. Complex numbers is always entirely real. $cos\theta + jsin\theta$

Argand diagram

Although we cannot evaluate a complex number as a real number, we can represent diagrammatically in an argand diagram. Refer to Engineering Mathematics by K.A Stroud to learn more on how to represent complex numbers on an argand diagram. Use the same back learn three forms of expressing a complex number.

Demoivre's Theorem

Demoivre's theorem states that $[r(cos\theta + jsin\theta)]^n = r^n(cosn\theta + jsinn\theta)$

It is used in finding powers and roots of complex numbers in polar

Example

Find the three cube roots of $z = 5(cos225^0 + jsin225^0)$

$$Z_1 = Z^{\frac{1}{3}}\left(Cos\frac{225^0}{3} + jsin\frac{225^0}{3}\right)$$

$1.71\ (cos75^0 + jsin75^0$

$z_1 = 1.71\ (cos75^0 + jSin75^0)$

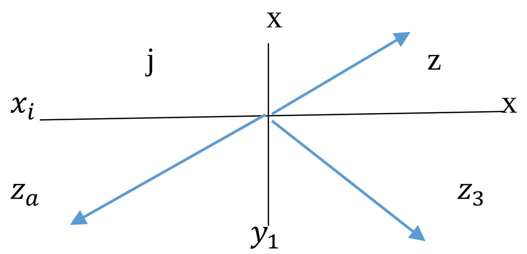
Cube roots are the same size (modules) i.e 1.71 and separated at intervals of $\frac{360^0}{3}$, i.e 120^0

$z_{1=1.71\ /}\ 75^0$

$z_{2=1.71\ \cos(195^0+jSin195^0}$

z_s = 1.71 $(315^+ + jSin315^0)$

Sketched Argand diagram.



Refer to engineering mathematics by K.A Stroud and learn more on how to find the expansion of

$cos^n\theta$ and $cos^n\theta$

LOCI problems

We sometimes required to find the locus of a point which moves in the Argand diagram according to some stated condition.

Examples

If $Z = x + jy$, find the equation of the locus $\left[\frac{z+1}{z-1}\right] = 2$

$sin\theta Z = x + jy.$

$Z + 1 = X + jy + 1 = (x + 1) + jy = r_1 angle\ \theta_1 = z_1$

$z - 1 = x + jy - 1 = (x - 1) + jy = r_2 r_1 angle\ \theta_2 = z_2$

$\therefore\ \frac{z+1}{z-1} = \frac{r_{1\theta_1}}{r_{2\theta_2}} = \frac{r_1}{r_2}\ \theta_1$ -θ_2

$\therefore\ \left(\frac{Z+1}{z-1}\right) = \frac{r_1}{r_2} = \left(\frac{z_1}{z_2}\right) = \frac{[(x+1)^2 + y^2]}{[(x-1)^2) + y^2]}$

$$\frac{[(x+1)^2 + y^2]}{(x-1)^2 + y^2}$$

$$\therefore \frac{(x+1)^2 + y^2}{(x-1)^2 + y^2} + 4$$

$\therefore (x + 1)^2 + y^2 = 4\ ((x - 1)^2 + y^2)$

$x^2 + 2x + 1 + y^2 = 4(x^2 - 2x + 1 + y^2)$

$=4x^2 - 8x + 4 + 4y^2$

$\therefore 3x^2$-10x+3+$3y^2 = 0$

2.3.4.3. Self-Assessment

1. Find the fifth roots of $-3 + j3$ in polar form and in exponential form
2. Determine the three cube roots of $\frac{2-j}{2+j}$ giving the results in a modulus/ argument form.

   Express the principal root in the form $a + jb$
3. If $z = x + jy,\ where\ x\ and\ y$ are real, show that the locus $\left(\frac{Z-2}{z+2}\right) = 2$ is a circle and determine its center and radius.
4. Describe De Moirés theorem
5. Perform calculations involving complex number using De Moirés theorem
6. Explain Argand diagram
7. A number of the form $a + ib$ is called complex number where $a\ and\ b$ are real numbers and $i = \sqrt{-1}$ TRUE OR FALSE?
8. Demoivre's theorem states that $[r(cos\theta + jsin\theta)]^n = r^n(cosn\theta + jsinn\theta)$ TRUE OR FALSE?

2.3.4.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Calculator
- Writing materials
- Geometrical set.

2.3.4.5. References

1. Technician Mathematics Book (4 and 5) by J.O Bird
2. Engineering Mathematics by K.A Stround
3. Mathematics for Engineers by Dass

2.3.5. Learning Outcome No. 4. Apply Co-ordinate Geometry

2.3.5.1. Learning Activities

Learning Outcome No. 4. Apply Co-Ordinate Geometry	
Learning Activities	Special Instructions
• Calculating polar equations using coordinate geometry • Drawing graphs of given polar equations using the Cartesian plane • Determining normal and tangents using coordinate geometry	

2.3.5.2 Information Sheet No. 2/LO4

Introduction

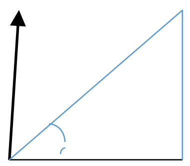
The position of a point in a plane can be represented in two forms

i) Cartesian co-ordinate (x, y)

ii) Polar co-ordinate (r, θ)

The position of a point in the corresponding axis can therefore generate Cartesian and polar equations which can easily change into required form to fit the required result.

Example



Convert $r^2 = sin\theta$ into Cartesian form.

$$cos\theta = \frac{x}{y}$$

$$sin\theta = \frac{y}{x}$$

Form Pythagoras theorem $r^2 = x^2 + y^2$

$$r^2 = sin\theta$$

$$(x^2 + y^2) = \frac{y}{x}$$

$$(x^2 + y^2)r = y$$

$$(x^2 + y^2)(x^2 + y^2)^{\frac{1}{2}} = y$$

$$(x^2 + y^2)^{\frac{3}{2}} = y$$

Example 2

Find the Cartesian equation of

(i) $r = a(1 + 2cos)$ (ii) $rcos(\theta - \alpha) = p$

[The $Cos\theta$ suggest the relation$X = COS\theta$, so multiplying through by r}

$$\therefore r^2 = a(r + 2rcos\theta)$$

$$\therefore x^2 + y^2 = a\left(\sqrt{(x^2 + y^2)} + 2x\right)$$

$$\therefore x^2 + y^2 + 2x = a\sqrt{(x^2 + y^2})$$

Therefore the Cartesian equation of $r = a(1 + 2cos)$ is $(x^2 + y^2 - 2ax)^2 = a^2(x^2 + y^2)$

(ii) $rcos(\theta - \alpha) = p$

$cos(\theta - \alpha)$ May be expanded

$\therefore rcos\theta cos\alpha + rsin\theta sin\alpha = p$

(iii) Therefore the Cartesian equation of $rcos(\theta - \alpha) = p$ is $xcos\alpha + ysin\alpha = p$

Example 3

Find the polar equation of the circle whose Cartesian equation is $x^2 + y^2 = 4x$

$x^2 + y^2 = 4x$

Put $x = rcos\theta, y = rsin\theta$, then

$r^2cos^2\theta + r^2sin^2\theta = 4rcos\theta$

$\therefore r^2 = 4rcos\theta$

Therefore the polar equation of the circle is $r^2 = 4rcos\theta$.

For more information on the conversion of Cartesian equation to polar equation and vice versa refer to pure mathematics by J.K Backhouse

2.3.5.3. Self-Assessment

1) Obtain the polar equation of the following loci
   (i) $x^2 + y^2 = a^2$
   (ii) $x^2 - y^2 = a^2$
   (iii) $y = 0$
   (iv) $y^2 = 4a(a - x)$
   (v) $x^2 + y^2 - 2y = 0$
   (vi) $xy = c^2$
2) Obtain the Cartesian equation of the following loci
   (i) $r = 2$
   (ii) a(1+cosθ)
   (iii) $r = acos\theta$
   (iv) $r = atan\theta$
   (v) $r = 2a(1 + sin2\theta)$
   (vi) $2r^2sin2\theta = c^2$
   (vii) $\frac{l}{r} = 1 + 8cos\theta$
   (viii) $r = 4acot\theta cosec\theta$
3) Differentiate between Cartesian co-ordinate and Polar co-ordinate
4) Perform calculations on polar equations
5) The position of a point in a plane can be represented in two forms: Cartesian co-ordinate $(x, y) or$Polar co-ordinate (r, θ) TRUE OR FALSE?
6) The equation $r^2 = x^2 + y^2$ illustrates Pythagoras theorem. TRUE OR FALSE?

2.3.6 Learning Outcome No.5 Carry out Binomial Expansion
2.3.6.1 Learning Activities

Learning Outcome No. 5. Carry Out Binomial Expansion	
Learning Activities	Special Instructions
• Determining roots of numbers using binomial theorem • Determining errors and small changes using bionomical theorem • To cover the Performance Criteria statements • Trainees to demonstrate knowledge in relation to; The *Range* in the Occupational Standards and *Content* in the curriculum	

Carry out Binomial expansion

Binomial is a formula for raising a binomial expansion to any power without lengthy multiplication. It states that the general expansion of $(a+b)^n$ is given as

$(a+b)^n = a^n b^0 + na^{n-1}n^1 + \frac{n(n-1)a^{n-2}b^2}{2!} + \frac{n(n-1)(n-2)a^{n-3}b^3}{3!}+\ldots$

Where n can be a fraction, a decimal fraction, positive or negative integer.

Example 1

Use binomial theorem to expand $(2+x)^3$

Solution

$(a+b)^n = a^n b^0 + na^{n-1}n^1 + \frac{n(n-1)a^{n-2}b^2}{2!} + \frac{n(n-1)(n-2)a^{n-3}b^3}{3!}+\ldots$

$A = 2, b = x\ and\ n = 3$

$(2+x)^3 = 2^3x^0 + 32^2x^1 + \frac{3(3-1)2^1x^2}{2!} + \frac{3(3-1)(3-2)2^0x^3}{3!}+\ldots$

$= 18 + 12x + 6x^2 + x^3$

For more examples on positive power refer to Technician Mathematic Book by J.O Bird.

Binomial theorem for any index

It has been shown that

$(1+x)^n = 1 + nx + \frac{n(n-1)}{2!}x^2 +\ldots.$

The series may be continued indefinitely for any value of n provide $-1 < x < 1$

Example

Use the binomial theorem to expand $\frac{1}{1-x}$ in ascending power of x as far as the term in x^3.

Solution

Since $\frac{1}{1-x}$ may be written$(a - x + x)^{-1}$, the binomial theorem may be used. Thus

$(1-x)^{-1} = 1 + -1(-x) + \frac{-1(-2)}{2!}x^2 + \frac{-1(-2)(-3)}{3!}+\ldots.$

$$\frac{1}{1-x} = 1 + x + x^2 + x^3 + \cdots$$

Provided $-1 < x < 1$

Practical application of binomial theorem

Example1

The radius of a cylinder is reduced by 4% and its height increased by 2%. Determine the appropriate percentage change in its volume neglecting products of small quantities.

Solution

Volume $V = \pi r^2 h$

Let original values be, $radius = r$

$Height = h$

New values $radius = (1 - 0.04)r$

$Height = (1 + 0.02)h$

New volume $= \pi(1 - 0.004)^2 r^2 (1 + 0.04)h)$

Using binomial theorem, $(1 - 0.04)^2 = 1 - 2(0.04) + (0.04)^2 = 1 - 0.08$

$=\pi r^2 h(1 - 0.08)(1.02) = \pi r^2 h(0.94)$

Percentage change $= \frac{(0.94-1)100\%}{1} = -6\%$

The new volume decreased by 6%

2.3.6.3. Assessment

1. Expand as far as the third term and state the limits at which the expansions are valid.
   (i) $\frac{1}{(1+2x)^3}$
   (ii) $\sqrt{4+x}$
2. Show that if higher power of x are neglected
$$\sqrt{\frac{1+x}{1-x}} = 1 + x + \frac{x^2}{2}$$
3. The second moment of area of a rectangular section through its centroid is given by$\frac{bl3}{12}$. Determine the appropriate change in the second moment of area if b is increased by 3.5% and l is reduced by 2.5%
4. Explain binomial theorem
5. Describe binomial expansion
6. Identify roots of numbers using binomial theorem
7. Bionomical theorem can be used to identify small changes and errors TRUE OR FLASE?
8. Binomial is a formula for raising a binomial expansion to any power without lengthy multiplication. TRUE OR FALSE?

2.3.6.5. References

1. John Bird- Higher Engineering Mathematics sixth edition
2. Pure Mathematics: JK BackHouse

2.3.7. Learning Outcome No. 6. Apply Calculus

2.3.7.1. Learning Activities

Learning Outcome No. 6. Apply Calculus	
Learning Activities	Special Instructions
• Determining Derivatives from first principles • Determining derivatives of inverse trigonometric functions • Determining the rate of change and small changes using differentiation • Determining integrals of algebraic functions • Determining integrals of trigonometric functions • Determining integrals of logarithmic functions • Determining integrals of hyperbaric and inverse hyperbaric functions.	

2.3.7.2 Information Sheet No. 2/ LO6

Calculus is a branch of mathematics involving calculations dealing with continuously varying functions. The subject falls into two parts namely differential calculus (differentiation) and integral calculus (integration)

Differentiation

The central problem of the differential calculus is the investigation of the rate of change of a function with respect to charges in the variables on which it depends.

Differentiation from first principles.

To differentiate from first principles means to find $f'(x)$ using the expression.

$$f'(r) = \lim_{\delta x \to 0} \left\{ \frac{f(x + \delta x)}{\delta x} \right\}$$

$$\delta x \to 0 \left\{ + \frac{(x+\delta x) - f(x)}{\delta x} \right\}$$

$$f(x) = x^2$$

$$f(x + \delta x) = (x + \delta x)^2 = x^2 + 2x\delta x + \delta x^2$$

$$f(x + \delta x) - f(x) = x^2 + 2\, x\delta x + \delta x^2 - x^2$$

$=2x\delta x + \delta x^2$

$$\frac{f(x + \delta x) - f(x)}{\delta x} = \frac{2x\delta x + \delta x^2}{\delta x}$$

$=2x + \delta x$

As $\delta x \to 0$, $\frac{f(x+\delta x) - f(x)}{\delta x} \to 2x + 0$

$\therefore f'(x) = \lim_{\delta x \to 0} \left\{ \frac{f(x+\delta x) - f(x)}{\delta x} \right\} = 2x$

At $x = 3$, the gradient of the curve i.e $f'(x) = 2(3) = 6$
Hence if $f(x) = x^2$, $f'(x) = 2x$. The gradient at $x = 3$ is 6

Methods of differentiation

There are several methods used to differentiate different functions which include:

(i) Product Rule
(ii) Quotient Rule
(iii) Chain Rule
(iv) Implicit Rule

Example:

Determine ${dy}/{dx}$ given that $y = x^2 Sinx$

Solution

From product rule: $uv(x) = u\frac{dv}{dx} + v\frac{du}{dx}$

$u = x^2$ and $v = Sinx$

$\frac{du}{dx} = 2x$ $\frac{dv}{dx} = Cosx$

$\therefore \frac{dy}{dx} = x^2(Cosx) + Sin\,(2x)$

$= x^2 Cos\,x + 2x\,Sin\,x$

$$y = \frac{x^2 + 1}{x - 3}$$

Soln. Using Quotient rule:

$$\frac{u(x)}{v(x)} = \frac{v\frac{du}{dx} - u\frac{dv}{dx}}{v^2}$$

$u = x^2 + 1$ $v = x - 3$

$\frac{du}{dx} = 2x$ $\frac{dv}{dx} = 1$

$\therefore dy/dx = \frac{(x-3)(2x)-(x^2+1)(1)}{(x-3)^2}$

$= \frac{2x^2-6x-x^2-1}{(x-3)^2}$

$= \frac{x^2-6x-1}{(x-3)^2}$

$$\frac{x^2 - 6x - 1}{x^2 - 6x + 9}$$

For more examples on the cases of application of the other, highlighted rates refer to Engineering Mathematics by K Stroud.

Application of differentiation

Differentiation can be used to determine velocity and acceleration of a moving body. It can also be applied to determine maximum and minimum values.

Example: A rectangular area in formed using a pieced of wire 30cm long. Find the length and breadth of the rectangle if it is to enclose the maximum possible area.

Solution.
Let the dimension a rectangle be $x \text{ and } y$
Perimeter of rectangle = $2x + 2y = 36$
i.e $x + y = 18$………………(i)
Since it's the maximum area that is required a formula for the area A must be obtained in terms of one variable only.
Area = $A = xy$
From equation (i) $y = 18 - x$
Hence $A = x(18 - x) = 18x - x^2$
Now that an expression for the area has been obtained in terms of one variable it can be differentiated with respect to that variable
$\frac{dA}{dx} = 18 - 2x \text{ } for \text{ } maximum$ or minimum value i.e $x = 9$

$$\frac{d^2A}{dx^2} = -2, which \text{ } is \text{ } negative \text{ } giving \text{ } a \text{ } maximum \text{ } value$$

$$y = 18 - x = 18 - 9 = 9$$

Hence the length and breadth of the rectangle of maximum area both 9 cm i.e a square gives the maximum possible area for a given perimeter length When perimeter is 36cm maximum area, possible is $81cm^2$.

Integration

Process of integration reverses the process of differentiation. In differentiation if $f(x) = x^2$ then $f'(x) = 2x$.
Since integration reverse the prices of moving from $f(x)$ to f'(x), it follows that the integral of $2x \text{ } is \text{ } x^2 \text{ } i.e \text{ } its \text{ } the \text{ } process \text{ } of \text{ } moving \text{ } from \text{ } f'$(x) to $f(x)$. Similarly if $y = x^2$ then $\frac{dy}{dx} = 3x^2$. Reversing this process shows that the integral of $3x^2$ and x^3.
Integration is also the process of summation or adding parts together and on elongate $'s'$ shown a $\int$ is used to replace the words 'integrated of "Thus $\int 2x$=x^2 and $\int 3x^2 = x^3$
Refers to engineering mathematics by K.A strond and learn those on definite and indefinite integrals.

Methods of integration and application of integration

The methods available are:

a. By using an algebraic substitution
b. Using trigonometric identifies and substitutions

c. Using partial fraction
d. Using the $t = tan\frac{\theta}{2}$ substitution
e. Using integration by parts

Refer to Engineering mathematics by K.A strond and learn more about methods of integration,
Also we the above stated book to learn more on application on integration to find areas, volumes of revolutions etc

2.3.7.3. Self-Assessment

1. Find the co-ordinator, of the points on the curve
$$y = \frac{1/3(5-6x)}{3x^2+2}$$
Where the gradient is zero.

2. If $y = \frac{4}{3x^3} - \frac{2}{x^2} + \frac{1}{3x} - \sqrt{x}$. Find $\frac{d^2y}{dx}$ $and \frac{d^3y}{dx}$

3. Find $\int cos6x\ Sin\ 2x\ \ dx$

4. Evaluator $\int_3^4 \frac{x^3-x^2-5x}{x^2-2x+2}dx$
5. Explain calculus
6. Perform calculations on inverse trigonometric functions
7. Differentiate algebraic functions, trigonometric functions and logarithmic functions
8. Perform calculations on integrals of hyperbaric and inverse hyperbaric functions.
9. Cross product is a method of differentiation. TRUE OR FASE?
10. Use of partial fraction is a method of differentiation. TRUE OR FLASE

2.3.7.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Writing materials
- Calculator

2.3.7.5. References

1. Technician Mathematics Book (4 and 5) by J.O Bird
2. Engineering Mathematics by K.A Stround
3. Mathematics for Engineers by Dass

2.3.8. Learning Outcome No. 7. Solve Ordinary Differential Equations

2.3.8.1. Learning Activities

Learning Outcome No. 7. Solve Ordinary Differential Equations	
Learning Activities	Special Instructions
• Solve first order and second order differential equations using the method of undetermined coefficients. • Apply boundary conditions to find the particular solution	• Find general solution • Find particular solution

2.3.8.2. Information Sheet No. 2/ LO7

An equation involves differential co-efficient is called a differential equation examples.

(i) $\frac{dy}{dx} = \frac{1+x^2}{1-y^2}$

(ii) $\frac{d^2y}{dx^2} + 2\frac{dy}{dx} - 8y = 0$

The order of a differential equation is the order of the highest differential is coefficient present in the equation.

Differential equations represent dynamic relationship i.e quantities that change, and are thus

An equation which involve differential co-efficient is called a differential equation.

Example:

(i) $\frac{dy}{dx} = \frac{1+x^2}{1-y^2}$

(ii) $\frac{d^2y}{dx^2} + 2\frac{dy}{dx} - 8y = 0$

The order of a differential equation is the order of the highest differential coefficient present in the equation.

A differential equation represent dynamic relationships, ie quantities that change, and are thus frequently occurring in scientific and engineering problems.

Formation of a differential equation

Differential equations may be formed in practice from a consideration of the physical problem to which they refer. Mathematically, they can occur when arbitrary constants are eliminated from a given function.

Example

Consider $y = Asinx + Bcosx$, where A and B are two arbitrary constants. If we differentiate, we get

$\frac{dy}{dx} = ACosx - BSinx$ and $\frac{d^2y}{dx^2} = -ASinx - BCosx = -(aSinx + BCosx)$

i.e $$\frac{d^2y}{dx^2} = -y$$

∴ $$\frac{d^2y}{dx^2} - y = 0$$

This is a differential equation of the second order.

For the formation of first order differential equations, refer to Technician Mathematics 4 and 5 by J.O Bird.

Types of first order differential equations:

1. By separating the variables
2. Homogeneous first order differential equations
3. Linear differential equations
4. Exact differential equations

Refer to Engineering Mathematics by K.A Stround, Technician 4 and 5 by J.O Bird for worked out examples and further exercises.

Application of first order differential equations.

Differential equations of the first order have many applications in engineering and science.

Example:

The rate at which a body cools is given by the equations $\frac{d\theta}{dt} = -k\theta$ where θ the temperature of the body above the surroundings is and k is a constant. Solve the equation for θ given that $t = 0$,

$\theta = \theta_0$

Solution

$$\frac{d\theta}{dt} = -k\theta$$

Rearranging gives

$$dt = \frac{-1}{k\theta}$$

Integrating both sides gives $\int dt = \frac{-1}{k}\int \frac{d\theta}{\theta}$

i.e $t = \frac{-1}{k} ln\theta + c$…………………..(i)

Substituting the boundary conditions $t = 0$, $\theta = \theta_0$ to find c gives

$$0 = \frac{-1}{k} ln\theta_0 + c$$

i.e $$c = \frac{1}{k} ln\theta_0$$

Substituting $c = \frac{-1}{k} ln\theta_0$ in equation (i) gives

$$t = \frac{-1}{k} ln\theta + \frac{1}{k} ln\theta_0$$

$$t = \frac{1}{k}(ln\theta_0 + ln\theta) = \frac{1}{k}\ln\left(\frac{\theta_0}{\theta}\right)$$

$$kt = ln\left(\frac{\theta_0}{\theta}\right)$$

$$e^{kt} = \frac{\theta_0}{\theta}$$

$$e^{-kt} = \frac{\theta}{\theta_0}$$

Hence $$\theta = \theta_0 e^{-kt}$$

Further problems on application of differential equations may be found in Engineering Mathematics by K.A Stround, Technician 4 and 5 by J.O Bird.

Formation of the second order differential equation

For, formation of second order differential equations refer to *Engineering Mathematics by K.A Stround, Technician 4 and 5 by J.O Bird.*

Application of second order differential equations

Many applications in engineering give rise to the second order differential equations of the form

$$a\frac{d^2y}{dx^2} + b\frac{dy}{dx} + cy = f(x)$$

Where a, b, c are constants coefficient and $f(x)$ is a given function of x.

Example include:

(1) Bending of beams
(2) Vertical oscillations and displacements
(3) Damped forced vibrations

For more worked examples refer to Engineering Mathematics by K.A Stround, Technician 4 and 5 by J.O Bird.

2.3.8.3 Self-Assessment

Q1. Solve the following equations:

(i) $x(y-3)\frac{dy}{dx}4y$

(ii) $(xy + y^2) + (x^2 - xy)\frac{dy}{dx} = 0$

(iii) $\frac{dy}{dx} + ytanx = sinx$

Q2. The change, q, on a capacitor in an LCR circuit satisfies the second order differential equation

$$L\frac{d^2q}{dt^2} + b\frac{dq}{dt} + \frac{1}{c}q = E$$

Show that if $2L = cR^2$ the general solution of this equation is

$$q = e^{\frac{-t}{cR}}\left(A cos\frac{1}{cR}t + B sin\frac{1}{cR}t\right) + cE$$

If $i = \frac{dq}{dt} = 0$ and $q = 0$ when $t = 0$. Show that the current in the circuit is

$$i = \frac{2E}{R}e^{\frac{-t}{cR}}sin\frac{1}{cR}$$

3. Explain differential equations
4. Describe method of undetermined coefficients
5. Perform calculations on first order and second order differential equations using the method of undetermined coefficients
6. An equation which involve differential co-efficient is called a differential equation. TRUE OR FALSE?
7. Linear differential equations is not a first order differential equation. TRUE OR FALSE?

2.3.8.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Calculator
- Writing materials

2.3.8.5. References

1. Technician Mathematics Book (4 and 5) by J.O Bird
2. Engineering Mathematics by K.A Stround
3. Mathematics for Engineers by Dass

2.3.9 Learning Outcome No. 8. Apply Laplace transforms

2.3.9.1 Learning Activities

Learning outcome No. 8. Apply Laplace transforms	
Learning Activities	Special Instructions
• Derive Laplace transform from first principle. • Solve Laplace transforms using initial and final value theorem. • Determine inverse using Laplace transform using partial fractions, • Solve differential equations by using Laplace transform • To cover the Performance Criteria statements • Trainees to demonstrate knowledge in relation to; The *Range* in the Occupational Standards and *Content* in the curriculum	• Rule of partial fractions

2.3.9.2. Information Sheet No 2/LO8

Definition

The Laplace transform of a function $F(t)$ is denoted by $\mathcal{L}[F(t)]$ and is defined as the integral of $F(t)e^{-st}$ between the limits $t = 0$ and $t = \infty$.

i.e $\mathcal{L}[F(t)] = \int_0^\infty F(t)e^{-st}$ dt

in determining the transform of any function, you will appreciate that the limits are substituted for t, so that the result will be a function of s.

$$\therefore\ \mathcal{L}[F(t)] = \int_0^\infty F(t)e^{-st}\,\mathrm{dt} = f(s)$$

Deriving the Laplace transform from the first principles

To find the Laplace transform from first principles.

Example

To find the Laplace transform of $F(t) = a$ (constant)

$$\mathcal{L}(a) = \int_0^\infty a\,e^{-st}dt = \left[a\frac{e^{-st}}{-s}\right]_0^\infty = -\frac{a}{s}[e^{-st}]_0^\infty$$

$$= \frac{-a}{s}[0-1] = \frac{a}{s}$$

$$\therefore \mathcal{L}(a) = \frac{a}{s}$$

Example

To find the Laplace transform of $F(t) = e^{at}$

Solution

$$\mathcal{L}(e^{at}) = \int_0^\infty e^{at}\, e^{-st} dt$$

$$= \int_0^\infty e^{-(s-a)t}\, dt$$

$$= \left[\frac{e^{-(s-a)t}}{-(s-a)}\right]_0^\infty$$

$$= \frac{-1}{s-a}(0-1)$$

$$= \frac{1}{s-a}$$

$$\therefore \mathcal{L}(e^{at}) = \frac{1}{s-a}$$

For more worked examples on how to derive the Laplace transform from first principles refer to Advanced Engineering Mathematics by K.A Stround.

Inverse Transforms

Here we have the reverse process, ie given a Laplace transform, we have to find the function of t to which it belongs.

For example, we know that $\frac{a}{s^2+a^2}$ is the Laplace transform of $Sinat$ so we can write

$$\mathcal{L}^{-1}\left(\frac{a}{s^2+a^2}\right) = Sinat$$

The symbol $\mathcal{L}^{-1}$ indicating the inverse transform and not the reciprocal.

For worked examples on how to find inverse of the Laplace transform refer to Further Engineering Mathematics by K.A Stround.

Solution of differential equation by Laplace transforms.

To solve a differential equation by Laplace transform we go through four distinct stages.

(1) Re-write the equation in terms of Laplace transform
(2) Insert the given initial conditions
(3) Rearrange the equation algebraically to given the transform of the solution.

For worked examples and exercises refer to Further Engineering Mathematics by K.A Stround.

2.3.9.3. Self-assessment

Q1. Derive the Laplace transform of each of the following expressions

(i) $f(t) = Sin2t$

(ii) $f(t) = Cosat$

(iii) $f(t) = e^{at}$

Q2. Find the inverse Laplace transform of each of the following expressions

(i) $\frac{4}{s^2+4s+5}$

(ii) $\frac{s+5}{s^2+10s+29}$

(iii) $\frac{2s-3}{s^2+6s+10}$

Q3. Solve the following differential equations using Laplace transforms

(i) $x'' + x' + 2x = 4Cos2t$

(ii) $x'' - 4x = 4t$

4. Describe Laplace transform from first principle
5. Explain inverse transform
6. Differentiate initial and final value theorem.
7. Perform calculations using Laplace transform
8. The Laplace transform of a function $F(t)$ is denoted by $\mathcal{L}[F(t)]$ and is defined as the integral of $F(t)e^{-st}$ between the limits $t = 0$ and $t = \infty$. TRUE OR FALSE
9. Insert the given initial conditions is not one of the stages of solving a differential equation by Laplace transform. TRUE OR FALSE

2.3.9.4 Tools, equipment's

- Calculator
- Laplace transform Tables
- Writing material

2.3.9.5 References

1. Further Engineering Mathematics by K.A Stround
2. Mathematics for Engineers by Dass

2.3.10. Learning Outcome No. 9. Apply Power Series

2.3.10.1 Learning Activities

Learning Outcome No. 9. Apply Power Series	
Learning Activities	Special Instructions
• Obtaining power series using Taylor's the Obtaining power series using Taylor's theorem • Obtaining power series using Maclaurins Theorem.	

2.3.10.2 Information Sheet No. 2/ LO9

The power series of claurins theorem different functions can be carried out using two theorems.

(i) Taylor's Theorem

(ii) Maclarins theorem

Taylor's series states that;

$$f(x+h) = f(x) + hf'(x) + \frac{h^2}{2!}f''(x) + \frac{h^3}{3!}f'''(x) + \cdots$$

Examples

Express$Sin(x+h)$ as a series of powers of h and hence evaluates $Sin\ 44^0$ correct to four decimal places.

Soln

$f(x+h) = f(x) + hf'(x) + \frac{h^2}{2!}f''(x) + \frac{h^3}{3!}f'''(x) + \cdots$

$f(x) = Sinx$

$f'(x) = cos\ x$

$f''(x) = -sinx$

$f'''(x)$ =-cosx

$f^{iv}(x) = \sin x$

$\therefore Sin(x+h) = \sin x + hcos\ x - \frac{h^2}{2}$ sin x - $\frac{h^3}{6}$ $cos\ x$ ....

$Sin44^0 = \sin(45^0 - 1^0)$

=$Sin(^{\pi}/_{4}) - 0.01745$

=$\sin {}^{\pi}/_{4} - 0.01745\ cos\frac{\pi}{4}$ - $\frac{0.01745^2}{2}$ $sin\ {}^{\pi}/_{4}$ + $\frac{0.0174s^3}{6}$ $cos\ {}^{\pi}/_{4}$

$But\ sin45 = cos\ 45 = 0.707$

$= 0.707\ (1 - 0.01745 - 0.0001523 + 0.0000009)$

$= 0.707(0.982395)$

$= 0.69466$

$0.6947(4dp)$
For the use Maclaurns theorem refer to Engineering Mathematics by Strond.

2.3.10.3. Self-Assessment

1. Use Manchurians theorem to expand $ln(3x + 1)$. Hence use the expansion to evaluate $\int_0^1 \frac{ln(3x+1)}{x^2} dx$ to four decimal places
2. Use Taylors series to expand $\cos\left(\frac{\pi}{3} + h\right)$ in terms of h as far as h^3. Hence evaluate $cos68^0$ correct to four decimal places
3. Describe power series of claurins theorem
4. Differentiate between Taylor's Theorem and Maclarins theorem
5. Perform calculations on power series using Taylor's theorem
6. Perform calculations on power series using Maclaurins Theorem
7. Taylor's Theorem can be used to obtain power series. TRUE OR FALSE?
8. Taylor's series states that;
9. $f(x + h) = f(x) + hf'(x) + \frac{h^2}{2!}f''(x) + \frac{h^3}{3!}f'''(x) + \cdots TRUE\ OF\ FALSE?$

2.3.10.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Advanced Calculator

2.3.10.5. References

1. Strond, 6th Edition Advanced Engineering mathematics

2.3.11. Learning Outcome No. 10. Apply statistics

2.3.11.1. Learning Activities

Learning Activities No. 10. Apply Statistics	
Learning Activities	Special Instructions
• Perform identification collection and organization of data • Perform interpretations analysis and presentation of data in appropriate format • Evaluate mean median mode and standard deviation obtained from the given data • Performing calculations based on laws of probability • Performing calculations involving probability distributions and mathematical expectation sampling.	

2.3.11.2. Information Sheet No. 2/ LO10

Statistics is discipline which deals with collection, organization, presentation and analysis of data.
Data consist of set of record observations that carry information on a particular setting with the availability of data.
A statistical exercise normally consist of four stages.

1. Collection of data
2. Organization and presentation of data in convenient form
3. Analysis of data to make their meaning clear
4. Interpretation of 1b results and the conclusion

In statistic we consider quantities that are varied. This quantities are referred as variables.

Variables are denoted by letters

Examples

- Heights
- Ages
- Weighs
- Times

Types of data;

1. Quantitative data
2. Qualitative data

Presentation of data

The aim of presenting data is to communicate information.

The type of presentation chosen depend on the requirement and the interest of people receiving that particular information.

Frequently the first stage in presenting is preparing a table.

Tabulation of data

Frequency distribution

Given a set of draw data we usually arrange into frequency distribution where we collect like quantities and display them by writing down their frequencies.

For those on data presentation refer to engineering mathematics by K.A stroud.

Measures of central tendencies

This is single value which used to represent entire set of data. It is typical value to which most observation fall closest than any other value.

There are mainly measures of central tendencies.

i. Arithmetic mean
ii. Median
iii. Mode

Refer to Engineering mathematics for Engineers by H.K Dass

Measurers of Dispersion

They include;

1. Range
2. Standard deviation
3. Quartiles

Normal Distribution

This is a continuous distribution. It is derived as the limiting for of the Binomial distribution for large values of n and p and q are not very small.

The normal distribution is given by the equation

$fx) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2\sigma^2}(x-\mu)^2}$

Where μ is the mean and σ is the standard deviation, $\pi = 3.14159$ and $e = 2.71828$

$$P(x_1 < x < x_2) = \int_{x_1}^{x_2} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2\sigma^2}(x-\mu)^2} dx \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

On substitution $z = \frac{x-\mu}{\sigma}$ in (1) we get $f(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2\sigma^2}z^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$

Here $mean = 0,\ standard\ deviation\ = 1$

Equation (2) is known as standard form of normal distribution.

Normal curve

Shown graphically: the probabilities of heads in 1 losses are

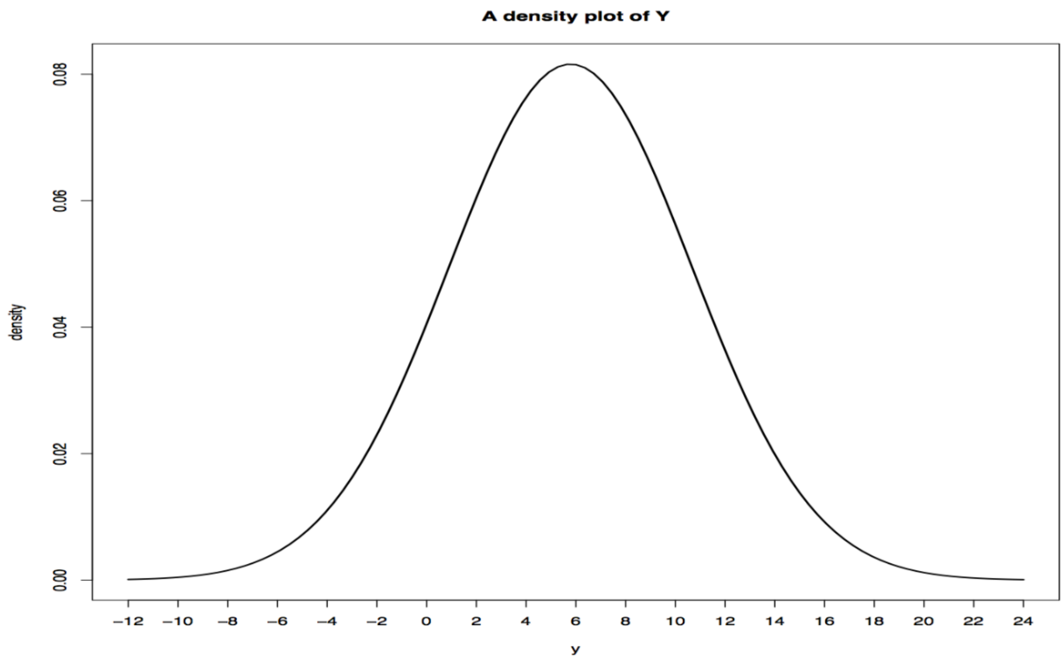


Figure 1: A density plot of Y

Area under the normal curve

By taking $z = \frac{x-\mu}{\sigma}$, the standard normal curve is formed.

The total area under this curve is 1. The area under the curve is divided into two equal parts by $z = 0$. Left had side area and right hand side area to $z = 0$ is 0.5. The area between the ordinate $z = 0$ and any other ordinate can be calculated.

Example 1

On the final examination in mathematics the mean was 72 and the standard deviation was15. Determine the standard scores of students receiving grades

a) 60 b) 93 c) 72

Solution

a) $z = \frac{x-\mu}{\sigma} = \frac{60-72}{15} = -0.8$

b) $z = \frac{93-72}{15} = 1.4$

c) $z = \frac{72-72}{15} = 0$

For more refer to Mathematics for Engineers by H.K Dass .

Read on Poison and standard deviation of Binomial distribution.

2.3.11.3 Self-Assessment

1. A machine produced components whose masses are normally distributed with mean μ and standard deviation σ if 89.8 % of the components have a mass of at least 88g and 3% have a mass less than 84.5g. Find the mean and the standard deviation of the distribution (6mks).
2. The diameters of bolts produced by a certain machine are distributed by a probability density function

$$f(x) = \begin{cases} kx(3-x), & 0 \leq x \leq 3 \\ 0 & Otherwise \end{cases}$$

Find the;

a. Constant$k$.

b. Probability that the diameter of a bolt-selected at a random will fall in the interval

$$1 < x < 2.5$$

c. Mean and the variance of the distribution (14mks)

3. Tumaini Ltd, is supplied with petrol once a week. The weekly demand, x hundreds of liters, has the probability density function

$$f(x) = \begin{cases} k(1-x), & 0 \leq x \leq 1 \\ 0 & Otherwise \end{cases}$$

Where c is a constant

Determine the

(i) Value of c

(ii) Mean of x

(iii) Minimum capacity of the petrol tank if the probability that it will be exhausted in a given week is not to exceed 0.02.

4. Metal bars produced in a factory have masses that are normally distributed with mean μ and standard deviationσ. Given that 9.4% have a mass less than 45kg and 7% have a mass above 75kg.

(i) Evaluate the values of μ and σ and

(ii) Find the probability that a mass of a metal bar selected at random will be less tan 40kg.

5. Define statistics
6. Differentiate between mean, mode and median
7. Perform data collection and organization techniques
8. Perform interpretations analysis and presentation of data in appropriate format
9. Evaluate mean median mode and standard deviation obtained from the given data
10. Describe laws of probability and perform appropriate calculations based on the laws
11. In statistic we consider quantities that are varied. TRUE OR FALSE?
12. Measures of central tendencies is a single value which used to represent entire set of data. TRUE OR FALSE?

2.3.12. Learning Outcome No. 11. Solve Ordinary differential equations

2.3.12.1 Learning Activities

Learning Outcome No. 11. Apply Fourier series	
Learning Activities	Special Instructions
• Obtain Fourier coefficients using Fourier series • Obtain Fourier series for a periodic function of period 2π • Obtain Fourier series for a periodic function of period T • Obtain Fourier series for odd and even functions using Fourier series techniques • Obtain half-range Sine and Cosine series	• Harmonic analysis

2.3.12.2. Information sheet No 2/Lo11

Problem involving various forms of oscillations are common in field of modern technology and Fourier series enable us to represent a periodic function as an infinite trigonometrical series in sine and cosine series.

Periodic functions

A function $f(x)$ is said to be periodic if its function values repeat at regular intervals of the independent variable. The regular interval between repetitions is the period of the oscillations.

For more examples refer to Further Engineering Mathematics by K.A Stround on page 826.

Fourier series periodic functions of period 2π

We define Fourier series in the form

$$f(x) = \frac{1}{2}a_0 + a_1 cosx + a_2 cos2x + a_3 cos3x \pm - - - +$$

$+b_1 sinx + b_2 sin2x + b_3 sin3x \pm - - -$

This is written in the form

$$f(x) = \frac{1}{2}a_0 + \sum_{n=1}^{\infty}(a_n Cosnx + b_n sinnx)$$

Where n is a positive integer.

Fourier coefficients, $a_0, a_n, and\ b_n$ are given by

$$a_0 = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x)dx$$

$$a_n = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x)cosnxdx$$

$$b_n = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x)sinnxdx$$

For worked examples on how to determine the Fourier series to represent a periodic function of period 2π refer to Further *Engineering Mathematics by K.A Stround on page 842 to 876.*

Functions with periods other than 2π

If $y = f(x)$ is defined in the range $\frac{-T}{2}$ to $\frac{-T}{2}$ i.e has a period T, we can convert this to an interval of 2π by changing the units of the independent variable.

In many practical cases involving physical oscillations, the independent variable is time (t) and the periodic interval is normally denoted by T

i.e $f(t) = f(t + T)$

The Fourier series to represent the function can be expressed a

$$f(t) = \frac{1}{2}a_0 + \sum_{n=1}^{\infty}(a_n Cosnwt + b_n sinwt)$$

With the new variable, the Fourier coefficients becomes

$$f(t) = \frac{1}{2}a_0 + \sum_{n=1}^{\infty}(a_n Cosnwt + b_n sinwt)$$

$$a_0 = \frac{2}{T}\int_0^T f(t)dt$$

$$a_n = \frac{2}{T}\int_0^T f(t)cosntdt$$

$$b_n = \frac{2}{T}\int_0^T f(T)sinwtdt$$

For worked examples on how to determine Fourier series for a periodic function of period T, refer to *Further Engineering Mathematics by K.A Stround on page 879 to 886.*

Odd and even functions

For information about odd and even functions refer to Further Engineering Mathematics by K.A Stround on page 858. Also find worked out examples on odd and even functions.

Half-range series

Sometimes a function of period 2π is defined over the range 0 to π, instead of the normal $-\pi \ to\ \pi$ or 0 to 2 π. In this case we make an assumption on how a function behaves between $x = -\pi$ to $x = 0$, and the resulting Fourier series will therefore apply only to $f(x)$ between $x = 0$ and $x = \pi$ for which it is defined. For this reason, such series are called half range series. For more information, worked example and exercises refer to Further Engineering Mathematics by K.A Stround on page 868.

2.3.12.3. Self-Assessment

1. Describe Ordinary differential equations
2. Explain Fourier series

3. Perform calculations on Fourier series for a periodic function of period 2π and T
4. Perform calculations on Fourier series for odd and even functions using Fourier series techniques
5. A function $f(x)$ is said to be periodic if its function values repeat at regular intervals of the independent variable. TRUE OR FALSE?
6. If $y = f(x)$ is defined in the range $\frac{-T}{2}$ to $\frac{-T}{2}$ i.e has a period T. TRUE OR FALSE?
7. Determine half-range Sine and Cosine series
8. Determine the Fourier served for the function defined by

$$f(x) = \begin{cases} 1 - x & -\pi \leq x < 0 \\ 1 + x & 0 < x \leq \pi \\ f(x + 2\pi) \end{cases}$$

Find the half-range Cosine series for the function defined by

$$f(t) = \begin{cases} 4 - t & 0 < t < 4 \\ f(t + 8) \end{cases}$$

2.3.12.4. Tool, equipment

- Calculator

2.3.12.5 References

1. Further Engineering Mathematics by K.A Stround
2. Mathematics for Engineers by Dass

2.3.13. Learning Outcome No. 12. Apply Vector theory

2.3.13.1. Learning Activities

Learning Activities No. 12. Apply Vector theory	
Learning Activities	Special Instructions
• Calculate vector algebra dot and cross products using vector theory • Determine the gradient, divergence and curl. • Perform vector calculation using Greens theorem • Perform vector calculations using Stroke's theorem • Determine conservative vector fields, line and surface integrals using Gauss's theorem	

2.3.13.2. Information sheet No. 2/LO12

Physical quantities can be divided into two main groups, scalar quantities and vector quantities.

A Scalar quantity is one that is defined completely by a single number with appropriate units e.g Lengths, area, volume, mass, time etc.

A Vector quantity is defined completely when we know not only its magnitude but also the direction in which it operates, e.g. force, velocity, acceleration etc.

Refer to *Engineering mathematics by K. A Stroud* to learn more on components of 0 Vector in terms of unit Vectors on page 368.

Dot and cross product of vectors. The Scalar product of two vectors is denoted by $\bar{a}.\bar{b}$(sometimes called the 'dot product'.

The dot product of two vectors is defined as $a.b = |a||b|cos\theta$ where θ is the angle between a and b.

Refer to Technician mathematics 3 by J.O. Bird on page 297.

Examples

Solution

$\bar{a} = 2i + 3j + 5k$ And$\bar{b} = 4i + j + 6k,\ \bar{a}.\bar{b}$

$\bar{a}\ .\ \bar{b} =\ 2.4\ + 3.1\ + 5.6$

= 8 + 3+ 30

=41

A typical application of scalar products is that of determining the work done by a force when moving a body. The amount of work done is the product of the applied force and the distance moved in the direction of the applied force.

Example

Find the work done by a force F newtons acting at point A on a body, when A is displaced to point B, the coordinates of A and B being (3, 1, -2) and (4, -1, 0) metres respectively and when

$F = -i - 2j - k$ Newton's.

Solution

If a vector displacement from A to B is d, then the work done is F. d Newton Meters or joules. The position vector OA is $3i + j - 2k$ and OB is $4i - j$

$AB = d = OB - OA$

$= (4i - j) - (3i + j - 2k)$

$i - 2j + 2k.$

Work done $= F.d = (-1)/1) + (-2)(-2) + (-1)(2)$

$= -1 + 4 - 2$

$=1$ Nm or $joul$e

For more worked examples refer to Technician mathematics 3 by J. O. Bird.

Cross Product

The vector or Cross product of two vectors ā and $\bar{b}$ is C where the magnitude of C is $|ā||b|Sin\theta$ where θ the angle between is $\bar{a}$ and b.

For more information refer to Technician mathematics 3 by J.O Bird and Engineering mathematics by K. A Stroud.

Examples

$\bar{p} = 2i + 4j + 3k$ and $Q = i + 5j - 2k$ find $\bar{P}$ x $\bar{Q}$ = $\begin{vmatrix} i & j & k \\ 2 & 4 & 3 \\ 1 & 5 & -2 \end{vmatrix}$

$=i\begin{vmatrix} 4 & 3 \\ 5 & -2 \end{vmatrix} - j\begin{vmatrix} 2 & 3 \\ 1 & -2 \end{vmatrix} + k\begin{vmatrix} 2 & 4 \\ 1 & 5 \end{vmatrix}$

$=-23i + 7j + 6k$

Typical applications of vector products are to moments and to angular velocity.

Refer to Technician mathematics. 3 by J.O Bird on page 308.

Vector field Theory

Refer to further Engineering mathematics by K.A Stroud to learn and also go through the worked examples and exercises on:

(i) Gradient
(ii) Divergence
(iii) Curl

Greens theorem

Learn how to perform vector calculations using Green's theorem by referring to further Engineer mathematics by KA. Stroud

Stoke's Theorem

Refer to further Engineer Mathematics by K.A Stroud to learn how to perform vector calculations using Stroke's theorem.

Gauss's Theorem

Refer to the some book to learn how to determine line and surface integrals using Gauss's theorem.

2.3.13.3 Self-Assessment

1) Differentiate between algebra dot and cross products in vector calculations
2) A Scalar quantity is one that is defined completely by a single number with appropriate units e.g Lengths, area, volume, mass, time. TRUE OR FALSE?
3) The vector or Cross product of two vectors ā and $\bar{b}$ is C where the magnitude of C is $|\bar{a}||b|Sin\theta$ where θ the angle between is $\bar{a}$ and b. TRUE OR FALSE?
4) Describe Greens theorem, Stroke's theorem and Gauss's theorem and their applications
5) Explain gradient, divergence and curl.
6) If $\bar{a}$ =$2i$ - $3j + 4k$ and $\bar{b}$ = i + $2j + 5k$ determine

   $(\acute{2})$ $\bar{a}$. $\bar{b}$

   $(2\acute{2})$ $\bar{a}$ x $\bar{b}$

Find the work done by a force F Newtons acting at a point A on a body, when A is displaced to point B ,the coordinates of A and B being (5, 2, -4) and (3,-1,1) meters respectively , and when $F = -2i - 3j - 2k$ Newton's.

2.3.13.4. Tools, Equipment

- Calculator

2.3.13.5 References

1. Further engineering mathematics by KA Stroud.
2. Mathematics for Engineers by Dass.
3. Technician mathematics book 3 by J.O. Bird.

2.3.14. Learning Outcome No.13 Apply Matrix

2.3.14.1 Learning Activities

Learning Activities No. 13. Apply Matrix	
Learning Activities	Special Instructions
• Apply matrix in calculating operation on matrices in addition and subtraction, multiplication	

2.3.14.2. Information sheet No. 2/ LO13

Introduction

A matrix is a set of real or complex numbers (or elements) arranged in rows and columns to form a rectangular array.

A matrix having M rows and N columns is called a $M \times N$ $(i.e\ M\ by\ N)$ matrix and is referred to as having order $M \times N$.

A matrix is indicated by writing the array with large square brackets e.g

$\begin{bmatrix} 5 & 7 & 2 \\ 6 & 3 & 8 \end{bmatrix}$ is a 2×3 matrix i.e $2\ by\ 3$ matrix where $5,7,2,6,3\ and\ 8$ are the elements of the matrix.

Operation on matrices

1. Addition and subtraction

Matrices can be added or subtracted if they are of the same order.

Example

Given matrix $A = \begin{bmatrix} -1 & 2 & 5 \\ 3 & 0 & 4 \\ 1 & -3 & 2 \end{bmatrix}$ and $B = \begin{bmatrix} 3 & 2 & -1 \\ -2 & 1 & 6 \\ 1 & -4 & 5 \end{bmatrix}$

$$A + B = \begin{bmatrix} -1 & 2 & 5 \\ 3 & 0 & 4 \\ 1 & -3 & 2 \end{bmatrix} + \begin{bmatrix} 3 & 2 & -1 \\ -2 & 1 & 6 \\ 1 & -4 & 5 \end{bmatrix} = \begin{bmatrix} (-1+3) & (2+2) & (3 \pm -1) \\ (3+-2) & (0+1) & (4+6) \\ (1+1) & (-3+-4) & (2+5) \end{bmatrix}$$

$$= \begin{bmatrix} 2 & 4 & 4 \\ 1 & 1 & 10 \\ 2 & -7 & 7 \end{bmatrix}$$

2. Multiplication of Matrices

Example

Given matrix $A = \begin{bmatrix} -1 & 2 & 5 \\ 3 & 0 & 4 \\ 1 & -3 & 2 \end{bmatrix}$ and $B = \begin{bmatrix} 3 & 2 & -1 \\ -2 & 1 & 6 \\ 1 & -4 & 5 \end{bmatrix}$

$$A \times B = \begin{bmatrix} -1 & 2 & 5 \\ 3 & 0 & 4 \\ 1 & -3 & 2 \end{bmatrix} \begin{bmatrix} 3 & 2 & -1 \\ -2 & 1 & 6 \\ 1 & -4 & 5 \end{bmatrix}$$

$$= \begin{bmatrix} 1 \times 3 + 2 \times -2 + 5 \div 1 & -1 \times 2 + 2 \times 1 + 6 \times -4 & -1 \times 1 + 2 \times 6 + 5 \times 5 \\ 3 \times 3 + 0 \times -2 + 4 \times 1 & 3 \times 2 - 0 \times 1 + 4 \times -4 & 3 \times -1 + 0 \times 6 + 4 \times 5 \\ 1 \times 3 + -3 \times -2 + 2 \times 1 & 1 \times 2 - 3 \times 1 + 2 \times -4 & 1 \times -1 + 6 \times -3 + 2 \times 5 \end{bmatrix}$$

$$= \begin{bmatrix} -3 - 4 + 5 & -2 + 2 - 20 & -1 + 12 + 25 \\ 9 + 0 + 4 & 6 + 0 - 16 & -3 + 0 + 20 \\ 3 + 6 + 2 & 1 - 3 - 8 & -1 - 1 + 10 \end{bmatrix}$$

$$= \begin{bmatrix} 2 & -20 & 36 \\ 13 & *10 & 17 \\ 11 & -10 & -9 \end{bmatrix}$$

Note that in matrices $AB \neq BA$

For more examples on matrices operations refer to Pure Mathematics I.

Determinant of a 3×3 matrix

Refer to engineering mathematics by K.A Stround and learn more on how to find the determinant of a 3×3 (“3 by 3”) matrix.

Inverse of a 3×3 matrix

Example

To find the inverse of $A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 1 & 5 \\ 6 & 0 & 2 \end{bmatrix}$

Evaluate the determinant of A i.e $|A|$

a) For $A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 1 & 5 \\ 6 & 0 & 2 \end{bmatrix}$, $|A| = 1(2-0) - 2(8-30) + 3(0-6) = 28$

b) Now from the matrix of the cofactors

$$C = \begin{bmatrix} 2 & 22 & -6 \\ -4 & -16 & 12 \\ 7 & 7 & -7 \end{bmatrix}$$

c) Next we have to write down the transpose of “C” to find the adjoint of “A”

$$Adj\ A = C^T = \begin{bmatrix} 2 & -4 & 7 \\ 22 & -16 & 7 \\ -6 & 12 & -7 \end{bmatrix}$$

d) Finally we divide the elements of adj A by the value of $|A|$ i.e 28 to get A^{-1} the inverse of A.

$$A^{-1} = \begin{bmatrix} \frac{2}{28} & \frac{-4}{28} & \frac{7}{28} \\ \frac{22}{28} & \frac{-16}{28} & \frac{12}{28} \\ \frac{-6}{28} & \frac{7}{28} & \frac{-7}{28} \end{bmatrix} = \frac{1}{28}\begin{bmatrix} 2 & -4 & 7 \\ 22 & -16 & 7 \\ -6 & 12 & -7 \end{bmatrix}$$

Solution of linear equation in three unknowns

Solve the set of equations

$$x_1 + 2x_2 + x_3 = 4$$
$$3x_1 - 4x_2 - 2x_3 = 2$$
$$5x_1 + 3x_2 + 5x_2 = -1$$

First write the set of equations in matrix form

$$\begin{bmatrix} 1 & 2 & 1 \\ 3 & -4 & -2 \\ 6 & 3 & 5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 4 \\ 2 \\ 1 \end{bmatrix}$$

Next step is to find the inverse of A where A is the square matrix on the left hand side.

$$|A| = \begin{vmatrix} 1 & 2 & 1 \\ 3 & -4 & -2 \\ 5 & 3 & 5 \end{vmatrix} = -14 - 50 + 29 = 29 - 64 = -35$$

Therefore $|A| = -35$

Matrix of co-factors $C = \begin{bmatrix} -14 & -25 & 29 \\ -7 & 0 & 7 \\ 0 & 5 & -10 \end{bmatrix}$

The matrix of the $Adj\ A = C^T = \begin{bmatrix} -14 & -7 & 0 \\ -25 & 0 & 5 \\ 29 & 7 & -10 \end{bmatrix}$

Now $|A| = -35,$ therefore $A^{-1} = \frac{adj\ A}{|A|} = \frac{1}{35}\begin{bmatrix} -14 & -7 & 0 \\ -25 & 0 & 5 \\ 29 & 7 & -10 \end{bmatrix}$

$$\therefore\ x = A^{-1}.b = \frac{1}{35}\begin{bmatrix} -14 & -7 & 0 \\ -25 & 0 & 5 \\ 29 & 7 & -10 \end{bmatrix}\begin{bmatrix} 4 \\ 2 \\ -1 \end{bmatrix}$$

Finally $x = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 2 \\ 3 \\ -4 \end{bmatrix}$

$$\therefore x_1 = 2, x_2 = 3, x_3 = -4$$

Eigen values and Eigen vectors

In many applications of matrices to technological problems involving coupled oscillations and vibrations equations are of the form

$$A.x = \lambda x$$

Where A is a scale matrix and λ is a number. The values of λ are called he eigenvalues. Characteristic values or latent roots of the matrix A and the corresponding solution of the given equation $A.x = \lambda x$ are called the eigevectors or characteristics vector of$A$.

For more information refer to Engineering Mathematics by K.A Stroud.

2.3.14.3. Self- Assessment

1. Define a matrix
2. A matrix having M rows and N columns is called a $M \times N$ $(i.e\ M\ by\ N)$ matrix and is referred to as having order $M \times N$. TRUE OR FALSE?
3. $A.x = \lambda x$ are called the eigevectors or characteristics vector of$A$. TRUE OR FALSE?
4. Differentiate between Eigen values and Eigen vectors
5. Perform calculations using matrix
6. Determine a Determinant of a 3×3 matrix
7. Determine an Inverse of a 3×3 matrix
8. Solve the following set of linear equations by matrix method

   $x_1 + 3x_2 + 2x_3 = 3$

   $2x_1 - x_2 - 3x_3 = -8$

   $5x_1 + 2x_2 + x_2 = 9$

9. Find the inverse of the matrix $A = \begin{bmatrix} 2 & 1 & 4 \\ 3 & 5 & 1 \\ 2 & 0 & 6 \end{bmatrix}$

10. If $A.x = \lambda x$, $A = \begin{bmatrix} 2 & 2 & -2 \\ 1 & 3 & 1 \\ 1 & 2 & 2 \end{bmatrix}$. Determine the eigenvalues of the matrix A and an eigenvector corresponding to each eigenvalue.

2.3.15. Learning Outcome No.14. Apply Numerical Methods

2.3.15.1. Learning Activities

Learning Activities No.14 Apply Numerical Methods	
Learning Activities	Special Instructions
• Apply numerical methods in solving engineering problems	

2.3.15.2. Information Sheet No. 2/ LO14

The limitation of analytical methods, have led engineers and scientist to evolve graphical and numerical methods. The graphical methods though simple give results to a low degree of accuracy. Numerical methods can, however, be derived which are more accurate.

Numerical methods are often of a repetitive nature. These consist of repeated execution of the same process where at each step the results of the proceeding step is used. This is known as iteration process and is repeated till the result is obtained to a derived degree of accuracy.

The numerical methods for the solution of algebra and transcendental equations include

1) Method of false solution/ regular false method
2) Newton-Raphson method.

Example

Find by Newton Raphson method the real roots of $xe^x - 2 = t$ correct to 3 decimal places.

Solution

Let $f(x) = xe^x - 2$ and $f(1) = e - 2 = 0.7183$

So a root lies between 0 and 1. Its near to 1 let's take $x_0 = 1$

Also $f'(x) = xe^x + e^x$ and $f'(1) = e + e = 5.4366$

Therefore by Newton-Raphson rule, the first approximation x_1 is given by

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)} = 1 - \frac{0.7183}{5.4366} = 0.8679$$

Therefore $f(x_1) = 0.0672, \quad f'(x_1) = 4.4491$

Thus the first approximation x_2 is given by

$$x_2 = x_1 - \frac{f(x_1)}{f'(x_1)} = 0.8679 - \frac{0.0672}{4.4491} = 0.8528$$

Hence the required root is 0.853 correct to 3 dp

Finite differences and interpolation

Suppose we are given the following values for $y = f(x)$ for a set of values of x:

$$x: x_0 \;\; x_1 \;\; x_2 \;\; \dots . x_n$$

$$y: y_0 \;\; y_1 \;\; y_2 \;\; \dots . y_n$$

Then the process of finding any value of y corresponding to any value of $x = x_i$ between x_0 and x_n is called interpolation.
The interpolation is the technique of estimation the value of a function for any value of the intermediate value of the independent variable while the process of computing the value of the function outside the given range is called extrapolation.

Example
The table gives the distance in nautical miles of the visible horizon for the given height in feet above the earth's space.

Height (x)	100	150	200	250	300	350	400
Distance (y)	10.63	13.03	15.04	16.81	18.42	19.90	21.27

Find values of y when x =2.8 feet and 410 $feet$
The difference table is as given below

x	y	Δ	Δ^2	Δ^3	Δ^4
100	10.63				
		2.40			
150	13.03		-0.39		
		2.01		0.15	
200	15.04		-0.24		-0.07
		1.77		0.08	
250	16.81		-0.16		-0.05
		1.61		0.03	
300	18.42		-0.13		-0.01
		1.48		0.02	
350	19.90		-0.11		
		1.37			
400	21.27				

i) If we take $x_0 = 200$, then $y_0 = 15.04$, $\Delta_{y_0} = 1.77$ $\Delta^2{}_{y_0} = -0.16$ $\Delta^3{}_{y_0} = 0.03$ etc

Since $x = 218$ and $h = 50 \therefore p = \frac{x - x_0}{h} = \frac{18}{50} = 0.36$

Using Newton Raphson forward interpolation formula, we get

$$y_{218} = y_0 + p\Delta_{y_0} + \frac{p(p-1)\Delta^2{}_{y_0}}{1.2} + \frac{p(p-1)(p-2)}{1.2.3} \Delta^3{}_{y_0} + \cdots$$

$$f(218) = 15.04 + 036(1.77) + \frac{0.36(-0.64)}{2}(-0.16) + \frac{0.36(0.64)(-1.64)(0.03)}{6}(0.03) + \cdots$$

$$= 15.04 + 0.637 + 0.018 + 0.001 + \cdots . = 15.696\, nautical\ miles$$

ii) Since $x = 410$ is near the end of the table, we use Newton backward interpolation formula.

Therefore taking $x_n = 400p = \frac{x-x_n}{h} = \frac{10}{50} = 0.2$

Using the backward differences

$y_n = 21.27, \nabla_{y_n} = 1.37 \quad \nabla^2{}_{y_n} = 0.11 \quad \nabla^3{}_{y_n} = 0.02$

Newton backward difference gives

$$y_{410} = y_{405} + p\Delta_{y_{400}} + \frac{p(p+1)\nabla^2{}_{y_{400}}}{1.2} + \frac{p(p+1)(p+2)}{1.2.3} \quad \nabla^3{}_{y_{400}} + \cdots$$

$$21.27 + 0.2(1.37) + \frac{0.2(1.2)}{2}(-0.11) + \cdots. = 21.53\ nautical\ miles$$

Refer to *Higher Engineering Mathematics by Dr B.S* and learn forward and backward interpolation formulae

2.3.15.3 Self-Assessment

1. Describe numerical methods
2. The graphical methods though simple give results to a low degree of accuracy. Numerical methods can, however, be derived which are more accurate. TRUE OR FALSE
3. The process of computing the value of the function outside the given range is called interpolation. TRUE OR FALSE
4. Differentiate between Method of false solution/ regular false method and Newton-Raphson method.
5. State the applications of numerical methods
6. Using Newton-Raphson forward formula find the values of $f(1.6)$, if

X	1	1.4	1.8	2.2
$f(x)$	3.49	4.82	5.96	6.5

7. State Newton interpolation formula and use it to calculate the value of $\exp(1.85)$ given the following table

X	1.7	1.8	1.9	2.0	2.1	2.2	2.3
$f(x)$	5.474	6.000	6.686	7.389	8.166	9.025	9.914

CHAPTER 3: WORKSHOP TECHNOLOGY /PERFORM WORKSHOP PROCESSES

3.1. Introduction of the Unit of Learning / Unit of Competency

Workshop Technology processes is the use of electrical skills gained from various electrical workshop practices to install and troubleshoot electrical instrument and devices in electrical wiring, or distribution and power generation. These skills are applied in various industries e.g. in telecommunication, electrical manufacturing. This unit covers electrical safety, use and storage of workshop tools/instruments /equipment/materials, installation of electrical instruments and devices, and troubleshooting and repair/replacement of electrical tools and equipment. Upon completion of this unit of competency, a trainee should be able to perform installation, troubleshooting and maintenance of electrical instruments and devices while observing the appropriate safety measures. This unit prepares trainees to pursue electronics as a gainful career in the field of electrical engineering.

3.2. Performance Standard

Calibrate, operate safely and maintain the workshop tool and equipment as per standard operating procedures, manufacturer's recommendations, perform first aid procedures as per standard operating procedures, dispose waste materials as per the EHS requirements, identify and diagnose faulty tools as per diagnostic procedures and the standard operating procedures, repair/replace faulty tools/equipment as per the workplace procedures, and test& troubleshoot repaired or replaced tool/equipment as per the standard operating procedures. Observe safety as per IEE Standards

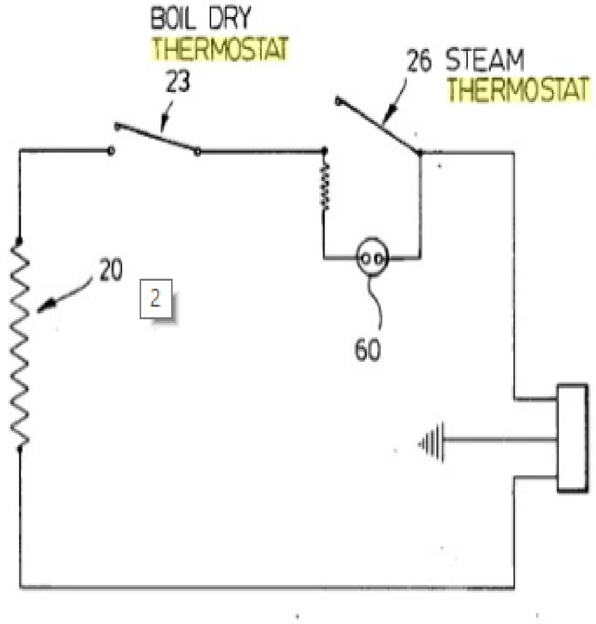
3.3. Learning outcomes

3.3.1. List of Learning Outcomes

a) Apply workshop safety
b) Use of workshop tools, Instruments and equipment.
c) Prepare workshop tools and instruments for an electrical installation practical
d) Prepare the workshop for an Electrical practical
e) Store Electrical tools and materials after practical.
f) Troubleshoot and repair workshop tools and equipment

3.3.2. Learning Outcomes No. 1 Apply workshop safety

3.3.2.1 Learning activities

Learning Outcome No. 1. Apply workshop safety	
Learning Activities	Special Instructions
 Activity: Obtain and an electrical kettle to be connected to a power supply • Wear PPEs • Obtain the necessary tools for inspecting/testing the functionality of the kettle. • Check safety of power supply socket/system as per the standard operating procedures. • Perform safety inspection of the electrical kettle as per standard operating procedures	• Observe manufacturer's manual instructions for the specific electrical kettle • Observe IEE regulations • Observe organizational procedures manual • Provide the trainee with varied opportunities to learn safety precautions taken in handling different electrical appliances, equipment, and machines.

3.3.2.1. Information Sheet No. 3/ LO1

Introduction

This learning outcome entails the trainee observing electrical safety and procedures, safety regulations in obtaining electrical equipment, earthing concepts in electrical safety, electrical machine, handling electric power systems, and demonstrating knowledge of workshop rules, electrical hazards and treatment/first aid procedures in accordance with the need of an activity. Also, it covers, various technical facilities in the electrical workshop including mechanical and electrical equipment.

Definition of key terms

Classes of fires: These are the types of fires based on the burning material e.g. word, charged electrical device, etc.

Electrical equipment: These are the essential requirements for electrical workshop practices to take place. They include; set of screw drivers, pliers, phase testers, multimeter, etc.

Recommended sources for further information; *Electrical Safety Handbook 3E by Cadick. J. et al.*

Set up procedure for an electrical equipment;

1. Wear PPE
2. Obtain the electrical equipment, set of screw drivers, pliers, phase testers, multimeter
3. Check the condition of the equipment components, thermostat, heating element, switch, and the indicator light
4. Connect power cable to the equipment and to the power supply socket.
5. Ensure the electrical equipment is set up properly, and the power cable is in good condition.

Recommended sources for further information; *Electrical Safety Handbook 3E by Cadick. J. et al.* 2016 IEEE IAS Electrical Safety Workshop (ESW)

Watch an 8.42 min video on electrical safety and electrical safe work from the web link: https://slideplayer.com/slide/8724303/

Content

Safety: types of electrical hazards and safety precautions, use of PPE, working environment, classifications of fires, first aid for electrical operator, overview of OSHA regulations and workplace procedures. Electrical, tools & equipment: types of screw drivers, pliers, and electrical measuring instruments and measure various electrical parameters like current, voltage, power

Personal protective equipment in electrical workshop practices:

- Safety cloth
- Gloves
- Shoes

Source: Electrical Protection Handbook (©1990)Bussman, Cooper Industries, Inc

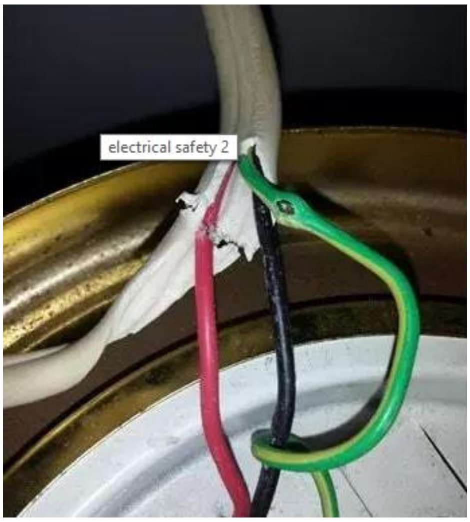


Figure 3: damaged insulation

Source: Electrical Protection Handbook (©1990)Bussman, Cooper Industries, Inc.

Conclusion

This outcome covered electrical safety, symbols in electrical circuit diagrams, electrical tools & equipment.

Trainees' assignment;

- Observe safe working of electrical circuit protective devices.
- Perform safety procedures for conducting, insulating materials, capacitors, inductors, and resistors.
- Perform fire safety inspection of the working area.
- Perform safety procedures of first aid in case of electrical hazards.
- Perform testing of electrical appliance for safety

Trainer

Check that the trainee working behaviour exhibit evidence of application of safety practices and electrical housekeeping procedures and policies. Ensure assignments are completed on time. Observe trainees' working behaviour on an on-going basis.

Recommended sources for further information; *Electrical Safety Handbook 3E by Cadick. J. et al.*

3.3.2.3 Self-Assessment

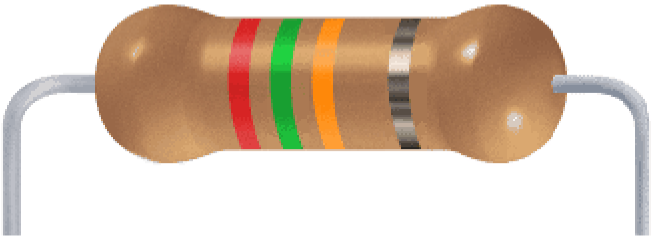
1.

This sign means Highly Flammable.

A. True

B. False

2.

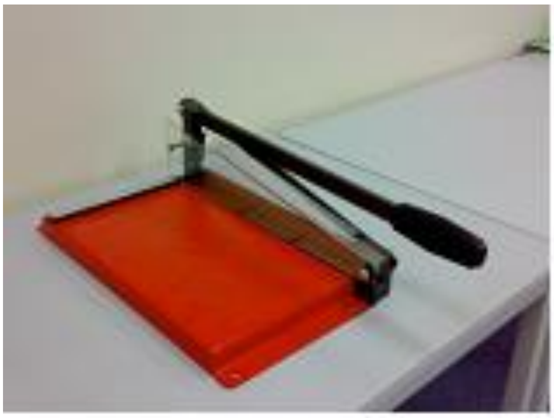


a. 25000 ohms +- 10%
b. 27000 ohms +- 10%
c. 250000ohms +- 5%
d. 27000 ohms +- 5%

3. To clean the tip of of the soldering iron, use
   a. A PCB eraser
   b. A cloth
   c. A dry sponge
   d. A wet sponge

4. The first stage in PCB fabrication is
   a. Preparing the artwork
   b. Exposure
   c. Developing and rinsing
   d. Tinning

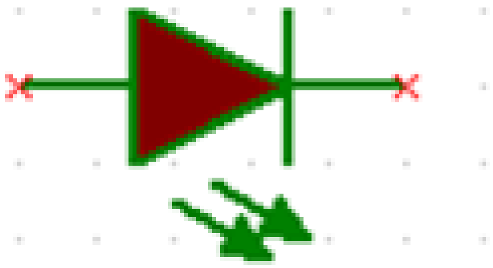
5. Identify the component



a. Edge rounder
b. PCB mega station
c. PCB cutter

d. UV exposue unit

6. Identify the component



a. Diode
b. LED
c. LDR
d. CAPACITOR

7. An oscilloscope is a device that is used to generate different waveforms.
   a. True
   b. False

8. The edge rounder is an equipment used to drill holes on the PCB.
   a. True
   b. False

9. Developing and rinsing is the last stage in PCB fabrication.
   a. True
   b. False

10. Solder wire is an alloy made up of tin and lead.
    a. True
    b. False

11. It is not possible to measure voltage values across resistances in a circuit using a function generator.
    a. True
    b. False

Practical question

1. Adhere to proper use of PPE as per standard operating procedure
2. Follow workshop rules as per standard operating procedure
3. Follow proper use of safety equipment as per the manufacturers recommendations
4. Adhere to first aid procedures

3.3.2.4.Tools, Equipment, Supplies and Materials for the specific learning outcome

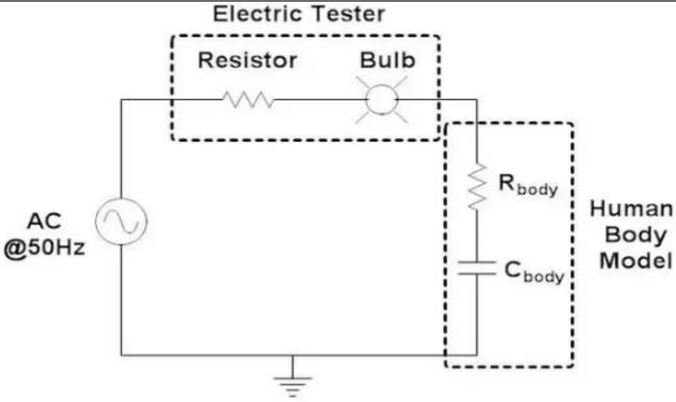
- Set of screw drivers
- Pliers
- Phase testers
- Multimeter
- Electrical measuring instruments
- Lab coat
- Gloves

3.3.2.5. References

1. Cadick, J. (2012). Electrical safety handbook. McGraw-Hill Professional.
2. Brian Scaddan, Electric Wiring: Domestic
3. Peter J. Seebacher, Home Infrastructure (Project 3) (PDF)

3.3.3. Learning Outcomes No. 2 Use of Workshop Tools, Instruments and Equipment

3.3.3.1 Learning activities

Learning Outcome No. 2. Use of workshop tools, Instruments and equipment.	
Learning Activities	Special Instructions
 Activity 1: Use circuit testers or electrical tester • Obtain a specific circuit tester e.g. a phase, continuity tester, etc. • Check safety/ inspect the specific tester as per the standard operating procedures. • Use the tester as per the manufacturer's instructions Activity 2: Use cordless drills • Obtain a specific circuit drill. • Check safety/ inspect the specific dril as per the standard operating procedures. • Use the drill as per the manufacturer's instructions Activity 3: Use voltmeters or multimeters • Obtain a specific voltmemers/ multimeters. • Check safety/ inspect the specific dril as per the standard operating procedures. • Calibrate the specific instrument as per the standard operating procedures. • Use the instrument as per the manufacturer's instructions	• Observe manufacturer's manual instructions for the specific electrical kettle • Observe IEE regulations • Observe organizational procedures manual • Provide the trainee with varied opportunities to learn use of various electrical testers.

3.3.3.2. Information Sheet No. 3/ L02

Introduction
This learning outcome involves the safety, classification, use, care, and maintenance of various workshop tools, instruments, and equipment. It also, involves demonstration of knowledge of workshop rules, electrical hazards and first aid procedures in accordance with the need of an activity. It also covers, wiring regulations, types of cables and electric accessories including switches, plugs, circuit breakers, fuses etc., symbols for electrical wiring schematics e.g. switches, lamps, sockets etc., drawing and practice in simple house wring and testing methods, wiring schemes of two-way and three-way circuits and ringing circuits, voltage and current measurements. Electric soldering and soldering tools; soldering methods and skills, drilling and soldering components.

Definition of key terms
Ampere: The SI unit of electrical current.
Electrical equipment: These are the essential requirements for electrical workshop practices to take place. They include; set of screw drivers, pliers, phase testers, multimeter, etc.
Apparent Power: Apparent power is the product of the rms voltage and the rms current. Measured in volt-amperes.

Recommended sources for further information;

- Electrical Safety Handbook 3E by Cadick. J. et al.
- Watch a 1.04min on use of an electrical tester - circuit tester from the link: https://youtu.be/Moad9c1wTwk?t=41
- Watch a 5.24min on use of an electrical circuit testers from the link: https://youtu.be/togB4pyjdUA?t=98

Electrical principles
An electric circuit is formed when a conductive path is established to allow free electrons to move continuously. This free movement of electrons through an electric conduct is called current. Voltage motivates electrons to flow in a circuit. Voltage is the measure of how much of potential energy exists to move electrons from one specific point in a circuit to another specific point the circuit. While the electrons move in a circuit, they experience some friction or opposition motion. This is called resistance. It is the force resisting the flow of electrons across two points in a circuit. Resistance and voltage determines the amount of current in a circuit,
Recommended sources for further information;
Electrical Safety Handbook 3E by Cadick. J. et al. 2016 IEEE IAS Electrical Safety Workshop (ESW)
Watch a 22.10 min video on electrical principles from the web link:
https://youtu.be/49Zlel5XaDU?t=474

Watch a 13.44 min video on electrical principles from the web link:
https://youtu.be/ytATo6tS9yE?t=192
Content
Safety: safety and care precautions in using various electrical tools. Electrical tools, equipment and instruments: use of screw drivers, pliers, electrical testers, and electrical measuring instruments and measure various electrical parameters like current, voltage, power.

Figure 4: Electric drill
Source: Electrical Safety Handbook 3E by Cadick. J. et al.

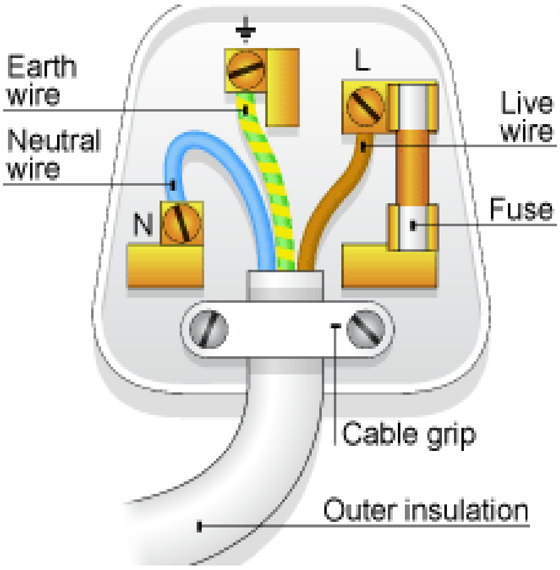


Figure 5 : cable head
Source: Electrical Safety Handbook 3E by Cadick. J. et al.

Figure 6: receptacle
Source: Electrical Safety Handbook 3E by Cadick. J. et al.

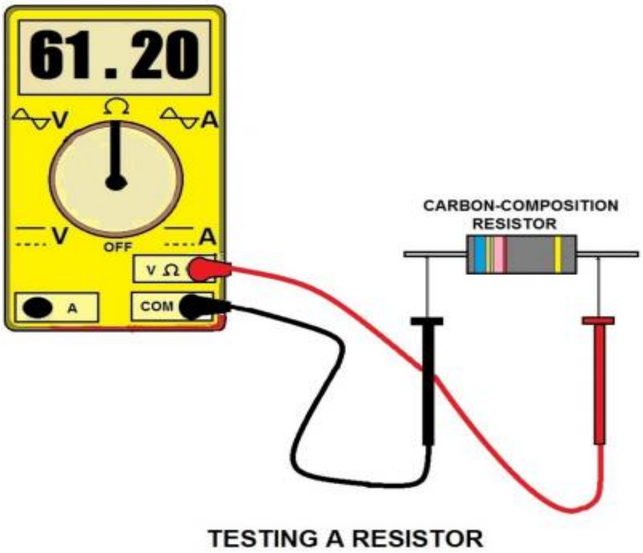


Figure 7: testing a resistor
Source: Electrical Safety Handbook 3E by Cadick. J. et al.

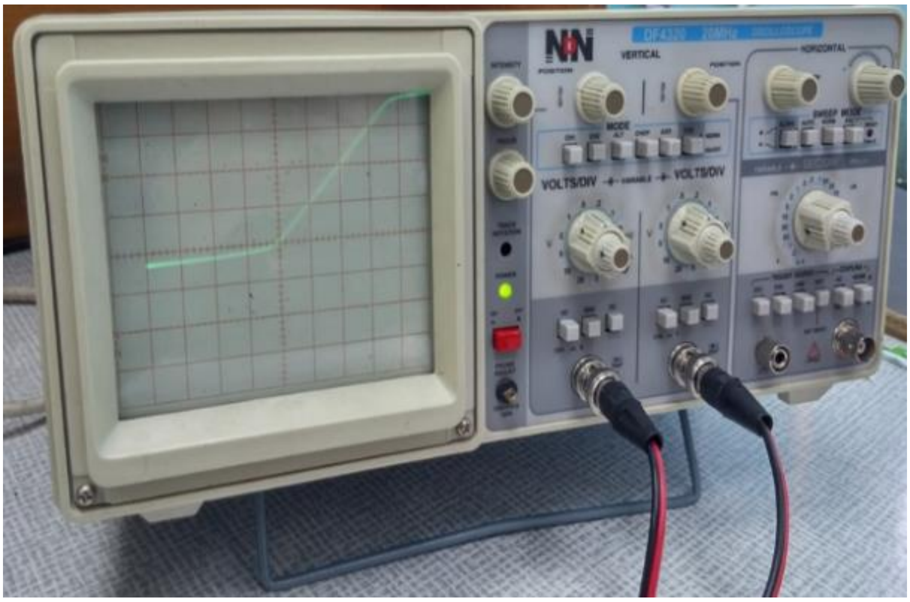


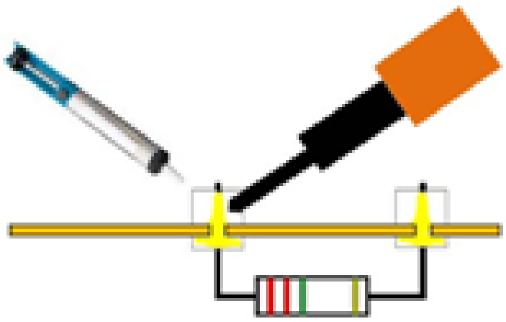
Figure 8: Continuity tester Multimeter, Oscilloscope
Source: Electrical Safety Handbook 3E by Cadick. J. et al.

Conclusion
This outcome covered electrical safety, classification, use, care, and maintenance of various workshop tools, instruments, and equipment.
Trainees' assignment;
i. Set and use oscilloscope

Trainer
Check that the trainee working behaviour exhibit evidence of application of safety practices and electrical housekeeping procedures and policies. Ensure assignments are completed on time. Observe trainees' working behaviour on an on-going basis.

Recommended sources for further information; *Electrical Safety Handbook 3E by Cadick. J. et al.*

3.3.3.3. Self-Assessment
1. The process shown below is called



a. Soldering
b. Desoldering
c. Tinning
d. Drilling

2. Name the following

			
1	2	3	4

3. Ampere is the SI unit of electrical voltage. TRUE OR FALSE?
4. Real power is the product of the rms voltage and the rms current. Measured in volt-amperes. TRUE OR FALSE?

Practical question;

1. Identify Workshop tools, Instruments and equipment
2. Use Tools, Instruments and equipment as per the manufactures manuals
3. Perform Calibration of workshop instruments as per the standard operating procedure
4. Follow Proper handling of workshop tools, Instruments and equipment
5. Adhere to Care and Maintenance of workshop tools, Instruments and equipment

3.3.3.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

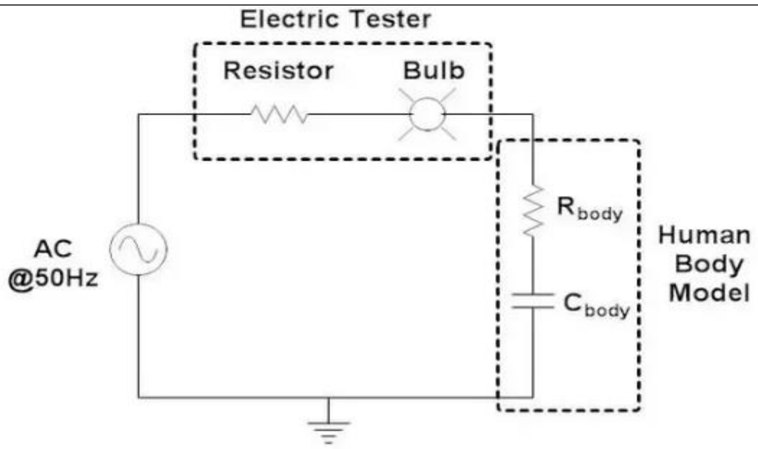
- Hacksaws
- Pliers
- Phase testers
- Multimeter
- Set of screw drivers
- Side cutters, etc.
- Lab coat
- Hammers

3.3.3.5. References

1. Cadick, J. (2012). Electrical safety handbook. McGraw-Hill Professional.
2. Brian Scaddan, Electric Wiring: Domestic
3. Peter J. Seebacher, Home Infrastructure (Project 3) (PDF)

3.3.4. Learning Outcomes No. 3. Prepare workshop tools, Instruments and equipment

3.3.4.1. Learning activities

<table>
<tr><td colspan="2">Learning Outcome No. 3. Prepare Workshop Tools For An Electrical Installation.</td></tr>
<tr><td>Learning Activities</td><td>Special Instructions</td></tr>
<tr><td>


Activity 1: Use circuit testers or electrical tester

Obtain a specific circuit tester e.g. a phase, continuity tester, etc.
Check safety/ inspect the specific tester as per the standard operating procedures.
Use the tester as per the manufacturer’s instructions

Activity 2: Use cordless drills

Obtain a specific circuit drill.
Check safety/ inspect the specific dril as per the standard operating procedures.
Use the drill as per the manufacturer’s instructions

Activity 3: Use voltmeters or multimeters

Obtain a specific voltmemers/ multimeters.
Check safety/ inspect the specific dril as per the standard operating procedures.
Calibrate the specific instrument as per the standard operating procedures.
Use the instrument as per the manufacturer’s instructions

</td><td>
Observe manufacturer’s manual instructions for the specific electrical kettle

Observe IEE regulations
Observe organizational procedures manual

Provide the trainee with varied opportunities to learn use of various electrical testers.
</td></tr>
</table>

3.3.3.1. Information Sheet No. 3/ L03

Introduction

This learning outcome involves the selection, classification, use, care, and maintenance of various workshop tools, instruments, and equipment. It also, involves application of procedures in accordance with the need of an activity for an electrical installation. It also covers, wiring regulations, types of cables and electric accessories including switches, plugs, circuit breakers, fuses etc., symbols for electrical wiring schematics e.g. switches, lamps, sockets etc., drawing and practice in simple house wring and testing methods, wiring schemes of two-way and three-way circuits and ringing circuits, voltage and current measurements. Electric soldering and soldering tools; soldering methods and skills, drilling and soldering components.

Definition of key terms

Cable – A cable is made up of one or more conductors and their insulated surrounding

Hammers – Voltage is the difference in electrical potential between two different points, it can be thought of as electrical pressure, and it is denoted by the letter V or U.

Circuit breaker – A type of protective device for circuits, it will protect a circuit from overload and fault currents.

Main switch – Although not a protective device, in a typical household, the mains switch is located in the consumer unit. Its purpose is to disconnect the supply of electricity to the installation.

How to proceed with an Electrical Installation;

Prepare a detailed electrical wiring diagram to start with.

Then calculates the Electrical Loads, Currents, Cable sizes and the Protective devices for the Electrical Installation.

Based on this information, worked out the quantities of material and components needed for the job.

There are specifications for carrying out Electrical Installation Work so that the completed installation will abide to rules and regulations of the Electrical Industry. The Electrical Conductors [cables or wires] needed to be selected according to the current rating [Capacity] and Voltage Drop when the rated current flows in the conductors. This selection of the conductor is called Conductor Sizing. The conductors can be of Copper or Aluminium. Copper is the material used mostly for indoor installations and Aluminium for mostly Power Transmission. The outer Insulation of the conductors are selected according to the Temperature, the conductors are used for when carrying current. The over current protection for conductors are very important and there are Fuses and Circuit Breakers incorporated to safeguard current carrying conductors. Ground Fault Circuit Interrupters or Earth Leakage Circuit Breakers or Residual Current Circuit Breakers will safeguard people from getting Electric Shock from Live or Hot Circuit conductors or equipment.

Power point

Power points (receptacles, plugs, wall sockets) need to be installed throughout the house in locations where power will be required. In many areas the installation must be done in compliance with standards and by a licensed or qualified electrician. Power points are typically located where there will be an appliance installed such as telephone, computers, television, home theater, security system, CCTV system.

Light fittings and switches

The number of light fitting does depend on the type of light fitting and the lighting requirements in each room. A lighting designer can provide specific recommendations for lighting in a home. Layout of lighting in the home must consider control of lighting since this affects the wiring. For example, multiway switching is useful for corridors and stairwells so that a light can be turned on and off from two locations. Outdoor yard lighting, and lighting for outbuildings such as garages may use switches inside the home.

Electrical this is cabling installed from the electrical switchboard to the light fitting or any other device that is to be controlled by the automation system. For example, if you have four down lights in a room and you wish to control each light individually, then each light will be wired back using electrical cabling back to the electrical switchboard. This means you will have four electrical cables installed from the electrical switchboard to the location where the light fittings will be installed. Each cable will be a three core active, neutral and earth cable. If in that room you also have a free standing lamp plugged into a power point and you also want to control this from your automation system, you will need to have that power point individually wired back to the electrical switchboard. So if you want to individually control every light fitting and every power point or power outlets then each one of these devices must be individually wired back to the electrical switchboard. As you can see this start to become quite a lot of electrical cabling so planning is essential.

Figure 9: industrial main switch

Source: Electrical Safety Handbook 3E by Cadick. J. et al.

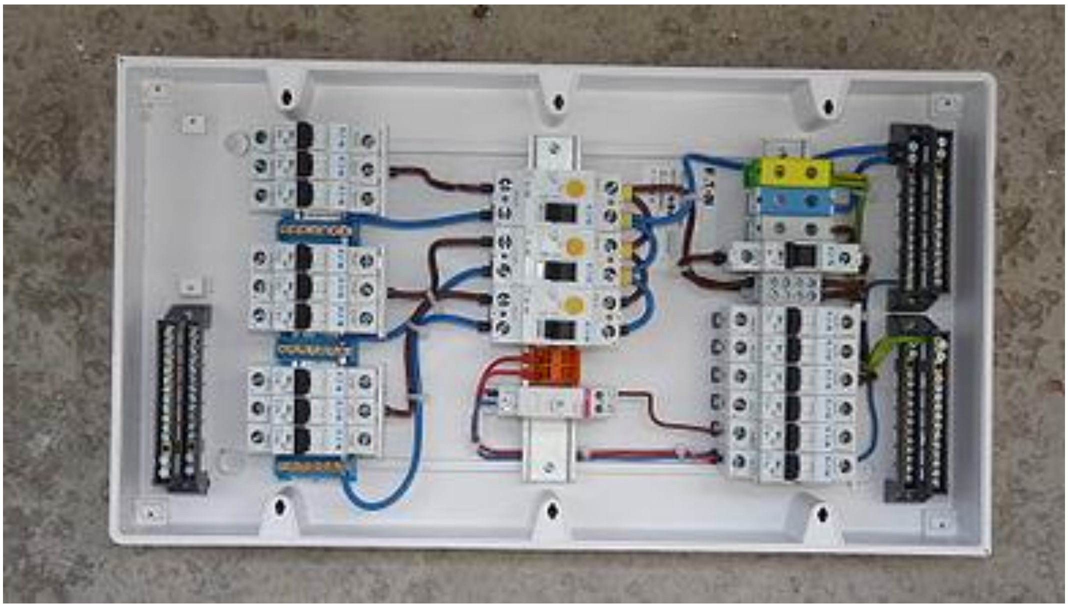


Figure 10: Single-phase ~230 V/40 A/9 kW fuse box for apartment rewiring
Source: Electrical Safety Handbook 3E by Cadick. J. et al.

Source; Brian Scaddan, Electric Wiring: Domestic; Peter J. Seebacher, Home Infrastructure (Project 3) (PDF)
Recommended sources for further information;
Brian Scaddan, Electric Wiring: Domestic
Peter J. Seebacher, Home Infrastructure (Project 3) (PDF)
Electrical Safety Procedures

1. Avoid loose wires, cables, and connections.
2. Assume any exposed wire/metal is live with electricity unless otherwise verified.
3. Familiarize oneself with all ON/OFF buttons on equipment, circuit breakers, and disconnect switches of a bench.
4. Only make changes to the experimental setup when the circuit power is turned off and all power sources read zero voltage and zero current, as applicable.
5. Use wires of suitable length for their appropriate applications. Long wires or connections can cause clutter on a bench, and very short wires or connections can be too tight and may be easily disconnected.
6. Separate higher power equipment and connections from lower power equipment, such as microcontrollers, to avoid both interference and electrical interconnections between sensitive electronic devices and higher power devices.
7. Make sure that all DC power supplies, AC sources, and other power sources start from a zero voltage and zero current output or as directed in an experiment. Starting from a non-zero voltage is possible in certain applications where a voltage source should have a specific initial condition.

8. Turn off all equipment before leaving the lab once an experiment concludes.
9. Do not allow a single user to perform an experiment alone. Make sure at least two users perform an experiment when operating more than 50 V DC and three-phase AC.

Energy management

Energy management is a new and upcoming topic in particular at the home. Older systems tended to be cable however all new systems use one of a variety of wireless solutions. This enables them to be effectively retrofitted into existing homes with the minimum of disruption.

If a cabled system is selected cabling needs to be deployed to the major appliances in the home. The cabling is installed as part of the data cabling as per detailed in this article in the section titled "Data Network Cabling". In addition to a cable being installed to every major appliance you also need to install a data cable near the electricity meter.

The major appliances being considered at this stage are:

- Electric hot water system
- Air Conditioning
- Pool pump
- Fridge / freezer
- Electric vehicle charger
- Battery energy storage systems (BESS)

Conclusion

Should a wireless system be selected the need for such disruption is removed. Smart plugs or switches can be used to connected the major appliances to the electricity supply and the home energy management system will wirelessly control them

Content

Safety: Safe working habits and precautions in setting up electrical work stations.
Electric Supply: Power sources, Electric wirings, signs, symbols and data.

3.3.3.2 Self-Assessment

1. The meter shown in the picture
A. Multimeter
B. Voltameter
C. Power meter

D. None of the above

2. 2. The shown above figure is called
A. Consumer unit
B. MCB
C. RCD
D. LCD

Practical question

1. Prepare List of required tools and instruments
2. Perform issuing of required tools and instruments
3. Perform confirmation of the issued tools and instruments
4. Check functioning of the issued tools and instruments in line with the standard operating procedure
5. Perform Sharpening of the cutting tools

3.3.3.3 Tools, Equipment, Supplies and Materials for the specific learning outcome;

- Hacksaws
- Pliers
- Phase testers
- Multimeter
- Set of screw drivers
- Side cutters, etc.
- Lab coat
- Hammers
- Oscilloscope
- Soldering tools, etc.

3.3.3.4 References

1. Cadick, J. (2012). Electrical safety handbook. McGraw-Hill Professional.
2. Electrical Safety Handbook 3E by Cadick. J. et al.
3. 2016 IEEE IAS Electrical Safety Workshop (ESW)
4. Brian Scaddan, Electric Wiring: Domestic
5. Peter J. Seebacher, Home Infrastructure (Project 3) (PDF)

3.3.5. Learning Outcomes No. 4. Prepare workshop for an electrical practical

3.3.5.1. Learning Activities

Learning Outcome No. 4. Prepare workshop for an Electrical practical.	
Learning Activities	Special Instructions
Activity: Disassembling & re-assembling an electrical equipment • Study the original connection of movable switch board • Remove the connection • Take out the equipment • Reinstall and reconnect the wire • Do the safety test	Observe manufacturer's manual instructions for the specific electrical kettle Observe IEE regulations Observe organizational procedures manual Provide the trainee with varied opportunities to learn preparation procedures required for electrical practices.

3.3.5.2 Information Sheet No. 3/L04

Introduction

This learning outcome involves the setting up of workstations, making provisions for power supply and availing tools, equipment and materials for a specific practice. It also, involves demonstration of knowledge of workshop rules and safe working procedures in accordance with the need of the practical and the standard operating procedures.

Definition of key terms

Configuration -Arrangement of nodes, elements, etc. to create an electronic circuit with a particular function.

Terminal -It is a point at which a conductor from an electrical component, device or network comes to an end and provides a point of connection to external circuits.

Recommended sources for further information; *Electrical Safety Handbook 3E by Cadick. J. et al.*

Watch a 1.39min on electrical wiring from the link:

https://youtu.be/9uMIQycxygQ?t=59

Electrical Safety Procedures

1. Avoid loose wires, cables, and connections.
2. Assume any exposed wire/metal is live with electricity unless otherwise verified.
3. Familiarize oneself with all ON/OFF buttons on equipment, circuit breakers, and disconnect switches of a bench.
4. Only make changes to the experimental setup when the circuit power is turned off and all power sources read zero voltage and zero current, as applicable.
5. Use wires of suitable length for their appropriate applications. Long wires or connections can cause clutter on a bench, and very short wires or connections can be too tight and may be easily disconnected.
6. Separate higher power equipment and connections from lower power equipment, such as microcontrollers, to avoid both interference and electrical interconnections between sensitive electronic devices and higher power devices.
7. Make sure that all DC power supplies, AC sources, and other power sources start from a zero voltage and zero current output or as directed in an experiment. Starting from a non-zero voltage is possible in certain applications where a voltage source should have a specific initial condition.
8. Turn off all equipment before leaving the lab once an experiment concludes.
9. Do not allow a single user to perform an experiment alone. Make sure at least two users perform an experiment when operating more than 50 V DC and three-phase AC.

Content

Safety: Safe working habits and precautions in setting up electrical work stations.

Electric Supply: Power sources, Electric wirings, signs, symbols and data.

Illustrations

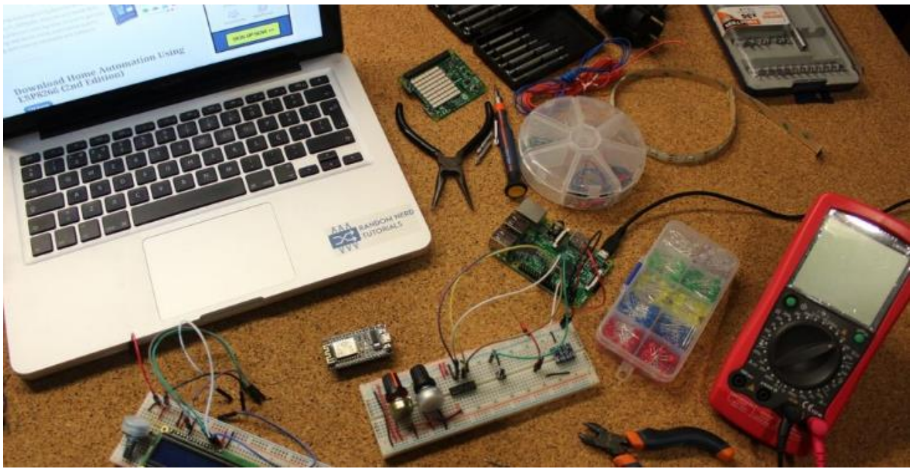


Figure 11: Electric supply

Source: Brian Scaddan, Electric Wiring: Domestic

Cadick, J. (2012).

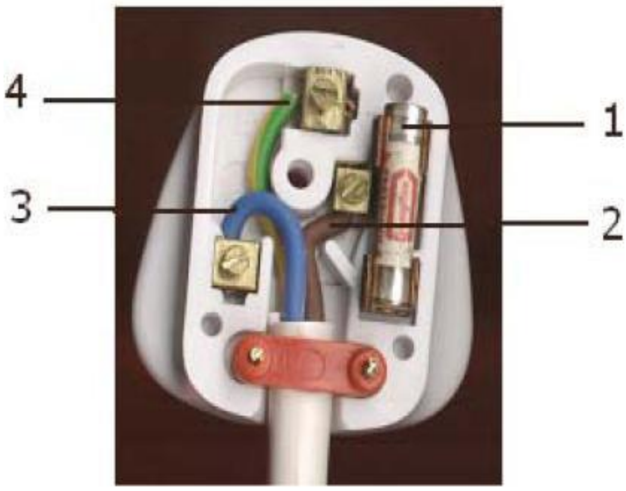
Figure 12: electric tools and equipment
Source: Brian Scaddan, Electric Wiring: Domestic

Conclusion
This outcome covered electrical safety, inspection, set up and powering of workstations.

Trainees' assignment;
Set up workstation for operating cathode ray oscilloscope and function generator for measurement of ac signal parameters.
Trainer
Check that the trainee working behaviour exhibit evidence of application of safety practices and electrical housekeeping procedures and policies. Ensure assignments are completed on time. Observe trainees' working behaviour on an on-going basis.
Recommended sources for further information; Electrical Safety Handbook 3E by Cadick. J. et al.

3.3.5.3. Self-Assessment

1. Arrangement of nodes, elements, etc. to create an electronic circuit with a particular function is called Configuration. TRUE OR FALSE?



2. The pin number 2 is connected to
   a. Earth
   b. Live
   c. Neutral
   d. Fuse
3. The pin number 4 of the plug is connected to
   a. Earth
   b. Live
   c. Neutral
   d. Fuse
4. Termination is a point at which a conductor from an electrical component, device or network comes to an end and provides a point of connection to external circuits. TRUE OR FALSE?
5. Schematic is Symbolic and simplified diagram of an electric or electronic circuit. TRUE OR FALSE

Practical question

1. Arrange Practical working section as per the number of practical to be carried out.
2. Confirm Power supply availability in every practical section as per the practical to be carried out
3. Supply Tools and materials required as per the practical to be carried out.

3.3.5.4.Tools, Equipment, Supplies and Materials for the specific learning outcome

- Hacksaws
- Pliers
- Phase testers

- Multimeter
- Set of screw drivers
- Side cutters, etc.
- Lab coat
- Hammers
- Oscilloscope

3.3.5.5. References

1. Cadick, J. (2012). Electrical safety handbook. McGraw-Hill Professional.
2. Electrical Safety Handbook 3E by Cadick. J. et al. 2016 IEEE IAS Electrical Safety Workshop (ESW)
3. Brian Scaddan, Electric Wiring: Domestic
4. Peter J. Seebacher, Home Infrastructure (Project 3) (PDF)
5. Watch a 22.10 min video on electrical principles from the web link: https://youtu.be/49Zlel5XaDU?t=474
6. Watch a 13.44 min video on electrical principles from the web link: https://youtu.be/ytATo6tS9yE?t=192

3.3.6. Learning Outcomes No. 5 Store Electrical tools and materials after practical
3.3.6.1 Learning Activities

<table>
<tr><th colspan="2">Learning Outcome No. 5. Store Electrical tools and materials after practical</th></tr>
<tr><td>Learning Activities</td><td>Special Instructions</td></tr>
<tr><td>
Activity: Return tools and materials for storage
• Checklists of tools and materials
• Sorting of tools and materials
• Functional tools in store
• Non-functional tools in the store</td><td>.</td></tr>
</table>

3.3.6.2. Information Sheet No. 3/ L06

Introduction
This learning outcome involves the classification of tools and materials, storage of workshop tools & equipment, disposal of waste and demonstration of knowledge of workshop rules and safe working procedures in accordance with the need of the practical and the standard operating procedures.

Definition of key terms
5S: Sort, Systematize, Sweep, Sanitize, and Self-Discipline
Lubricant: A substance introduced to reduce friction between moving surfaces.
Pneumatic tool: Instrument activated by air pressure.

Recommended sources for further information;
Electrical Safety Handbook 3E by Cadick. J. et al.

Watch a 1.39min on electrical wiring from the link:
https://youtu.be/9uMIQycxygQ?t=59

Procedure for taking the inventory of inventory of tools and equipment

i. Secure inventory forms of tools and equipment.
ii. Study the parts of the inventory form.
iii. Check whether the list of tools and equipment in the form tallies with the existing tools and equipment found in the workshop including their specifications and condition.
iv. List down any losses and damages you find while conducting the inventory
v. Fill out the remarks column of the inventory forms for any losses/ damages.
vi. Recommend for replacement of lost tools and equipment and repair/ replacement of damaged tools and equipment.

Recommended sources for further information;
Electrical Safety Handbook 3E by Cadick. J. et al. 2016 IEEE IAS Electrical Safety Workshop (ESW)
Watch a 22.10 min video on electrical principles from the web link:
https://youtu.be/49Zlel5XaDU?t=474
Watch a 13.44 min video on electrical principles from the web link:
https://youtu.be/ytATo6tS9yE?t=192

Content
Safety: Safe handling of electrical tools and equipment. Tools and Equipment: checklists of tools and materials, sorting of tools and materials, Conditions of PPE, functional tools in store, and non-functional tools in the store.
Illustrations

Table 2 Sample of inventory form of tools and equipment

Item No.	Quantity	Unit	Description	Condition	Remarks
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					

Prepared by: ______________________ Date: ________________________ Name and Signature

Conclusion
This outcome covered electrical safety, inspection, set up and powering of workstations.

Trainees' assignment;
Arrange and store tools and equipment accordingly in a specific tool cabinet and a tool rack assigned to you.

Trainer
Check that the trainee working for evidence of application of safety practices, classified tools and equipment according to their types, arranged the tools by their types in the shelves and placed equipment in designated location as per the standard operating procedures. Ensure assignments are completed on time. Observe trainees' working behaviour on an on-going basis.

Recommended sources for further information;
Electrical Safety Handbook 3E by Cadick. J. et al. Cardenas, Elpidio.1989, Fundamental and Elements of Electricity. Philippines: national Bookstore.
Max B. Fajardo Jr. & Leo R. Fajardo. 2nd edition, Electrical Layout and Estimate

3.3.6.3. Self-Assessment

1. Is a device for making, breaking, or changing connections in an electric circuit under the conditions of load for which it is rated? It is not designed for interruption of a circuit under short-circuit conditions?
    a. Generator
    b. Switch
    c. Fuse
    d. Transformer
2. A large single panel, frame, or assembly of panels on which are mounted, on the face or back or both, switches, over current and other protective devices, buses. This panel is generally accessible from the rear as well as from the front and are not intended to be installed in cabinets?
    a. Panelboard
    b. Switchboards
    c. Panelbox
    d. Substations
3. A single panel or a group of panel units designed for assembly in the form of a single panel, including buses and with or without switches and/or automatic over current protective devices for the control of light, heat or power circuits, designed to be placed in a cabinet or cutout box placed in or against a wall or partition and accessible only from the front.
    a. Panelboard
    b. Switchboards
    c. Outletbox

   d. Substations
4. An electrical shock is received when ………………………… passes through the body.
   a. Magnetic field
   b. Water
   c. Electric current
5. It is safe to use electrical appliances in a wet area.
   a. True
   b. False
6. The component inside a 3-pin plug is called a fuse.
   a. True
   b. False
7. Lubricant is a substance introduced to reduce friction between moving surfaces. TRUE OR FALSE?
8. Pneumatic tool is an instrument activated by air pressure. TRUE OR FALSE?
9. Explain inventory tools.

Practical question
1. Check Tools against the issuing list after practicals
2. Store out Tools as per their standard operating procedure
3. Clean Tools as per the workshop standard operating procedure
4. Dispose Waste materials as per the EHS
5. Store Tools in their respective sections as per the workshop procedures

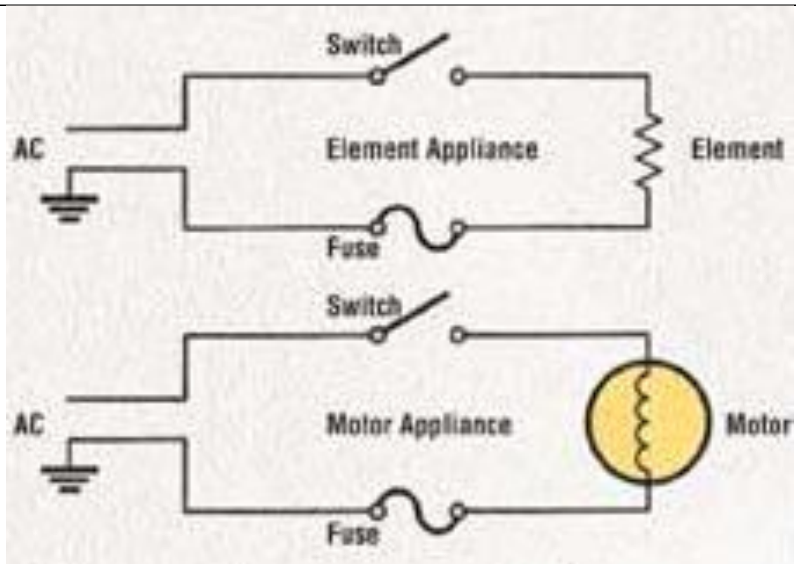
3.3.6.3. Tools, Equipment, Supplies and Materials for the specific learning outcome
- Hacksaws
- Pliers
- Phase testers
- Multimeter
- Set of screw drivers
- Side cutters, etc.
- Lab coat
- Hammers
- Oscilloscope
- Soldering tools, etc.

3.3.6.4.References

1. Cadick, J. (2012). Electrical safety handbook. McGraw-Hill Professional.
2. Electrical Safety Handbook 3E by Cadick. J. et al. 2016 IEEE IAS Electrical Safety Workshop (ESW)
3. Brian Scaddan, Electric Wiring: Domestic
4. Peter J. Seebacher, Home Infrastructure (Project 3) (PDF)

3.3.7. Learning Outcome No. 6. Troubleshoot and repair/replace workshop tools and equipment

3.3.7.1. Learning Activities

Learning Outcome No. 6. Troubleshoot and repair/replace workshop tools and equipment	
Learning Activities	Special Instructions
 Activity: Carry out troubleshooting on electric kettle not heating • Check the power socket if cable is properly plugged • Ensure sure the power switch is pushed ON • Check if the lead connector is properly pushed in • Check the power fuse and replace if possible • Check if there is power inside the kettle • Check the power switch or fuse which needs to be replaced. • Check the heating element and replace if possible.	Manufacturer's manual instructions should be followed

3.3.7.2.Information Sheet No3/L07

Introduction

This learning outcome covers common fault in electrical equipment, troubleshooting, safety in troubleshooting, rules and procedures on troubleshooting equipment, repair/replacement of the equipment, and safe testing of the equipment.

Definition of key terms

Troubleshooting: Troubleshooting is process of analysing the operation of a faulty circuit to determine what is wrong with the circuit, and identifying the defective component(s) and carrying out appropriate repair.

Recommended sources for further information;
Electrical Safety Handbook 3E by Cadick. J. et al.
Watch a 6.44min on Electric Kettle Repair from the link:
https://youtu.be/NyJXPTCEcu4?t=5

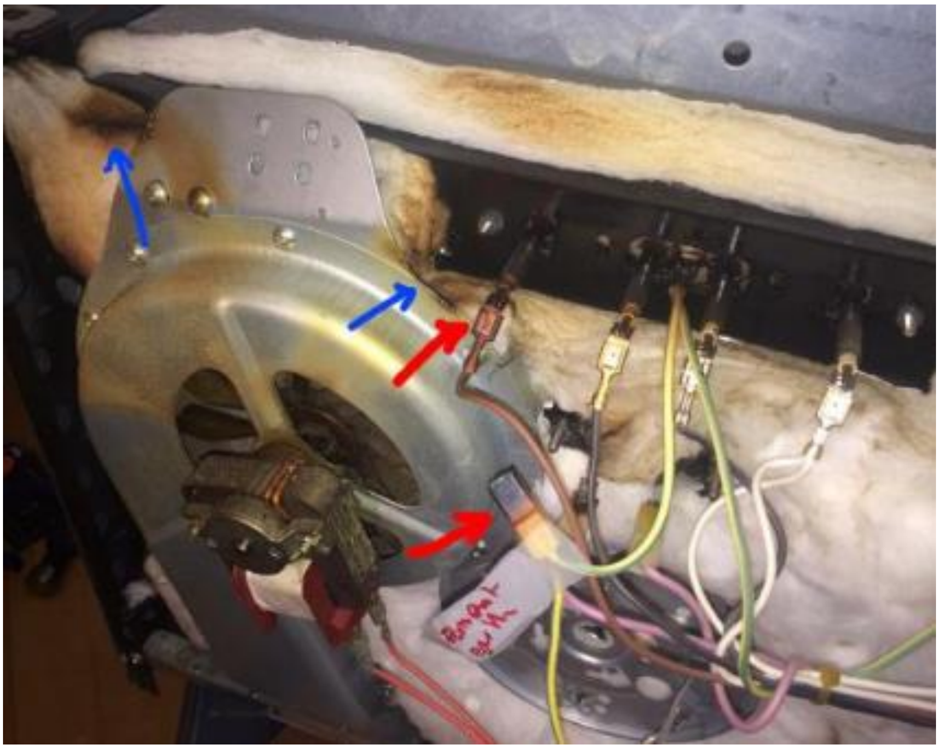
Procedure for investigating an electrical problem

- Gather the information
- Understand the malfunction
- Identify which parameters need to be evaluated
- Identify the source of the problem
- Correct/repair the component
- Verify the repair
- Perform root cause analysis

Recommended sources for further information;
Electrical Safety Handbook 3E by Cadick. J. et al.
2016 IEEE IAS Electrical Safety Workshop (ESW)
Watch a 22.10 min video on electrical principles from the web link:
https://youtu.be/49Zlel5XaDU?t=474
Watch a 13.44 min video on electrical principles from the web link:
https://youtu.be/ytATo6tS9yE?t=192

Content:
Safety in troubleshooting, common electrical faults, testing procedures, methods to troubleshoot electrical equipment, and procedure for repair/replacement of electrical tools and equipment.

Source: Cadick, J. (2012).



Source: Cadick, J. (2012).

Conclusion
This outcome covered electrical safety, inspection, set up and powering of workstations.

Trainees' assignment;
Carry out troubleshooting residential house wiring using fuse, switch, indicator, and lamp and energy meter.

Trainer
Check that the trainee working for evidence of application of safety practices, and adherence to manual instructions of the specific equipment as per the standard operating procedures. Ensure assignments are completed on time. Observe trainees' working behaviour on an on-going basis.

Recommended sources for further information;
Electrical Safety Handbook 3E by Cadick. J. et al.
Cardenas, Elpidio.1989, Fundamental and Elements of Electricity. Philippines: national Bookstore.

Max B. Fajardo Jr. & Leo R. Fajardo. 2nd edition, Electrical Layout and Estimate

3.3.7.3.Self-Assessment

1. Explain the terms
   A. Service entrance
   B. Service head
   C. Service point
   D. Service mast
2. A factory assemble cable of one or more conductors each individually insulated and enclosed in a metallic sheath of interlocking tape of smooth or corrugated tube. This type of cable is especially used for service feeders, branch circuit and for indoor, outdoor work. What is this cable?
   A. Metal Clad Cable (MC)
   B. Armor Cable (AC)
   C. Mineral Insulated Cable (MI)
   D. Underground Feeder (UF)
3. Fabricated assembly of insulated conductors enclosed in flexible metal sheath. It is used both on exposed and concealed work. Identify what type of cable.
   A. Metal Clad Cable (MC)
   B. Armor Cable (AC
   C. Mineral Insulated Cable (MI)
   D. Non Metallic Sheathed Cable (NM)
4. Is a moisture resistant cable used for underground connections including direct burial in the ground as feeder or branch circuit?
   A. Metal Clad Cable (MC)
   B. Armor Cable (AC)
   C. Mineral Insulated Cable (MI)
   D. Underground Feeder (UF)
5. Moisture and Heat Resistant Thermoplastic used for dry and wet locations?
   A. T
   B. XHHW
   C. THHN
   D. THW
6. Minimum vertical clearance of an overhead service drop measured from the ground, at the electrical service entrance or above areas or sidewalks accessible only to pedestrian lanes, measure from final grade line or other accessible surface only for service drop cabled together with a grounded bare messenger wire and limited to 300 volts to ground?
   A. 3.5 mts
   B. 3.00 mts
   C. 5.00 mts
   D. 5.50mts
7. A Machine which converts Electric Power into Mechanic all Power?
   A. Motor

B. Generator
C. Alternator
D. Rectifier

8. The Flow of Electricity in a circuit; rate of which electricity flows thru a conductor?
   A. Voltage
   B. Current
   C. Energy
   D. Power

Practical question

1. Identify Faulty tools as per their expected functioning
2. Diagnose Faulty component as per the fault diagnosis procedures
3. Repair/Replace faulty components as per the expected functioning
4. Test Repaired/Replaced tool as per the expected functioning

3.3.7.4.Tools, Equipment, Supplies and Materials for the specific learning outcome

- Hacksaws
- Pliers
- Phase testers
- Multimeter
- Set of screw drivers
- Side cutters, etc.
- Lab coat
- Hammers
- Oscilloscope
- Soldering tools, etc.

3.3.7.5.References

1. Cadick, J. (2012). Electrical safety handbook. McGraw-Hill Professional.
2. Cardenas, Elpidio.1989, Fundamental and Elements of Electricity. Philippines: national Bookstore.
3. Max B. Fajardo Jr. & Leo R. Fajardo. 2nd edition, Electrical Layout and Estimate

CHAPTER 4. ELECTRICAL PRINCIPLES/ APPLY ELECTRICAL PRINCIPLES

4.1. Introduction of the Unit of Learning/Unit of Competency

Electrical Principles presents the basic theories and concepts taught at entry level in Tertiary Institutions. This series of content provides examples to trainers to enable them to develop a strong foundational knowledge of electrical and electronics engineering. The unit comprises of basic theory and practical lessons. Electrical principles link to other core units by providing knowledge in mathematics, physical sciences, mechanical sciences, workshop technology, and electrical machines.
This unit is designed to equip the trainee with the knowledge skills and attitude necessary to understand a wide range of Electrical Principles in their work. This includes basic electrical quantities, direct current (DC) circuits, alternating current (AC) circuits in electrical installation, use of earthing in electrical installation, apply lighting protection measures, apply electromagnetic field theory, apply electrodynamics, apply energy and momentum in electromagnetic field, apply electrical circuit analysis, use two port network, demonstration of refrigeration and air conditioning.

It is recommended that a trainee should have the following learning resources to help him/her in this unit: scientific calculators, relevant reference materials, stationeries, relevant practical materials, and computers with internet connections. Trainees are expected to adhere to the strict rules and regulations once inside the electrical workshops to avoid accidents. The trainee should also read and understand OSHA and WIBA rules and regulations.

In this unit the trainee will be engaged in learning activities such as oral questioning, class discussions, practical activities, supervised exercises, assignments, and written tests.

4.2. Performance Standard

Use electronic calculators when performing calculations in the unit, maintain the area of your working clean to avoid accidents in the workshop, identify

4.3. Learning Outcomes

4.3.1. List of Learning Outcomes

a) Use the concept of basic electrical quantities
b) Use the concepts of DC to AC circuits in electrical installation
c) Use basic electrical machines
d) Use power factor in electrical installation
e) Use earthing in electrical installation
f) Apply lightning protection measures
g) Apply electromagnetic field theory
h) Apply electrodynamics
i) Apply energy and momentum in electromagnetic field

j) Apply transients in electrical circuit analysis
k) Use two port network
l) Demonstrate understanding of refrigeration and air conditioning

4.3.2. Learning Outcome No 1: Use of Basic Electrical Machines
4.3.2.1. Learning Activities

Learning Outcome #No.1 Use of Basic Electrical Machines	
Learning Activities	Special Instructions
• State the Ohms Law • Compute electrical parameters such as power, current , voltage and resistance when given any two parameters • Set up an experiment to test the Ohms law	

4.3.2.2. Information Sheet No4/01

Introduction
An **electrical machine** is generally a device that converts mechanical energy into electrical energy and vice versa with the exception of an electrical transformer, which does the conversion of AC power from one voltage level to another. Other electrical machines are electrical generator and electrical motor.
Electric Generator: It is an electrical machine that converts mechanical energy into electrical energy. It operates on the principle of electromagnetic induction. It follows faraday's laws of electromagnetic induction, which states that whenever a conductor moves in a varying magnetic field, an electromotive force, emf, is induced within the conductor. It is also known as the generator action.
Electric Motor: It is an electrical machine that converts electrical energy into mechanical energy. The operating principle states that a current-carrying conductor experiences a torque (mechanical force) whenever it is put in a magnetic field. It is also known as the motoring action.
Transformers: It is a special type of machine because it does not convert any energy form one form to another. Instead, it transfers electrical power between circuits with different electrical voltage levels. Transformers increase (step-up) or decreases (step-down) voltages as it corresponds with the decrease or increase in current. In an ideal situation, the input and output power and frequency are the same.

Meaning of SI Unit: SI Units means the standard international unit which represents a complete metric system of units of measurements.

SI Units of various Types of electrical parameters

Table 3: SI Units of electrical parameters

Unit Name	Unit Symbol	Quantity
Ampere (amp)	A	Electric current (I)
Volt	V	Voltage (V, E) Electromotive force (E) Potential difference (Δφ)
Ohm	Ω	Resistance (R)
Watt	W	Electric power (P)
Decibel-milliwatt	dBm	Electric power (P)
Decibel-Watt	dBW	Electric power (P)
Volt-Ampere-Reactive	var	Reactive power (Q)
Volt-Ampere	VA	Apparent power (S)
Farad	F	Capacitance (C)
Henry	H	Inductance (L)
siemens / mho	S	Conductance (G) Admittance (Y)
Coulomb	C	Electric charge (Q)
Ampere-hour	Ah	Electric charge (Q)
Joule	J	Energy (E)
Kilowatt-hour	kWh	Energy (E)
Electron-volt	eV	Energy (E)
Ohm-meter	Ω·m	Resistivity (ρ)
siemens per meter	S/m	Conductivity (σ)
Volts per meter	V/m	Electric field (E)
Newtons per coulomb	N/C	Electric field (E)
Volt-meter	V·m	Electric flux (Φ_e)
Tesla	T	Magnetic field (B)
Gauss	G	Magnetic field (B)
Weber	Wb	Magnetic flux (Φ_m)
Hertz	Hz	Frequency (f)
Seconds	s	Time (t)
Meter / metre	m	Length (l)
Square-meter	m^2	Area (A)
Decibel	dB	
Parts per million	ppm	

Source: https://www.rapidtables.com/electric

Ohm' Law

Ohm's law states that "voltage or potential difference between two points is directly proportional to the current or electricity passing through the resistance, and inversely proportional to the resistance of the circuit."

The formula for Ohm's law is **V=I/R**.

Applications of Ohm's Law

Used in determination of voltage, current or impedance or resistance of a linear electric circuit

Calculations involving various Electrical parameters. (Power, Current, Voltage, Resistance)

Power can be calculated using formulas illustrated below:

$$P = I \times V = R \times I^2 = V^2 / R$$

Where P is power in Watts, V (voltage), I (current in amperes) (DC) and R is the resistance.

Note: in case of AC (alternating current), it is important to find power factor.

$PF = \cos \varphi$ Where φ is the power factor angle, the angle between the voltage and the amperage

From the above combined with ohms law,

Power (P)

$$P = V \times I = R \times I^2 = V^2 / R$$

Current (I)

$$I = V / R = P / V = \sqrt{(P / R)}$$

Voltage (V)

$$V = I \times R = P / I = \sqrt{(P \times R)}$$

Resistance (R)

$$R = V / I = P / I^2 = V^2 / P$$

Instruments used in measuring various types of electrical parameters

1. Analogue meter

Can be used to measure either one circuit value for instance voltage, resistance and current or measure of these at ago. They have a needle that swings indicating the value to be measured as illustrated below.

Figure 15 analogue meter

Source: https://en.wikipedia.org/wiki/Ohm#/media/File:Electronic_multi_meter.jpg

2. Digital meter

Such meters are accurate as they indicate real digital value unlike the analog meters subject to parallax errors while reading the measurement.

Figure 16: digital meter

Source: https://en.wikipedia.org/wiki/Ohm#/media/File:Electronic_multi_meter.jpg

An Experiment to conduct Ohms Law
Circuit diagram for ohms law

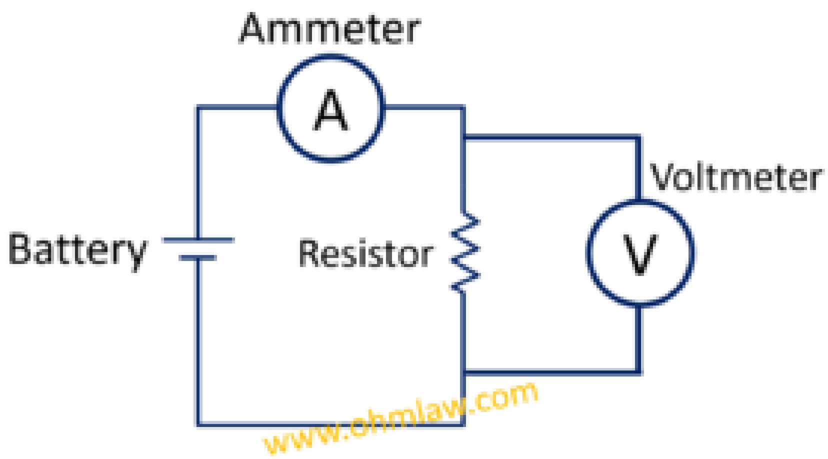


Figure 17: circuit diagram for ohms law

Source: www.ohmlaw.com

Experiment procedure
1. Connect the resistor on the breadboard.
2. Connect the source to the breadboard.
3. Connect the ammeter in series.
4. Connect the voltmeter in parallel.
5. Increase the voltage step-by-step from 0 to10 V and note the voltage/current.

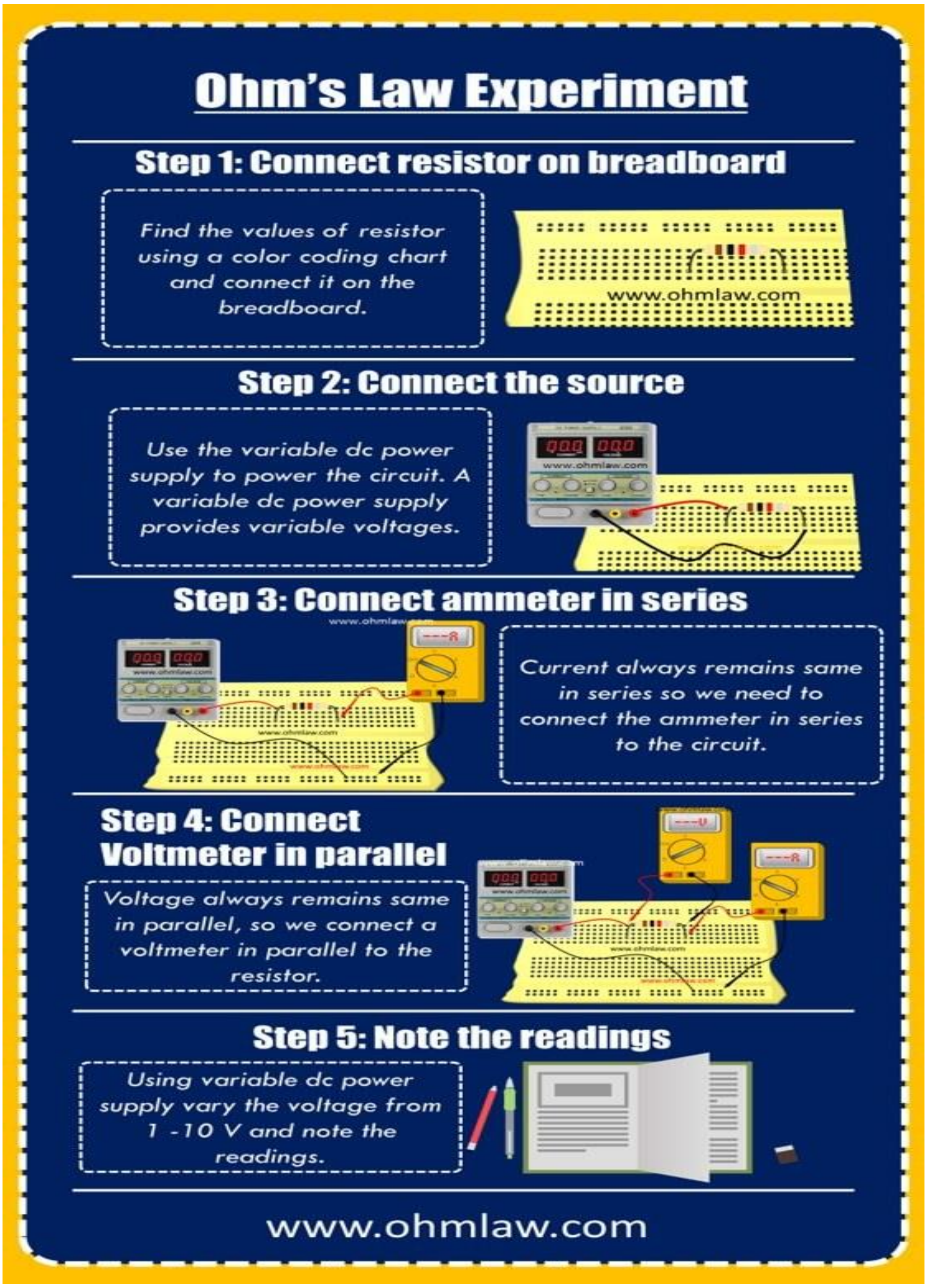


Figure 18: visual representation of steps

Source: (http://ohmlaw.com/ohms-law-experiment/)

4.3.2.3. Self-Assessment

a) Describe an electric generator and electric motor
b) Perform calculations on Voltage, current and voltage
c) State the Ohms Law
d) A generator is an electrical machine that converts electrical energy into mechanical energy. TRUE OR FALSE?
e) A transformer is a special type of machine because it does not convert any energy form one form to another. TRUE OR FALSE?
f) Conduct ohms experiment with ease
g) What types of losses occur in the magnetic frame of the transformer when the transformer is energized?
h) What information can be obtained from open circuit test of a transformer?
i) Why HV side is always kept open side in open circuit test?
j) What is the power factor of a transformer under no-load test situation?
k) How does no load current compare to full load current?

4.3.2.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Computers with internet connection

4.3.2.4 References

1. Juha Pyrhonen, Tapani Jokinen, Valeria Hrabovcova, Design of Rotating Electrical Machines, New York, NY: John Wiley & Sons, 2013.
2. http://ohmlaw.com/ohms-law-experiment/

4.3.3. Learning Outcome No. 2. Use the concept of DC and AC circuits in electrical installation

4.3.3.1. Learning Activities

Learning Outcome No. 2 Use the concept of DC and AC circuits in electrical installation	
Learning Activities	Special Instructions
• Conduct an experiment to measure Kirchhoff's voltage/ current law • Carry out calculation involving parallel and series circuits	

4.3.3.2 Information Sheet No. 4/ LO2

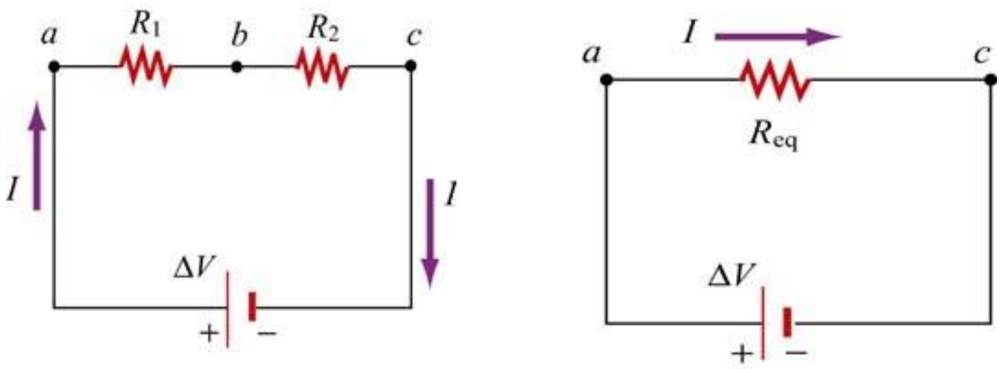
Introduction

Electrical circuits are used to connect loads to the power supply. Common loads are motors, resistors, lamps and heaters. A switch is used to close or open the path of electrical energy flow. Various loads are called circuit elements and can be in series or parallel. They are connected to the power supply using soldered wires called leads. A lead that connects several circuit elements is called a common lead.

Calculations Involving Parallel and Series Circuits

Resistors in Series and in Parallel

The two resistors R_1 and R_2 in Figure 7.3.1 are connected in series to a voltage source □*V*By current conservation, the same current *I* is flowing through each resistor.



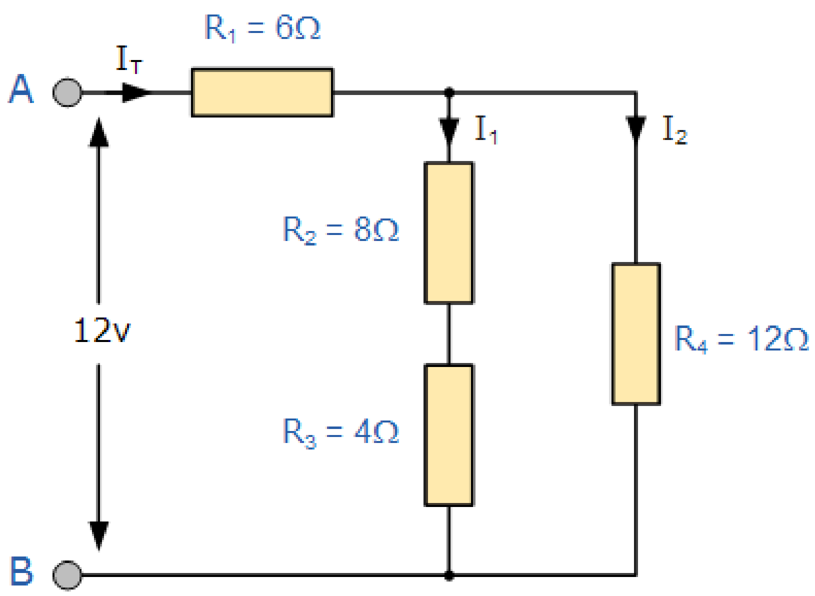


Figure 20: series calculation

Considering the above circuit, calculations of resistors in parallel and series can be calculated as follows

Series calculation

Resistors R1 and R2 are in series. The total resistance can be calculated as

$$R_2 + R_3 = 8\Omega + 4\Omega = 12\Omega$$

Replacing R1 and R2 result in the diagram below

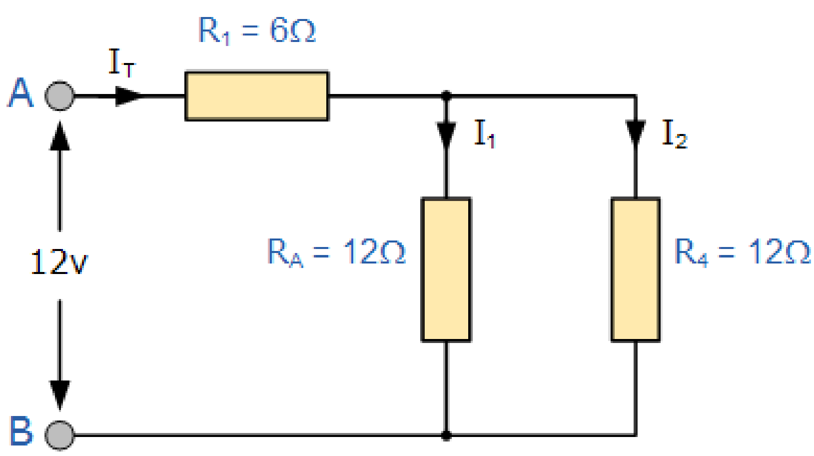


Figure 21: total resistance in circuit

Parallel calculation

From the above diagram RA is in parallel with R4

Using the resistor parallel equation, the total resistance can be calculated as :

$$R_{(combination)} = \frac{1}{R_A} + \frac{1}{R_4} = \frac{1}{12} + \frac{1}{12} = \frac{1}{R_{(com)}} = 6\Omega$$

The final resistive circuit can be illustrated as in the figure below.

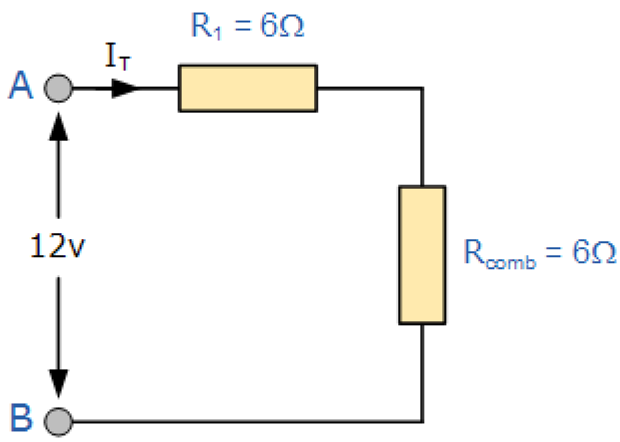


Figure 22: parallel calculation

Source :(https://www.electronics-tutorials.ws/resistor/res_5.html)

AC and DC network theorems

Electromotive Force

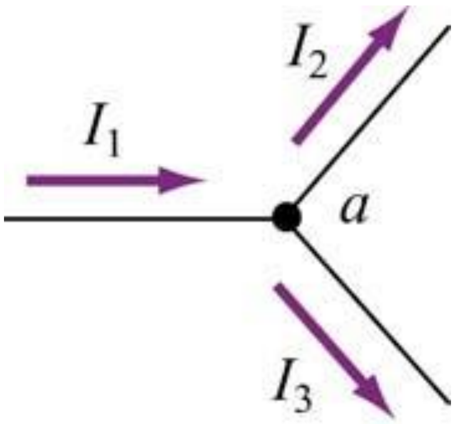
Electrical energy supply is necessary to maintain a constant current in a closed electrical circuit. The energy source is commonly referred to as electromotive force, emf. Popular emf sources are solar cells, batteries, and thermocouples. They are also considered as "charge pumps" since they push charges from areas of low potential to high one.

Kirchhoff's Circuit Rules

There are two fundamental rules used in analyzing electrical circuits, called Kirchhoff's Laws. They are two laws:

1. Kirchhoff's First Law: It states that at any junction of a circuit, the sum of currents coming into the junction is equal to the sum of currents leaving it. In other words, the sum of currents at a node is zero. It is also known as the Junction Rule or Kirchhoff's Current Law.

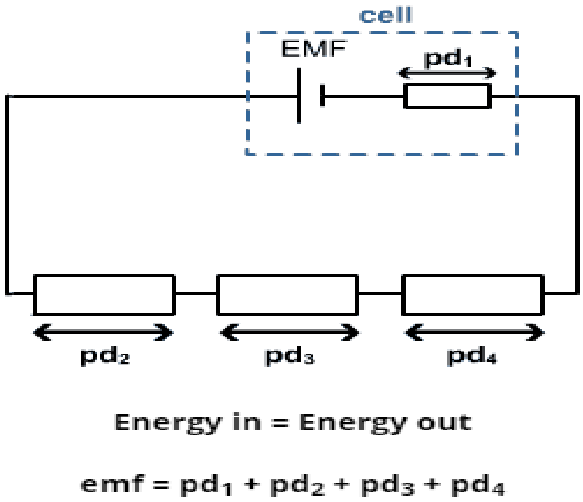
As an example, consider the figure below:



$I_1 = I_2 + I_3$ or $I_1 + I_2 + I_3 = 0$

2. Kirchhoff's Second Law: It states that the sum of voltage sources, emf, supplying a circuit loop is equal to the total energy absorbed by the elements in the circuit, potential differences, pd. In other words, the total amount of electrical energy put into a circuit is equal to the total amount of electrical energy taken out by the circuit elements. It is also known as Kirchhoff's Voltage Law.

As an example, consider the diagram below that shows a voltage source, emf and different loads with potential difference, Pd1, Pd2, Pd3 and Pd4.



Basic solar photovoltaic systems;

Materials that convert sunlight to electrical energy are known as photovoltaic. In attempt to boosting the output of the photovoltaic cells, they are interconnected to form large chains called panels/modules.

PV systems is made up of PV modules and arrays. Besides, the system is made up of mounting structures with pointing panels facing the sun and components that convert the produced direct current alternating current.

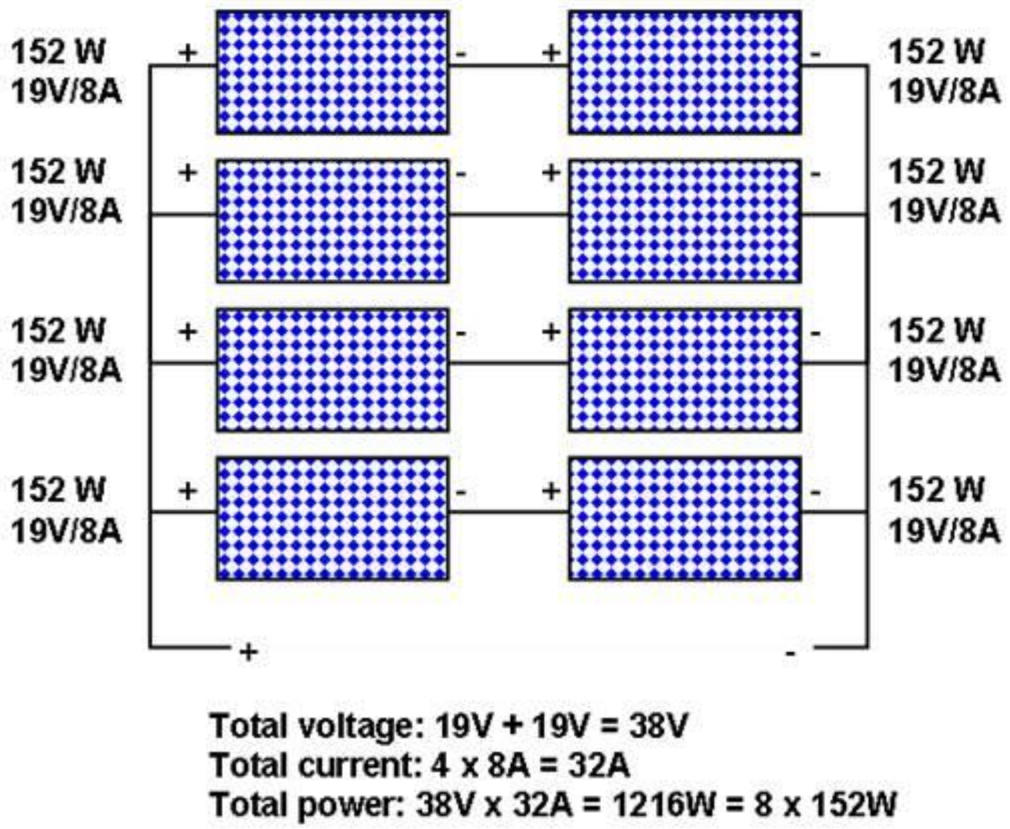
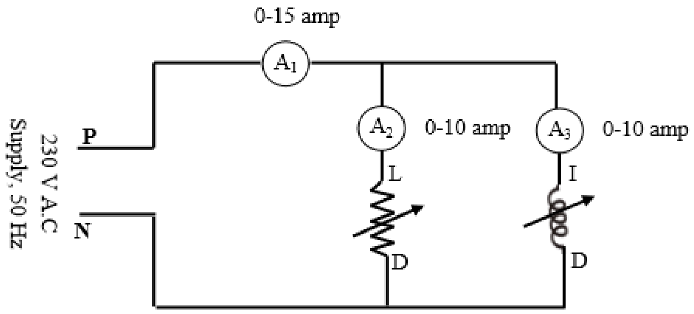


Figure 25: example of a PV solar panel

Experiment 2: Study Kirchhoff's Current Law (KCL) and Kirchhoff's Voltage Law (KVL)

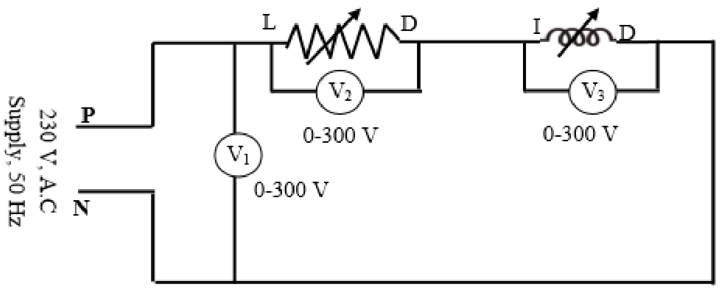
Apparatus:
3 AC Ammeters (0-10 amp)
3 AC Voltmeters (0-300 V)
Rheostat
Inductive Load
Connecting wires

Procedure:
KCL:



Note down the initial readings of all ammeters A_1, A_2, and A_3 and all voltmeters V_1, V_2 and V_3.
Connect the circuit as shown in the diagram.
Vary both the resistive and inductive load and record the readings of the ammeters and voltmeters
Repeat procedure (3) with different values
Calculate percentage error.

KVL:



Connect the apparatus as shown in the circuit diagram
Vary both the rheostat and inductive load to obtain and note down the readings V_1, V_2, and V_3.
Repeat procedure (3) with different values
Calculate percentage error.

Precautions
Make the connections properly
Accurately note down the voltmeter and ammeter readings
Ensure the connections are tight.

Figure 26: example 2

Observation Table:

Table 4: Observation table

KVL

Sl.No.	V_1 in (Volts)	V_2 in (Volts)	V_3 in (Volts)	$V_1' = \sqrt{V_2^2 + V_3^2}$	% Error
1					
2					
3					

KCL

Sl.No.	A_1 in (Volts)	A_2 in (Volts)	A_3 in (Volts)	$A_1' = \sqrt{A_2^2 + A_3^2}$	% Error
1					
2					
3					

4.3.3.3. Self-Assessment

1. State Kirchhoff's voltage law
2. State Kirchhoff's current law
3. Kirchhoff's voltage Law states that at any junction of a circuit, the sum of currents coming into the junction is equal to the sum of currents leaving it. TRUE OR FALSE?
4. Materials that convert sunlight to electrical energy are known as photovoltaic. TRUE OR FALSE?
5. Perform an experiment to demonstrate Kirchhoff's law
6. Differentiate between calculations Involving Parallel and Series Circuits
7. What are the applications of the Kirchhoff's laws?

4.3.3.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.3.5. References

James W. Nilsson, Susan Riedel, Electric Circuits, New Jersey: Prentice Hall Press, 2010.

4.3.4. Learning Outcome No. 3. Use of basic electrical machines

4.3.4.1. Learning Activities

Learning Outcome No.3. Use of basic electrical machines	
Learning Activities	Special Instructions
• Identify AC and DC machines • Demonstrate the understanding of application of AC and Dc machines • Demonstrate motor starting methods	

4.3.4.2. Information Sheet No. 4/ Lo3

Introduction

Electrical Machines

Any devices that does the conversion of electrical energy to mechanical energy and vice versa is called an electrical machine. Transformer form part of electrical machines although they only convert voltage level from one level to another.

Types of Electrical machine

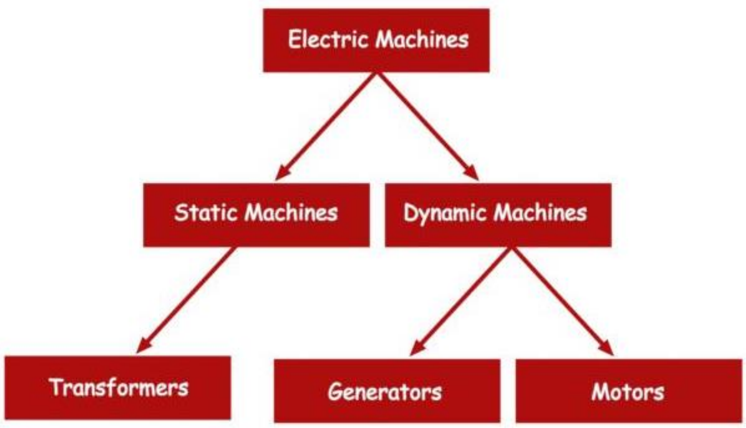


Figure 27: type of electrical machine

DC machines

Is a high versatile device that is likely to meet load demands requiring high acceleration and deceleration torques as well as high starting torque. The field winding for DC machines is located on the stator and windings of the armature is on the roto as shown below.

AC Single and three phase motors.

A motor is an electrical machine that converts electrical energy to mechanical energy.

Generators

Is an electrical machines that operates on the principal of electromagnetic induction hence converting mechanical energy to electrical energy? It is made up of a stator and a rotor. At the rotor, mechanical energy is provided through prime mover also called the turbine.

Transformers

Electrical machine that either steps up or down voltage suitable for consumption.

Working Principle of a Transformer

The basic principle of a transformer's operation is the phenomenon of mutual induction. The figure above shows the simplest form of a transformer. Basically a transformer It consists of two inductive coils; primary and secondary winding. Though the windings are electrically separated, they are magnetically linked.

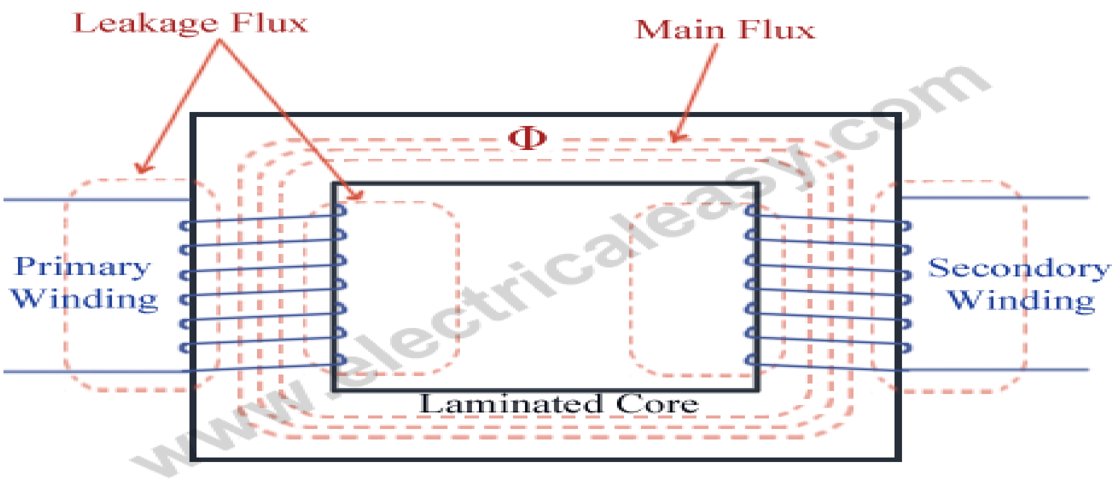


Figure 28: transformer

Source: www.electricaleasy.com

When the primary side is connected to an AC voltage supply, an alternating magnetic flux is produced around the primary winding. The laminated core provides magnetic path for the transfer of the flux on the primary side to the secondary winding. The flux that is successfully linked to the secondary side is called useful flux or main flux. The unlinked flux is known as leakage flux.

Since the induced flux is alternating, it forms a varying magnetic field, which meets the requirement of Faraday's law of electromagnetic induction. As a result, an emf is induced on the secondary winding called the mutually induced emf.

Types of Transformers

Transformers are broadly classified in terms of construction, purpose, type of power supply, use, and type of cooling.

Construction

Transformers fall into two categories based on their construction:

(i) Core type transformer
(ii) Shell type transformer

Core Type Transformer

The windings are wound in a cylindrical form then mounted on the core limbs. The windings are layered and the layers are insulated from each other using materials such as mica, paper and cloth. Low voltage windings are easier to insulate. Therefore, they are placed closest to the core.

Shell Type Transformer

The coils are wound in a rectangular or distributed form. They are also mounted in layers stacked with insulation between them.

- Purpose

1. Step up transformer: Increases the supply voltage with a corresponding decrease in current on the secondary side.
2. Step down transformer: Decreases supply voltage with a corresponding increase in current at the secondary side.

- Type of supply

1. Single phase transformer
2. Three phase transformer

- The use

1. Power transformer: Used in a power transmission network
2. Distribution transformer: Used in distribution network
3. Instrument transformer: Used in relay and protection purpose in different instruments in industries
    a) Current transformer (CT)
    b) Potential transformer (PT)

- Type of cooling
    a) Oil-filled self-cooled
    b) Oil-filled water cooled
    c) Air blast (air cooled)

Calculations involving single and three phase AC and DC transformers

Power Formulas in DC Circuits

- $P = V \times I$
- $P = I^2 \times R$
- $P = V^2 / R$

Where:

P = ***Power*** *in* ***Watts***

V = ***Voltage*** *in* ***Volts***

I = ***Current*** *in* ***Amperes***

R = ***Resistance*** *in* ***Ohms*** *(Ω)*

Power Formulas in Single Phase AC Circuits

- $P = V \times I \times \cos \Phi$
- $P = I^2 \times R \times \cos \Phi$
- $P = V^2 / R (\cos \Phi)$

Figure 29: single phase transformer calculations

Where:

P = ***Power*** *in* ***Watts***

V = ***Voltage*** *in* ***Volts***

I = ***Current*** *in* ***Amperes***

R = ***Resistance*** *in* ***Ohms*** *(Ω)*

Cos Φ = ***Power Factor***

Power Formulas in Three Phase AC Circuits

- $P = \sqrt{3} \times V_L \times I_L \times \cos \Phi$
- $P = 3 \times V_{Ph} \times I_{Ph} \times \cos \Phi$
- $P = 3 \times I^2 \times R \times \cos \Phi$
- $P = 3 (V^2 / R) \times \cos \Phi$

Where:

P = ***Power*** *in* ***Watts***

V = ***Voltage*** *in* ***Volts***

I = ***Current*** *in* ***Amperes***

R = ***Resistance*** *in* ***Ohms*** *(Ω)*

Cos Φ = ***Power Factor***

Three-phase Voltage and Current

Connection	Phase Voltage	Line Voltage	Phase Current	Line Current
Star	$V_P = V_L \div \sqrt{3}$	$V_L = \sqrt{3} \times V_P$	$I_P = I_L$	$I_L = I_P$
Delta	$V_P = V_L$	$V_L = V_P$	$I_P = I_L \div \sqrt{3}$	$I_L = \sqrt{3} \times I_P$

Figure 30: three-phase voltage and current

Source: V. Vodovozov,(2012)

Three-phase Transformer Line Voltage and Current

Primary-Secondary Configuration	Line Voltage Primary or Secondary	Line Current Primary or Secondary
Delta – Delta	$V_L \Rightarrow nV_L$	$I_L \Rightarrow \frac{I_L}{n}$
Delta – Star	$V_L \Rightarrow \sqrt{3}.nV_L$	$I_L \Rightarrow \frac{I_L}{\sqrt{3}.n}$
Star – Delta	$V_L \Rightarrow \frac{nV_L}{\sqrt{3}}$	$I_L \Rightarrow \sqrt{3}.\frac{I_L}{n}$
Star – Star	$V_L \Rightarrow nV_L$	$I_L \Rightarrow \frac{I_L}{n}$

Figure 31: three-phase line voltage and current

Source: (https://www.electronics-tutorials.ws/transformer/three-phase-transformer.html)

DC Machines

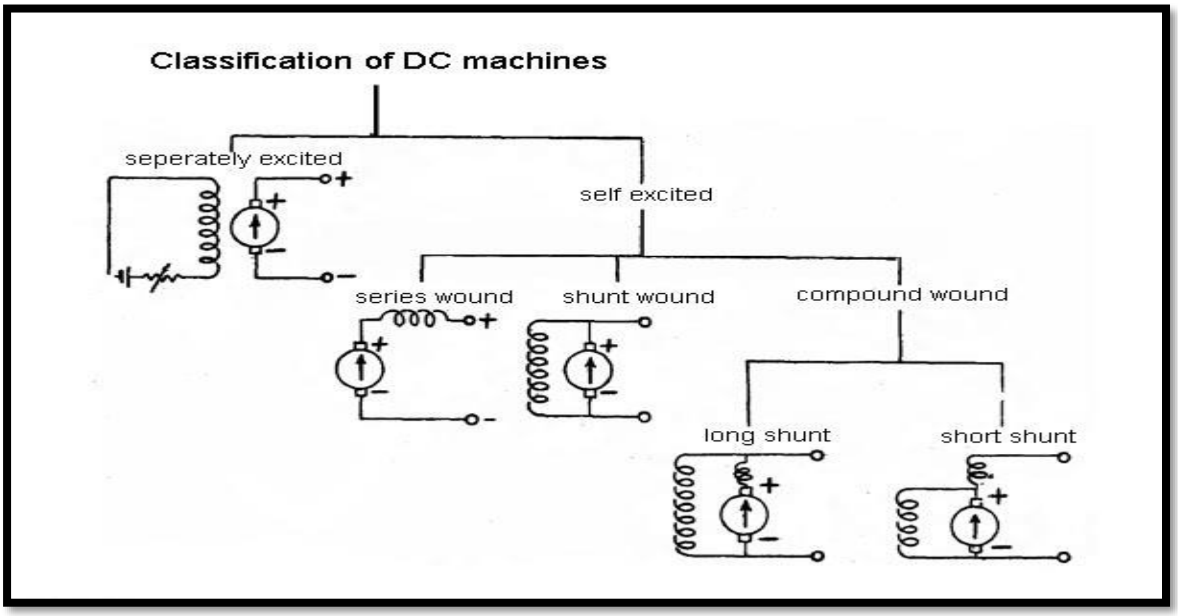


Figure 32: classification of DC machines

Source: (https://www.electronics-tutorials.ws/transformer/three-phase-transformer.html)

A DC machine can act as either a motor or a generator, which makes this classification suitable for both DC motors and DC generators. These machines are grouped into two broad categories based on the method of field excitation:

i) Separately excited DC Machines: The field and armature windings are powered by different power sources..
ii) Self-excited DC machines: The field and armature windings are interconnected in either series or parallel. They are further classified into:
    - Series Dc Machines: The field and the armature windings are connected in series. As a result, the field windings carry the entire load current.
    - Shunt Wound Dc machines: The field and armature windings are connected in parallel. As a result, the full voltage is applied on the field windings.
    - Compound Dc machines: There are two sets of field windings, one connected in series and another in parallel with the armature windings.

Motor Starting methods

- Direct-on-line starting

Refers to the connection of the motors directly to the supply at a specific voltage. It is suitably used stable supplies and shaft systems and pumps that are mechanically fit. It simple and most commonly used. Temperature rise during starting is the lowest among other starting methods.

- Star-delta starting

It is mostly used induction motors to reduce the starting current. The current supplied to the windings of the stator is Y connected, later it is reconnected to the windings in delta connection when it gains speed.

- Auto-transformer starting

Applies auto transformer coupled in series connection with the motor when it starts.

- Soft starting

The device ensures soft starting of the motor. These are usually based on semi-conductors that aid in reducing the initial voltage of the motor resulting in a lower torque of the motor.

- Frequency converter starting

They can either be used to either continuously feed the motor or for start-up only. It makes it possible for use of low current for startup since motors have the ability to produce rated torque at rated current from zero till maximum speed.

Source: (https://automationforum.co/starting-methods-of-motor/

Advantages and disadvantages of motor starting methods

Special machines

Are machines with specific design to perform particular applications not possible to be performed by other conventional machines. To design a special machine, the electrical control design integrates with the hydraulic, mechanical and pneumatic system.

Examples include;

- Assembly Machines
- Process Machines
  - Semi – Automatic
  - Fully Automatic
- Stand Alone Systems
- Integrated Systems
- Lifts, Pick and place, Transfer tables, Gantries

Application of AC and DC machines

- AC Motor Application
- Fan
- Pumping Motor
- Coolers
- DC Motor Application
- Printer
- Toy
- Electric Train

Table 5: experiment 1

EXPERIMENT 1	Special Instructions
Objective: Perform open circuit test on a single phase transformer to Calculate: The circuit parameters in reference to the primary side of the transformer Transformer's open circuit loss/iron loss/core loss Apparatus Required: One A.C Wattmeter - (0- 250 W) One A.C Voltmeter - (0-250 V) One A.C ammeter - (0-2.5 A) Variac: 230 V, 10 A, 50 Hz, 1-Phase Single Phase Transformer (50 Hz) Connecting wires	Precautions ➢ All connections should be tight and clean ➢ Special care necessary when selecting meter ranges for open circuit tests ➢ Strict adherence to workshop rules and regulations

<table>
<tr>
<td>
<table>
<tr><td>Voltmeter (V)</td><td>Ammeter (A)</td><td>Wattmeter (W)</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>
Procedure:
Make the connections as per the circuit diagram.
Ensure that the secondary side of transformer is open
Ensure the variac is at zero position before switching on the power supply.
Switch on A.C power supply.
Apply full voltage supply (230V) to the primary side of the transformer by varying the position of the variac.
Note down the ammeter, voltmeter and wattmeter readings

Reset the Variance to zero position before switching off the power Supply.
</td>
<td></td>
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</table>

4.3.4.3. Self-Assessment

1) Describe an electrical machine
2) Differentiate operation of various types of electrical machines
3) Explain the difference between DC and AC machines
4) Preform various motor starting methods
5) Describe special machines and their applications
6) Transformer form part of electrical machines although they only convert voltage level from one level to another. TRUE OR FALSE?
7) A generator is an electrical machine that converts electrical energy to mechanical energy. TRUE OR FALSE?
8) At the rotor, mechanical energy is provided through prime mover also called the turbine. TRUE OR FALSE?

4.3.4.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Electrical workshop
- Relevant practical materials

4.3.4.5 References

V. Vodovozov, Electric Drive Systems and Operation, London: Ventus Publishers, 2012.
Cicuitglobe.com

4.3.5 Learning Outcome No. 4: Demonstrate Understanding of Three Phase Power Supply

4.3.5.1 Learning Activities

Learning Outcome No.4. Demonstrate Understanding Of Three Phase Power Supply	
Learning Activities	Special Instructions
• Measure reactive power in a three-phase circuit using this method • Conduct an experiment to measure the readings of two wattmeter's in this experiment, if the load is purely resistive	

4.3.5.2 Information Sheet No. 4/ L03

Three Phase System

Definition: The system which has three phases, i.e., the current will pass through the three wires, and there will be one neutral wire for passing the fault current to the earth is known as the three phase system.

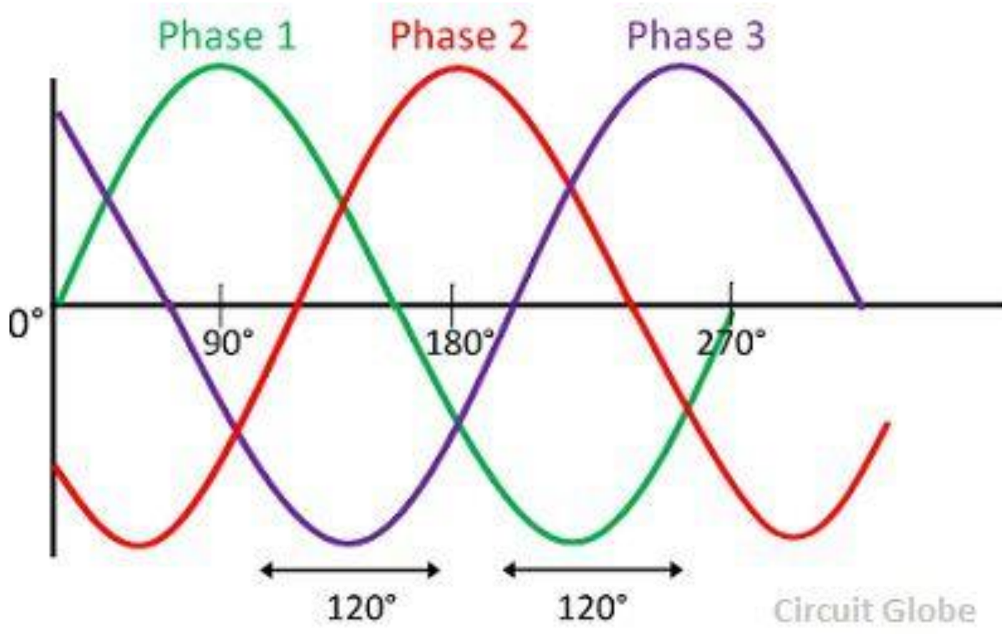


Figure 33: three phase system

Source: Source: (https://www.electronics-tutorials.ws/transformer/three-phase-transformer.html)

The 120º phase difference of the three phases is must for the proper working of the system. Otherwise, the system becomes damaged.

Types of Connections in Three-Phase System

Star Connection

The star connection requires four wires in which there are three phase conductors and one neutral conductor as shown below

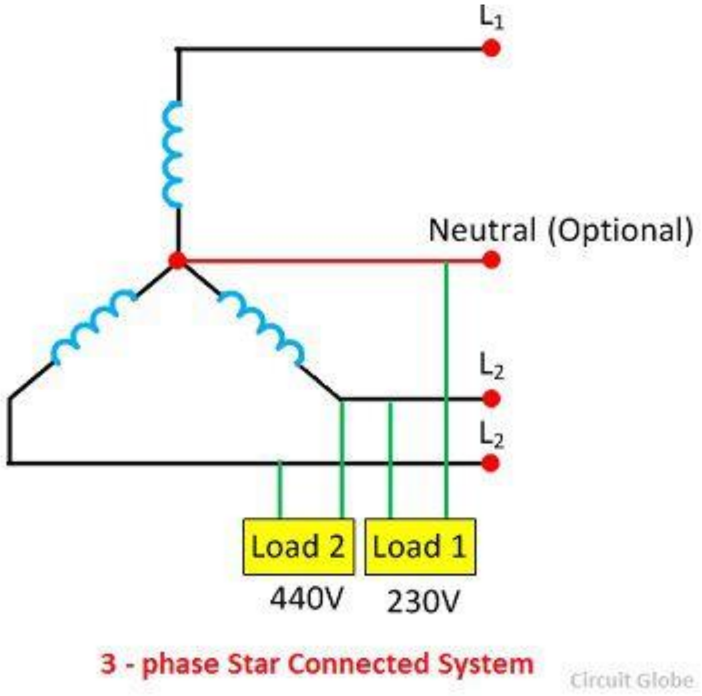


Figure 34: 3-phase star connected system

Source: circuit globe

The voltage between the single phase and the neutral is 230V, and the voltage between the two phases is equal to the 440V.

Delta Connection

The delta connection has three wires, and there is a no neutral point. The line voltage of the delta connection is equal to the phase voltage.

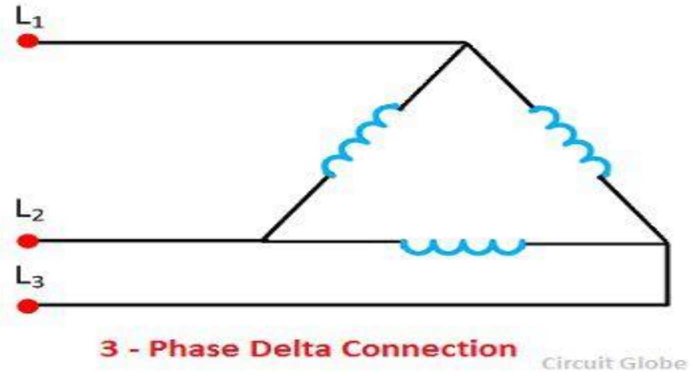
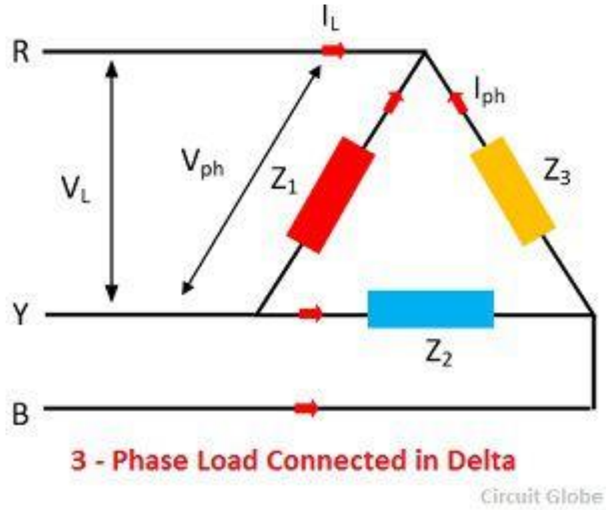


Figure 35:3-phase delta connection

Source: circuit globe

Connection of Loads in Three Phase System

The loads in the three-phase system may also connect in the star or delta. The three phase loads connected in the delta and star is shown in the figure below.



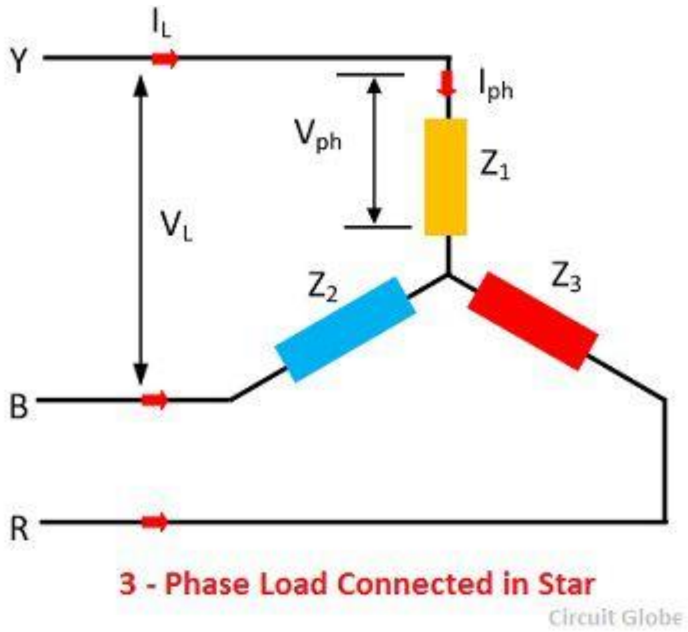


Figure 37: 3-phase load connected in star

Source: circuit globe

The three phase load may be balanced or unbalanced. Under balance condition, all the phases and the line voltages are equal in magnitude.

Review of Three-Phase Voltage System Properties

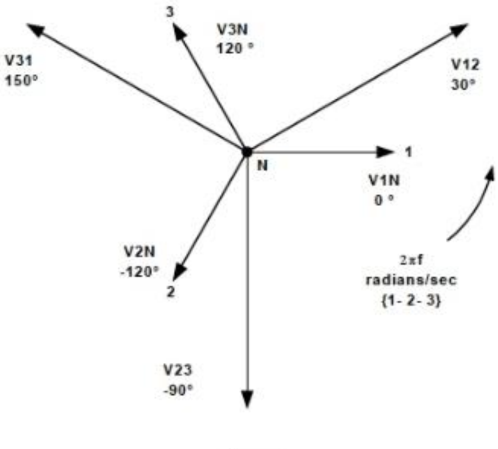


Figure 2
Three-Phase 4-Wire Wye System Voltage Phasors
Sequence {1-2-3}

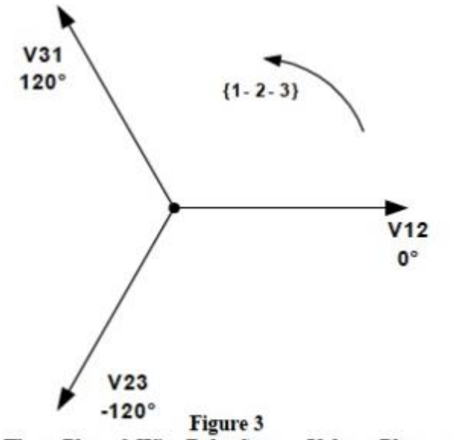


Figure 3
Three-Phase 3-Wire Delta System Voltage Phasors
Sequence {1-2-3}

Measurements of three phase power supply

1. Three watt meters method
2. Two watt meters method
3. Single wattmeter method.

The most common method is the three wattmeters method and it is used in measuring power in 3 phase, 4 wire system. The figure below describes connection for a star connected loads used in measuring power.

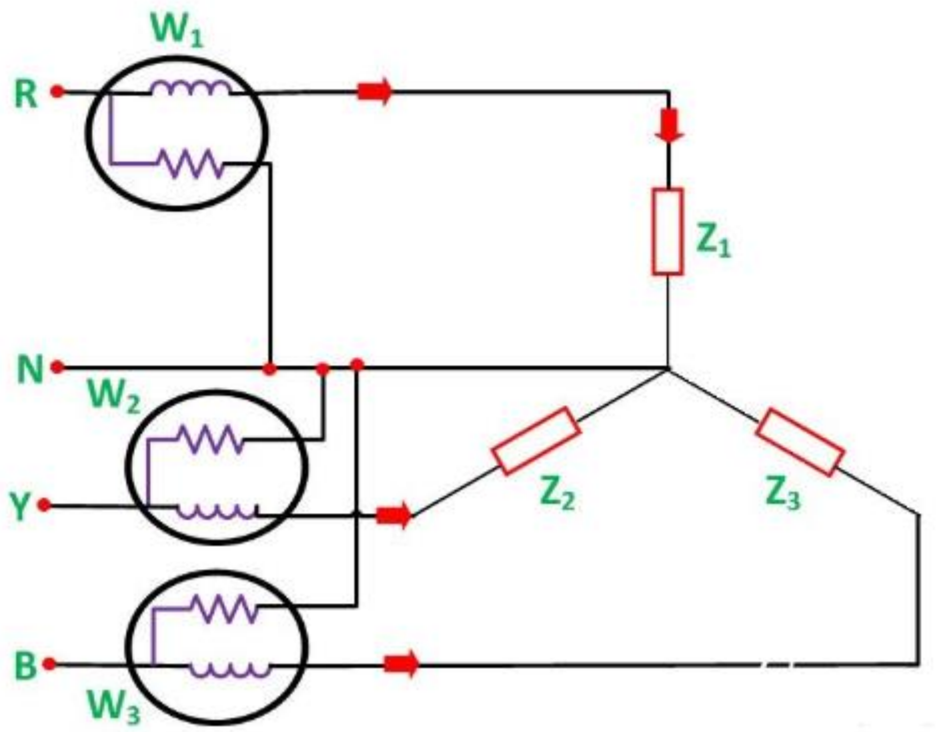


Figure 38: connection for a star connected loads used in measuring power

Source; circuit globe

$$\text{Total power } P = W_1 + W_2 + W_3$$

Where,

$W_1 = V_1 I_1$

$W_2 = V_2 I_2$

$W_3 = V_3 I_3$

Experiment 3: Measure power factor

Tabulation:

Table 6: measure power factor

Sl. No.	Condition	I_R	I_Y	I_B	V_R	V_Y	V_B	M.F.	W_1	W_2
1	Balanced Load									
2	Unbalanced Load									

To measure:	Precautions:
Three phase power and power factor in a balanced three-phase circuit by using two single-phase wattmeter. Calculate the three phase power for unbalanced load condition. Apparatus: 2 AC Wattmeters (0- 600 V, 750 W) 2 AC Voltmeters - 1 nos. (0-600 V) 3 AC Ammeters (0-5 A) Load Box Procedure: Connect the apparatus as shown on the circuit diagram Switch on AC power supply. Note down the ammeter, Voltmeter and ammeter readings for balanced load conditions Repeat procedure (3) but with unbalanced load condition Switch off the AC power supply Calculation: Calculate P_M, Pc and % Error. See Appendix 3 for the circuit diagram	Ensure the connections are tight and clean Ensure the ammeter readings does not exceed the ammeter's current ratings Reverse the connection of the measuring device in case of a negative deflection

Figure 39: circuit diagram

Source: circuit globe

4.3.5.3 Self-Assessment

Questions:

1. State reactive power
2. The delta connection requires four wires in which there are three phase conductors and one neutral conductor TRUE OR FALSE?
3. The loads in the three-phase system may also connect in the star or delta. TRUE OR FALSE?
4. Perform experiment on three phase power supply
5. Demonstrate three phase voltage system properties
6. Is it possible to measure reactive power in a three phase circuit using this method?
7. What would be the readings of two wattmeters in this experiment, if the load is purely resistive?
8. What would be the readings of two wattmeters in this experiment, if the load is purely inductive?
9. If one of the wattmeter reads zero, what is the power factor of the load?

4.3.5.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.5.5 References

1. V. Vodovozov, Electric Drive Systems and Operation, London: Ventus Publishers, 2012.
2. Circuitglobe.com

4.3.6 Learning Outcome No. 5. Use of Power Factor in Electrical Installation

4.3.6.1 Learning Activities

Learning Outcome No. 5. Use of Power Factor in Electrical Installation	
Learning Activities	Special Instructions
Demonstrate understanding of power factor Demonstrate understanding of power triangle Demonstrate understanding of power factor correction methods	

4.3.6.2. Information Sheet No. 4/L05

Power factor, active & reactive power basic concept

Power factor- In ac circuit there is often a phase difference between the current and voltage. Power factor or PF is the cosine of this angle phase difference, cos φ.

Power factor types-

- Leading power factor- Current leads voltage occurs in a capacitive load circuit,
- Lagging power factor- Current lags behind voltage. Occurs in inductive load circuit

Value of Power factor– As power factor is a cosine function its possible value ranges from -1 to +1

Active and reactive component of power factor

VI cosφ is called active or watt full component, whereas VI sinφ called reactive or watt less component.

AC Circuit Power Triangle

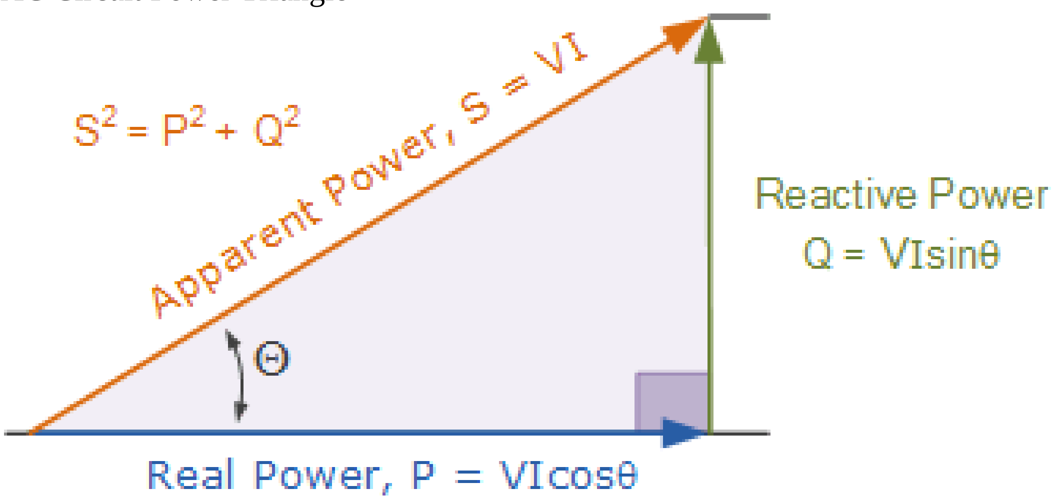


Figure 40: AC Circuit power triangle

Source: circuit globe

Where:

- P is the Real power that performs work measured in watts, W
- Q is the Reactive power measured in volt-amperes reactive, VAr
- S is the Apparent power measured in volt-amperes, VA
- θ is the phase angle in degrees. The larger the phase angle, the greater the reactive power
- Cos(θ) = P ÷ S = W/VA = power factor, p.f.
- Sin(θ) = Q ÷ S = VAr/VA
- Tan(θ) = Q ÷ P = VAr/W

The power factor is calculated as the ratio of the real power to the apparent power because this ratio equals cos (θ).

EXPERIMENT 4: To measure power factor in a single phase AC circuit by using three ammeters.

Table 7 to measure power factor in a single phase AC

Apparatus: 1 AC Wattmeter. (0- 250 V, 0- amp) 1 AC Ammeter (0-10 A) 2 AC Ammeter (0-5 A) 1 AC Voltmeter (0-300 V) Variance: 1-Phase, 230 V, 10 A, 50 Hz Resistor: 450 ohm R-L Load Box Connecting wires Procedure Connect the circuit as shown in the circuit diagram Ensure the variance is at zero position before starting the experiment Switch on AC supply. Set the supply voltage by varying the position of the Variance Vary the RL load to obtain different readings of ammeters, and wattmeter. Repeat step 5 and note down the readings. Reset the Variance to zero position before switching off the power supply Calculation: Calculate the value of P, cos Ø.	Precautions: All connection should be neat and tight The current should not exceed ammeter rating

See Appendix 4 for circuit diagram and tabulation table	

Appendix 4

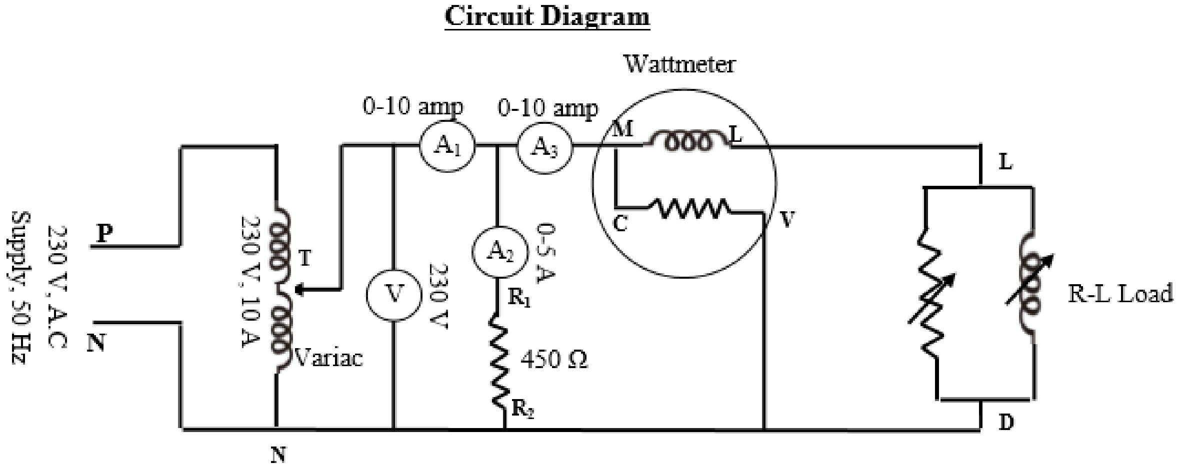


Figure 41: circuit diagram

Phasor Diagram

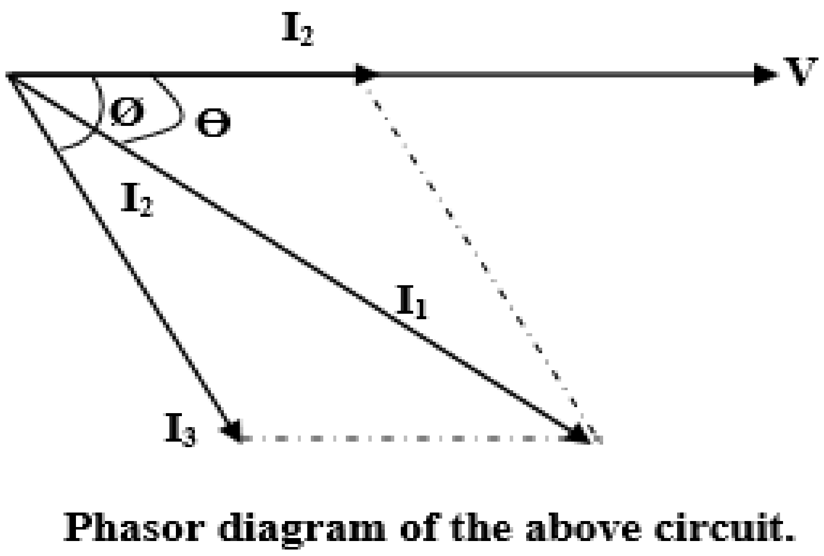


Figure 42: phasor diagram

Source; circuit globe

4.3.5.3 Self-Assessment

1. In an a.c. circuit which power is more apparent or real and why?
2. What is the basic difference between an inductive load and purely inductive load?
3. The practical loads are purely inductive or inductive?
4. Perform calculations on power factor correction methods?
5. Explain power factor
6. Differentiate active & reactive power
7. Demonstrate understanding of power triangle
8. Describe power factor correction methods
9. Lagging power factor- Current leads voltage occurs in a capacitive load circuit. TRUE OR FALSE?
10. Leading power factor- Current lags behind voltage. Occurs in inductive load circuit. TRUE OR FALSE?

4.3.5.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.5.5 References

1. S. P. Chandra, Principles of electric machines and power electronics. John Wiley & Sons, 2007.

4.3.7. Learning Outcome No. 6. Use of Earthing in Electrical Installation

4.3.7.1 Learning Activities

Learning Outcome No. 6. Use of Earthing In Electrical Installation	
Learning Activities	Special Instructions
• Connect earthing cable	

4.3.6.2 Information Sheet No5/L05

Introduction

Earthing is the process of connecting electric currents to the earth, purposely for safety. Electrical wiring is directed to the earth so that in case of exposure of the live wire or any other insulation mishaps, there is no immediate danger to the surrounding and the circuit. Live electric currents can cause extensive damages as it spreads faster and has devastating effects. The idea behind this action is neutralizing the electric currents in case they stray due to human neglect or equipment malfunctioning.

Earthing is done through embedding a metallic rod or plate into the ground. The process by which the metallic rode – earth electrode – is placed into the ground is technically called Earth Resistance, and is measured in Ohms.

Importance of Earth in Electrical Networking

1. The exercise helps in saving human beings from electrocution in case there is a fuse blow. Earthing neutralizes the electric currents by creating alternative current paths.
2. Helps to neutralize the effects of lightning or short circuits
3. If there is any faulty equipment or machinery connected to the network, earthing prevents it from being destroyed by the live currents.
4. Prevents friction from occurring in case of static electricity
5. Earthing stabilizes electric currents in electronics. Different equipment needs a certain voltage to function optimally, hence earthing regulates the amount of current passing through to avoid damage.

Functions of Electric Earthing Systems

1. To prevent the destruction of lives and properties in case of exposure to a live current
2. Keep the voltage of any electrical gadget in check
3. Create a harmless alternative path in case there is a faulty electric current

Types of Earthing

Earthing is divided into two:

1. System/Neutral, and
2. Equipment

System or neutral earthing is achieved by stabilizing the voltage to match that produced by the ground. It is designed to shield electrical equipment from being short-circuited. It is done by connecting part of the current of the plant to the ground. The ground provides a low-voltage path that prevents any live current from causing harm. As for the neutral earthing, the current is connected to the ground which acts as the central electric panel. As the neutral conductor, the ground should have an identical voltage to stabilise the current flow.

Equipment earthing maintains the current flow against harming people or things that are non-conductors. Its main target is people who are closer to live currents. This is done by connecting frames of these equipment to the earth.

The two types of earthing are enjoined so that the harmless (fault) current passing through its systems reduces the probability of someone or something being destroyed. It also maintains the potential gradient of current at the processing substation. If the systems have to work differently, the cons will be a higher current on short-circuiting, a reduced intensity of current flows and expenses in terms of materials used to relay earthing into the ground. If the two systems are integrated, the cost of implementation and efficiency gained will be worthwhile.

Experiment 5: *Measurement of Earth Resistance by use of Earth Tester by Three Point method or Fall Potential Test*

The fall potential is the most popular method of measuring the earth resistance of a grounding system.

Take measurement in different directions as shown in below fig.

Procedure

1. Connect C1 and P1 terminals on the test set to the earth electrode.
2. Drive a probe into the earth 100 to 200 feet from the center of the electrode and connect to terminal C2.This probe should be driven to a depth of 6 – 12 inches.
3. Drive another probe into the earth midway between the electrodes and probe C2 and connect to terminal P2. This probe should be driven to a depth 6 – 12 inches.
4. Record the resistance measurement.
5. Move the potential probe 10 feet farther away from the electrode and make a second measurement.
6. Move the potential probe 10 feet closer to the electrode and make a third measurement.

7. If the three measurements agree with each other within a few percent of their average, then the average of the three measurements may be used as the electrode resistance.
8. If the three measurements disagree by more than a few percent from their average, then additional measurement procedures are required.

4.3.6.3. Self-Assessment

1. **State earthing**
2. **Describe the importance of earthing**
3. **Differentiate various types of earthing**
4. **What is a Building Protection and Grounding System?**
5. **What existing objects are included in a Building Protection and Grounding System Design?**
6. **How does a Building Protection and Grounding System work?**
7. Electrical wiring is directed to the earth so that in case of exposure of the live wire or any other insulation mishaps, there is no immediate danger to the surrounding and the circuit. TRUE OR FALSE?
8. If there is any faulty equipment or machinery connected to the network, earthing prevents it from being destroyed by the live currents. TRUE OR FALSE?
9. The process by which the metallic rode – earth electrode – is placed into the ground is technically called Earth Resistance, and is measured in Ohms. TRUE OR FALSE?

4.3.6.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.6.5 References

1. T. Linsley, Basic Electrical Installation Works, Routledge, 2018.

4.3.8 Learning Outcome No. 7. Apply Lightning Protection Measures

4.3.8.1 Learning Activities

Learning Outcome No. 7. Apply Lightening Protection Measures	
Learning Activities	Special Instructions
ACTIVITY • Set up earthing equipment and materials • Carry out the earthing procedure PROCEDURE • Provide down conductor tapes in locations as indicated on the drawings. • Down conductors shall be either: Installed surface on the structure concealed behind the cladding OR Reinforcing bars within the concrete structure. 1. Down conductor tapes shall terminate on to dedicated reinforcing bars which shall be utilized as the final connection to earth via the pile foundations. The Contractor shall include for supervising and testing the installation of the reinforcing bars including all joints prior to the concrete being poured. 2. Down conductors to be connected at roof level to a common loop tape. Provide horizontally mounted conductor tapes at levels indicated on the drawings. These shall provide a common connection for all down conductors, structure, cladding, steelwork and exposed metalwork	

4.3.7.2. Information Sheet No 4/LO7

Lightning physics, effects, and risk assessment

Definition of Key Words

Lightning Flash/Discharge – it is the discharge of electrical currents in the atmosphere occasioned by two charged clouds. The cumulonimbus clouds often form these oppositely charged regions, and the flash comes about by when it touches the earth surface.

Lightning Flash Density – this is the frequency by which a specific type of lightning flashes in an area over a given period of time. It is measured yearly, documenting the number of times the flash discharge in a particular area.

Lightning Protection System – these are components designed from conductors that are installed to reduce the damaging effect of lightning.

Lightning Strike – this is the action or effect caused as a result of the lightning flash on or at a given point.
Lightning Strike attachment Point – this is the contact point where the lightning strike touches. It may be on the ground on a structure.
Lightning stroke – this is a single current impulse at the contact point from the lightning strike.
Thunderday – this is a presumptive date or day in a calendar year when thunder is recorded in a given location.
Zone of Protection – an area protected from the lightening by the lightning protection system.

Types of lightning strikes

- Direct strike: This type occurs when lightning strikes an individual
- Side flash: It occurs in case lighting strikes a tall object and part of strikes extends to individuals close to it.
- Ground current: Is in form of dissipated strikes that results from objects being transferred to the ground. The dissipated energy can possibly electrocute individuals that are near the point of focus.
- Conduction: Occurs in case an individual is in contact with a metal material that has been struck by lightning.

Components of lightening protection systems;
Copper air terminals are usually made up of either copper or aluminum. The air terminals are connected through cable with minimal two ground rods buried 10 feet below the grade.

- copper cable
- copper clad ground rods
- surge suppressors

Application of lightning systems

- Lightning protection system (LPS)
- Lightning arrester

Maintenance of lightening system

4.3.7.3. Self-Assessment

1. Define lightning
2. Describe the procedure for testing lightning system
3. Describe the various methods used in earthing in domestic installation
4. What are the applications of lightning systems?
5. Differentiate the various components of lightening protection systems
6. Lightning Flash Density is the frequency by which a specific type of lightning flashes in an area over a given period of time. TRUE OR FALSE

7. Zone of Protection is an area protected from the lightening by the lightning protection system. TRUE OR FALSE?

4.3.7.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.7.5. References

1. T. Linsley, Basic Electrical Installation Works, Routledge, 2018.

4.3.9. Learning Outcome No. 8. Apply Electromagnetic Field Theory
4.3.9.1 Learning Activities

Learning Outcome No. 7. Apply Electromagnetic Field Theory	
Learning Activities	Special Instructions
• Conduct the hertz experiment	

4.3.8.2 Information Sheet No4/LO8
Electromagnetic Field Theory
An electromagnetic field is a typical field produced when charged particles (electrons) are charged. Any particles charged electrically are surrounded by electric field. The charged particles produce magnetic field. In case of change in velocity of charged particle, and electromagnetic field is produced.

Sources of Electromagnetic Fields
Solar radiation/ natural radiation: Are radiations that originates from the sun

Artificial radiation: Originates from a remote sensing system
Terrestrial radiation: Are radiations emitted by the Earth's surface

Detectors of Electromagnetic radiation
1. X-ray machines,
2. radios
3. cell phones

Application of Electromagnetic waves
1. Communication
2. Heating water
3. Cooking
4. Detecting of fodged bank notes

Electromagnetics Laws
- Faraday's Law

It states that when the magnetic flux linking a circuit changes, an electromotive force is induced in the circuit proportional to the rate of change of the flux linkage.
- Lenz's law

It states that the direction of an induced current is always such as to oppose the change in the circuit or the magnetic field that produces it.
- Fleming's Laws

Fleming's Left Hand Rule

It states “Hold out your left hand with the forefinger, second finger and thumb at the right angle to one another. If the forefinger represents the direction of the field and the second finger represents that of the current, then thumb gives the direction of the force.”

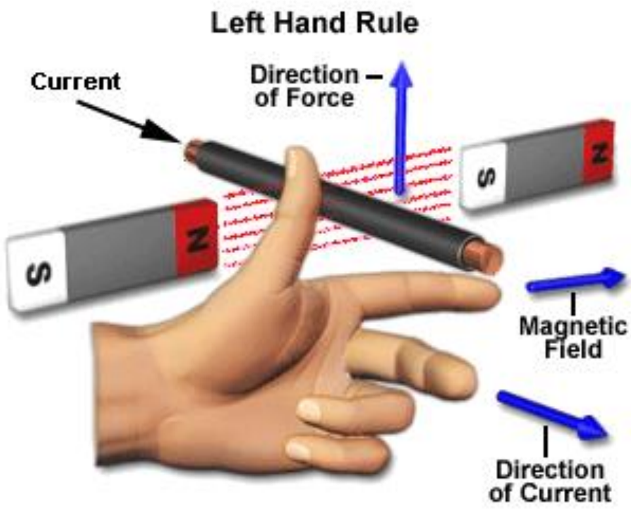


Figure 43: Fleming's left hand rule

Source: circuit globe

Fleming’s Right Hand Rule

This rule states “Hold out the right hand with the first finger, second finger and thumb at the right angle to each other. If forefinger represents the direction of the line of force, the thumb points in the direction of motion or applied force, then second finger points in the direction of the induced current”.

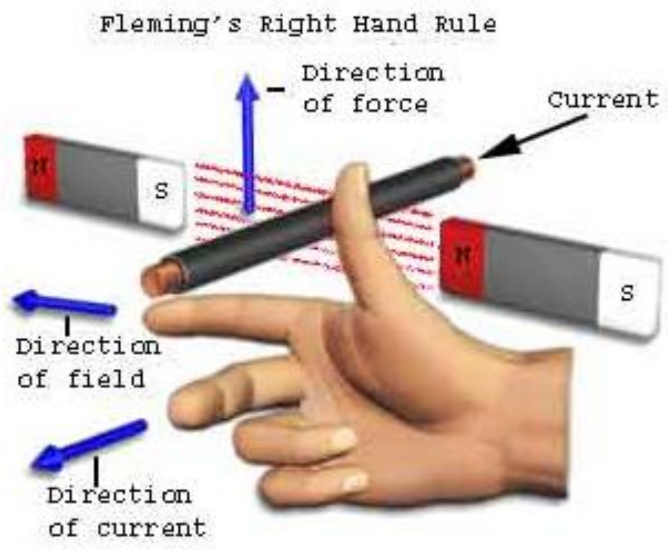


Figure 44: Fleming's right hand rule

Source: circuit globe

Properties and Effects of Electromagnetic waves

1. Energy and Momentum

Electromagnetic waves have energy and momentum that are both associated with their wavelength and frequency.

2. Energy

The energy (E) of a photon can be related to its frequency (f) by Planck's constant (h):

$$E=hf=hc/\lambda$$

The ratio of speed of light (c) to wavelength (λ) can be substituted in place off to give the same equation to energy in different terms. Note that energy cannot take any value: it can only exist in increments of frequency times Planck's constant (or Planck's constant time's c divided by wavelength). Energy of a wave is therefore "quantized."

3. Momentum

Momentum is classically defined as the product of mass and velocity and thus would intuitively seem irrelevant to a discussion of electromagnetic radiation, which is both massless and composed of waves.

However, Einstein proved that light can act as particles in some circumstances, and that a wave-particle duality exists. And, given that he related energy and mass (E=mc2), it becomes more conceivable that a wave (which has an energy value) not only has an equation to mass but a momentum as well.

And indeed, Einstein proved that the momentum (p) of a photon is the ratio of its energy to the speed of light.

Wave Characteristics and Shielding

An electromagnetic wave shield reduces the energy of electromagnetic waves by means of the reflection, absorption, and multiple reflection of the waves. By attenuating the electromagnetic waves, the shield avoids disruptions to precision equipment.

Skin Effect

It states that the tendency of a high-frequency alternating current to flow through only the outer layer of a conductor

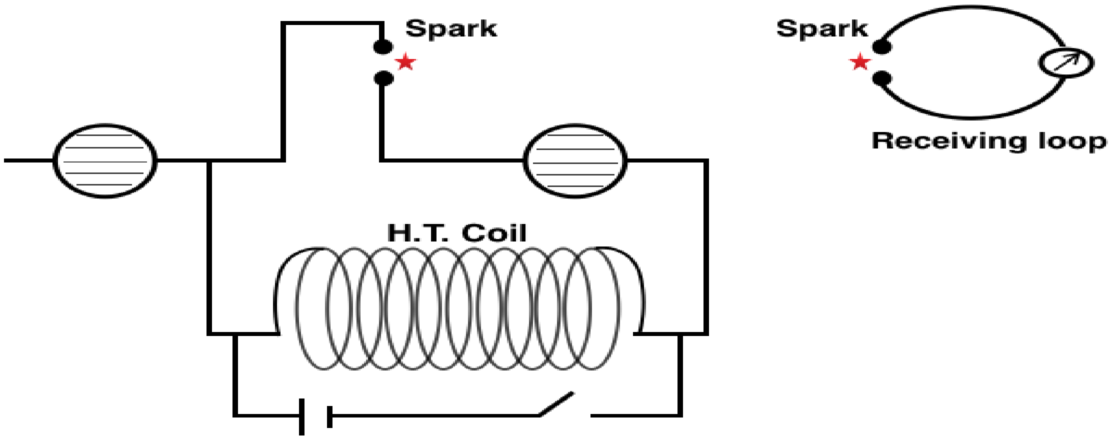
The hertz experiment

Description:

Hertz experiment was the first to prove the existence of electromagnetic waves. He also concluded that electromagnetic waves do not require a medium to travel.

Apparatus

1. High tension coil.
2. Polished brass knobs.
3. Receiving loop.



Working

Hertz used the high-tension coil to generate large amount of potential difference across the circuit. When the high potential difference was gained and propagated to the brass knobs, there appeared a spark between the knobs. Spark indicates that there was electron jump between the knobs.

As soon as the spark was observed between the knobs in the circuit, a spark was also seen between the knobs of the receiving loop.

4.3.8.3. Self-Assessment

a) Explain shielding
b) Explain sources of terrestrial radiation
c) Describe detectors of electromagnetic radiation
d) Differentiate various electromagnetic laws
e) Describes Flemings Left and Right-hand Rules
f) What is the importance of Flemings Rules?
g) Define Skin effect.
h) The charged particles produce magnetic field. TRUE OR FALSE?
i) Electromagnetic waves have energy and momentum that are both associated with their wavelength and frequency. TRUE OR FALSE?

4.3.8.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.8.5. References

1. J. C. T. Adolf, Engineering Electromagnetic Fields and Waves, New York: John Wiley and Sons, Inc., 1975.

4.3.10 Learning Outcome No. 9. Apply Electrodynamics
4.3.10.1 Learning Activities

Learning Outcome No. 9. Apply Electrodynamics	
Learning Activities	Special Instructions
• Determine factors that affect electrodynamics	

4.3.9.2. Information Sheet No. 4/ LO9

Meaning of Electrostatics Is the study of stationary electric charges.
A rod of plastic rubbed with fur or a rod of glass rubbed with silk will attract small pieces of paper and is said to be electrically charged.

Meaning of terms in magnetostatics
- Magnetic field or Magnetic Induction (B)

The field where the magnet attracts or repels magnetic materials
F=q x v x B

Where;
F= Force,
V = Speed of Particles,
B = magnitude of the field.

- Magnetic Field Strength (H)

The amount of magnetizing force (how much force it has to magnetize, magnetic materials
The SI unit of Magnetic Field Strength is Ampere/meter (A/m)
H=NI/1c
Where 1c = magnetic path in meter.

- Magnetic Flux (Φ)

Magnetic Flux which is denoted by Φ or Φm or ΦB. Or it is the amount of magnetic field or magnetic lines of force passing through a surface like conducting area, space, air, etc. The SI Unit of magnetic flux is Wb (Weber).
Φ=BAc
Where
Ac=area in m2

- Magnetization (M)

It is the density of permanent magnet or electromagnet dipole moments in magnetic materials. The SI Unit of Magnetization is Ampere/meter (A/m) and it is also a vector quantity. The SI formula for Magnetization is

M=m/V
Where,
m = Total magnetic moment
And V= volume in m3

Introduction

The earliest recorded study on the concept of electromagnetic induction gives credit to Henry (American) and Faraday (English). The two did independent research on this subject in the 19th century. Faraday, received the full credit because his publication earlier than Henry.

What is electromagnetism Induction?

It is the phenomenon whereby a fluctuating magnetic flux through a coil of wire generates an *emf* (electromotive force) in the wire. It is the basic principle behind the generation of electricity to date.

Emf generated depends on:

i. The strength of the magnetic flux, $\Delta\Phi_B$
ii. The number of loops in the coil of wire, N
iii. The rate at which the flux fluctuates, Δt

$$\varepsilon = -N\frac{\Delta\Phi_B}{\Delta t}$$

Apparatus:
bar magnet;
coil of magnet wire (20 or 22 awg);
three rectangular ceramic magnets;
a spring system;
slot weight system;
two large binder clips;
Pasco Science Workshop software and interface
Voltage leads
Motion sensor
Procedure:

Part I - Lenz's Law and the Induced Current

Boot up the computer (if necessary) and logon. Open Science Workshop.

Take a good look at your experimental setup. You will need to return it to this arrangement later in the experiment (step 8). But for now, unhook your spring from the lab stand and lay the entire assembly (spring, binder clips, magnets and slot weight hanger) on your lab table out of the way.

Goto file/open and then choose to look on the t: drive. Open the setup file frdy1-1
which you will find in the 151 Lab folder on the t:drive.

Now grab the bar magnet so that the red end (north pole) points downward, as though it were an arrow head on an arrow. Start the data collection by double clicking REC. Now center the magnet above the loops and thrust the magnet downward toward the loops from above. (The north end of the magnet should be approaching the plane of the loops first.) Watch the computer monitor as you do this. You should see a voltage peak displayed on your screen. Now pull the magnet upward and watch the display again. Repeat this down and up motion of the magnet several times, being careful to note the polarity of the voltage peak when you move the magnet down

and up. Stop the data collection by double clicking on STOP. Now record what you have observed in the provided data chart at the end of this handout Redo step 4 above, focusing on the silver end (south pole) of the magnet. Record your Observations. Analyze your table and conclude on the direction the induced current will flow in the loops when compared to the direction that the magnetic flux was changing. Begin the data collection by and move the magnet up and down as in steps 4 and 5. Have an alternating exercise whereby you move the magnets faster then slowly as you make observations. Conclude the data collection. Skeam through the data. Do you note anything about the magnitude of the induced voltage in comparison with the speed with which you moved the magnet? Tabulate your result and then make a bold conclusion. Do you agree with the findings of Henry and Faraday?	

Experiment 8: *To investigate electromagnetic induction and determine the factors that affect it*

Mass (g)	Period (s)	Frequency (Hz)	Peak Voltage (V)
50			
150			
250			
350			
450			

ANALYSIS:

1. Close Science Workshop and open up Vernier's Graphical Analysis software. If you are doing this somewhere other than Penn State's physics lab, you may use a spreadsheet software or some other graphing software.
2. Enter your data from steps 8 - 22 into the graphing software. Put the frequency value in the X data column and the peak voltage in the Y data column.
3. Do a linear curve fit and print out your graph.
4. Assuming the number of loops in your coil of wire was about 80, and using your graph you just printed out as needed, calculate the magnetic flux change that was occurring as you oscillated the magnets back and forth in steps eight through twenty two. Show your calculation and explain your reasoning step by step.

4.3.9.3. Self-Assessment

a) Explain Electrostatics
b) Perform calculations in magnetostatics
c) Explain electromagnetic Induction
d) What are the various applications of Electrostatics?
e) Perform calculations involving electromagnetic Induction
f) Magnetic field or Magnetic Induction (B) is the field where the magnet attracts or repels magnetic materials. TRUE OR FALSE?
g) The SI Unit of Magnetization is Ampere/meter (A/m) and it is also a vector quantity. TRUE OR FALSE?

4.3.9.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.9.5. References

1. J. C. T. Adolf, Engineering Electromagnetic Fields and Waves, New York: John Wiley and Sons, Inc., 1975.

4.3.11 Learning Outcome No. 10. Apply energy and momentum in electromagnetic field

4.3.10.1. Learning Activities

Learning Outcome No. 10. Apply energy and momentum in electromagnetic field	
Learning Activities	Special Instructions
Apply energy and momentum in electromagnetic field	

4.3.10.2. Information Sheet No. 4/ LO10

Energy conservation theorem:

- Poyntings' Theorem

The Poynting Theorem is in the nature of a statement of the conservation of energy for a configuration consisting of electric and magnetic fields acting on charges. Consider a volume V with a surface S. Then "the time rate of change of electromagnetic energy within V plus the net energy flowing out of V through S per unit time is equal to the negative of the total work done on the charges within V."

Momentum Energy Flow

Describing Fluid Flow

There are various mathematical models that describe the movement of fluids and various engineering correlations that can be used for special cases. However, the most complete and accurate description comes from *partial differential equations* (PDEs). For instance, a flow field is characterized by balance in mass, momentum, and total energy described by the continuity equation, the Navier-Stokes equations,

The solution to the mathematical model equations gives the velocity field, pressure, *p*; and temperature, *T*; of the fluid in the modeled domain. In principle, this set of equations is able to describe flows from the creeping flow in a microfluidic device to the turbulent flow in a heat exchanger and even the supersonic flow around a jet fighter. However, solving Equation for a case such as the jet plane shown below is not feasible and while it is possible to solve the whole of Equation for a microfluidic device, it is a lot of work down the drain. Much of computational fluid dynamics (CFD) is therefore devoted to selecting suitable approximations to Equation so that accurate results are obtained with a reasonable computational cost.

Electromagnetic Energy flow

Electromagnetic radiation, in classical physics, the flow of energy at the universal speed of light through free space or through a material medium in the form of the electric and magnetic fields that make up electromagnetic waves such as radio waves, visible light, and gamma rays. In such a wave, time-varying electric and magnetic fields are mutually linked with each other at right angles and perpendicular to the direction of motion.

An electromagnetic wave is characterized by its intensity and the frequency ν of the time variation of the electric and magnetic fields. In terms of the modern quantum theory, electromagnetic radiation is the flow of photons (also called light quanta) through space. Photons are packets of energy hν that always move with the universal speed of light.

Electron deflection tube: using an electric field Demonstration The deflection tube allows you to show the parabolic path of an electron beam passing through a uniform electric field. The graduated scale allows you to take measurements if you wish. This is the main advantage of the deflection tube over the fine beam tube. Most of the qualitative ideas of this experiment can be shown using the experiment Deflecting an electron beam. Apparatus and materials Power supply, EHT, 1 (or 2 if a second one is available) Power supply, 6.3 V, AC, for the heater filament (this is often included on the HT supply) Magnadur magnets, 2 (optional) Electron deflection tube and stand Health & Safety and Technical notes The tubes are fragile (and expensive!) and should be handled carefully. They will implode if broken. Use the stands specifically designed for holding them. Read our standard health & safety guidance Set the tube up according to the manufacturer's instructions. Ensure that you can identify the following: The 6.3 V supply to the cathode heater, if you connect the wrong voltage to the heater you can easily damage the tube beyond repair. The EHT supply for the anode. Set this to zero. The cathode is often one of the heater terminals. The terminals for the deflecting plates. Procedure a Set up the deflection tube in its special stand. b Connect the 6.3 V supply to the filament. Make sure you connect the 6.3 V supply to the filament. (See technical note 2 above.)	

c Start with the deflection plates connected together and also connected to the anode on the tube. d Connect the negative terminal of the EHT supply to the filament and the positive terminal to the anode. e Set the EHT to zero volts, and switch on the 6.3 V supply to the heater filament. f With no output from the EHT supply, the light from the filament produces a line on the inclined fluorescent screen where the light strikes it. g Increase the potential difference (p.d.) to about 3 kV: a fluorescent line appears. This is the path of the electron beam. Point out that the electron beam travels in a straight horizontal line. h Then, while one plate is left connected to the anode, connect the other plate to the negative terminal of the EHT supply. This produces a vertical electric field between the plates, deflecting the beam into a parabolic path. i If you have not shown an electron beam being deflected by magnets, you could do it here. (See Deflecting an electron beam.)	

1 This experiment is best demonstrated to the students in groups of four to five in a darkened room if full value is to be obtained.
2 Always reduce the anode to zero volts when not actually observing the beam, because the tube has a finite life time
3 The beam is deflected, which shows there is a force on it. The force is consistent with the beam being made of negatively charged particles.
4 The beam is deflected by a finite amount. So it must be made of something with mass. This seems obvious now, but, it is an important piece of deduction. We can deduce that the beam is made of particles with some mass and a negative charge.
5 The beam stays intact as it is deflected. At first glance, this suggests that all the particles are the same. However, the mathematics shows that the shape of the curve is independent of the charge and mass of the particles. This is because, if the charge

increases, the acceleration will increase in both the electron gun and between the deflection plates.

Likewise, any changes in mass will produce the same proportional change in acceleration in both the electron gun and the deflecting field (see Guidance note Deflection in electric fields).

6 The beam travels at a uniform horizontal velocity and so the horizontal displacement varies linearly with time. It also experiences a constant vertical force, so it has a constant vertical acceleration, *a*. The vertical displacement, s_v, varies as the square of time, *t*. ($s_v=0.5at^2$). Hence the path of the beam is a parabola (see Guidance note Deflection in electric fields).

7 The fluorescent screen has a gratitude on it, and the shape of the parabolic path for different accelerating voltages can be recorded.
8 This is analogous to a ballistic experiment in a uniform gravitational field. Whenever you throw something on the surface of the Earth, it traces out a parabola because the vertical *acceleration* is constant and the horizontal *velocity* is constant.

4.3.10.3 Self-Assessment

a) Explain Energy conservation theorem
b) Describe Poyntings' Theorem
c) Perform calculations on fluid flow calculations
d) Describe electromagnetic radiation
e) The most complete and accurate description comes from *partial differential equations* (PDEs). TRUE OR FALSE?
f) An electromagnetic wave is characterized by its intensity and the frequency ν of the time variation of the electric and magnetic fields. TRUE OR FALSE?
g) Photons are packets of energy hν that always move with the universal speed of light. TRUE OR FALSE?

4.3.10.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.10.5 References

1. J. C. T. Adolf, Engineering Electromagnetic Fields and Waves, New York: John Wiley and Sons, Inc., 1975.

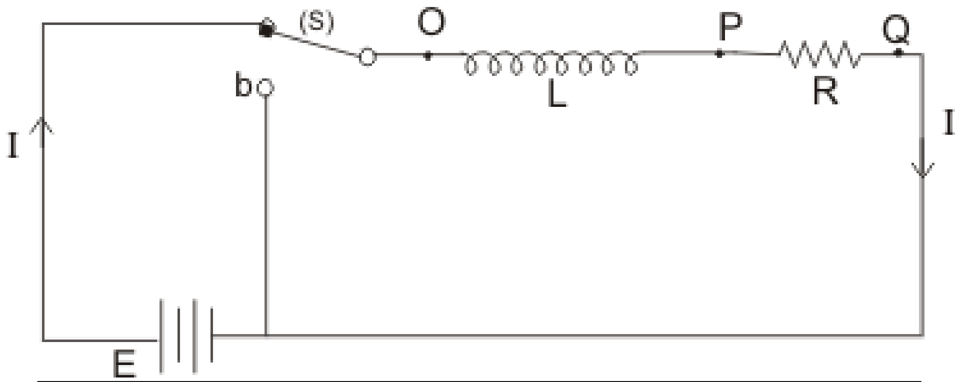
4.3.12. Learning Outcome No. 11. Apply Transients in Electrical Circuit Analysis
4.3.12.1. Learning Activities

Learning Outcome #No. 11. Apply Transients In Electrical Circuit Analysis	
Learning Activities	Special Instructions
• Apply Transients in Electrical Circuit Analysis	

4.3.12.2. Information Sheet No. 4/ LO11

Meaning of Growth and decay in R-L & R-C circuits
(A) Growth of current

- Suppose in the beginning we close the switch in the up position as shown in below in the figure



Switch is now closed and battery E, inductance L and resistance R are now connected in series

- Because of self-induced emf current will not immediately reach its steady value but grows at a rate depending on inductance and resistance of the c circuit
- Let at any instant I be the c current in the circuit increasing from 0 to a maximum value at a rate of increase dI/dt
- Now the potential difference across the inductor is
  $V_{op}=LdI/dt$
  and across resistor is
  $V_{pq}=IR$
  Since
  $V=V_{op}+V_{pq}$
  so we have,
  $$V = L\frac{dI}{dt} + IR \qquad \text{----(6)}$$
  Thus rate of increase of current would be,
  $$\frac{dI}{dt} = \frac{V - IR}{L} \qquad \text{---(7)}$$

- In the beginning at t=0 when circuit is first closed current begins to grow at a rate,

  $$\left(\frac{dI}{dt}\right)_{t=0} = \frac{V}{L}$$

  from the above relation we conclude that greater would be the inductance of the inductor, more slowly the current starts to increase.
- When the current reaches its steady state value I ,the rate of increase of current becomes zero then from equation (7) we have,

  0=(V-IR)/L

  or,

  I=V/R

  From this we conclude that final steady state current in the circuit does not depend on self-inductance rather it is same as it would be if only resistance is connected to the source
- Now we will obtain the relation of current as a function of time Again consider equation (6) and rearrange it so that

  $$\frac{dI}{\left(\frac{V}{R}\right) - I} = \frac{R}{L}dt$$

  let V/R=I_{max} ,the maximum current in the circuit .so we have

  $$\frac{dI}{I_{max} - I} = \frac{R}{L}dt \qquad \text{----(8)}$$

- Integrating equation (8) on both sides we have

  $$-\ln(I_{max} - I) = \frac{R}{L}t + C \qquad \text{---(9)}$$

  where C is a constant and is evaluated by the value for current at t=0 which is i=0

  so,

  C=-ln(V/R)=-ln I_{max}

  putting this value of C in equation (9) we get,

  $$\ln\left(\frac{I_{max} - I}{I_{max}}\right) = -\frac{R}{L}t$$

  Or,

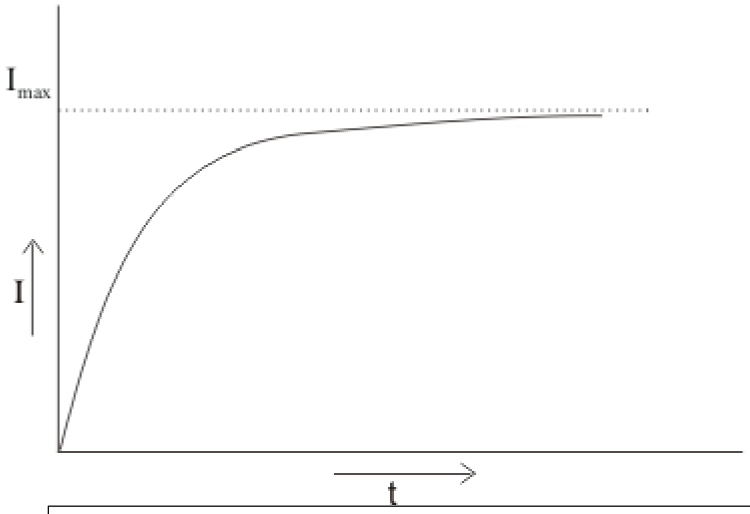
  $$\frac{I_{max} - I}{I_{max}} = e^{-\frac{R}{L}t}$$

  Or,

  $$I = I_{max}(1 - e^{-\frac{R}{L}t}) \qquad \text{---(10)}$$

This equation shows the exponential increase of current in the circuit with the passage of time

Figure below shows the plot of current versus time



- If we put $t=\tau_L=L/R$ is equation 10 then,

  $$I = I_{max}(1-\frac{1}{e}) = .63I_{max}$$

  Hence, the time in which the current in the circuit increases from zero to 63% of the maximum value of I_{max} is called the constant or the decay constant of the circuit.
- For LR circuit, decay constant is,

  $\tau_L=L/R$ ---(11)
- Again from equation (8),

  $$\frac{dI}{dt} = \frac{R}{L}(I_{max} - I_0) = \frac{I_{max} - I_0}{\tau_L}$$

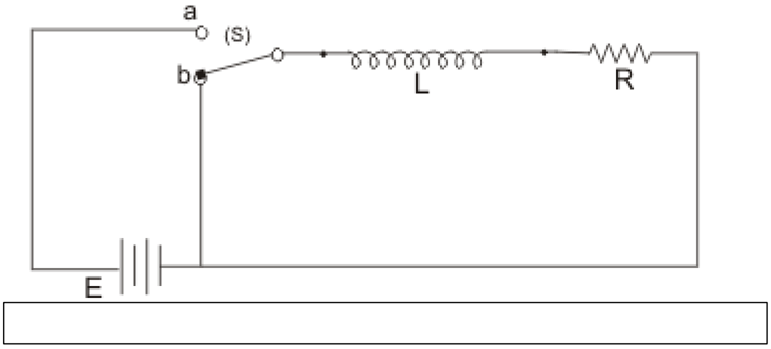
  Or,

  $$\frac{dI}{dt} \alpha \frac{1}{\tau_L}$$

  This suggests that rate of change current per sec depends on time constant.
- Higher is the value of decay constant, lower will be the rate of change of current and vice versa.

(B) Decay of current

- When the switch S is thrown down to b as shown below in the figure ,the L-R circuit is again closed and battery is cut off



- In this condition the current in the circuit begins to decay
- Again from equation (8) since V=0 this time, so the equation for decay is

$$L\frac{dI}{dt} + RI = 0$$

Or,

$$\frac{dI}{I} = \frac{-R}{L}dt$$

Integrating on both sides

$$\int\frac{dI}{I} = \frac{-R}{L}\int dt$$

Or,

$$\ln I = \frac{-R}{L}t + C_1 \qquad \text{----(12)}$$

In this case initially at time t=0 current $I=I_{max}$ so

$C_1=\ln I_0$

Putting this value of C_1 in equation (12)

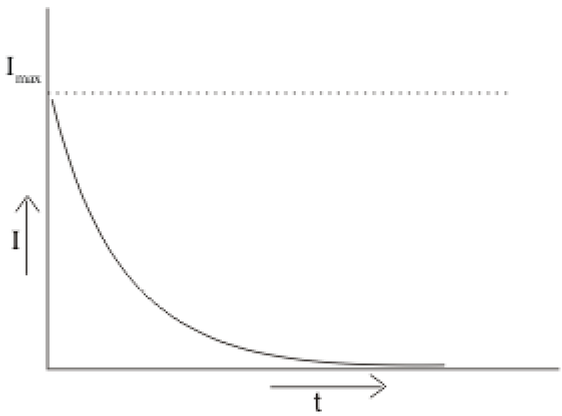
$$\ln I = \frac{-R}{L}t + \ln I_{max}$$

Or,

$$I = I_{max}e^{-\frac{R}{L}t} \qquad \text{---(13)}$$

Hence current decreases exponentially with time in the circuit in accordance with the above equation after the battery are cutoff from the circuit.

Figure below shows the graph between current and time



- If in equation (13)
  $t=\tau_L=L/R$
  then
  $I=I_{max}e^{-1}=.37I_{max}$
  hence the time in which the current decrease from the maximum value to 37% of the maximum value I_{max} is called the time constant of the circuit
- From equation (13) it is clear that when R is large ,current in the L-R circuit will decrease rapidly and there is a chance of production of spark
- To avoid this situation L is kept large enough to make L/R large so that current can decrease slowly
- For large time constant the decay is slow and for small time constant the decay is fast

Application of Growth and decay in R-L & R-C Circuits

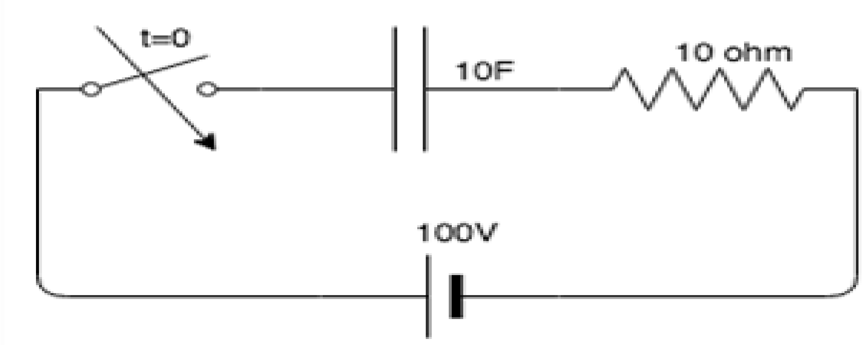
- Series Inductor Resistor
- Oscillator
- Capacitors

4.3.12.3. Self-Assessment

a) Differentiate R-L & R-C circuits
b) Perform calculations on R-L & R-C circuits
c) Describe growth of current in R-L & R-C circuits
d) the time in which the current in the circuit increases from zero to 63% of the maximum value of I_{max} is called the constant or the decay constant of the circuit. TRUE OR FALSE?
e) Higher is the value of decay constant,lower will be the rate of change of current and vice versa. TRUE OR FALSE?
f) Describe decay current in R-L & R-C circuits

g) What are the applications of Growth and decay in R-L & R-C Circuits?

If the switch is closed at t=0, what is the current in the circuit?



4.3.12.4.Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.12.5. References

1. James W. Nilsson, Susan Riedel, Electric Circuits, New Jersey: Prentice Hall Press, 2010.

4.3.13. Learning Outcome No. 12. Use two port networks
4.3.13.1 Learning Activities

Learning Outcome No. 12. Use two port networks	
Learning Activities	Special Instructions
Apply Transients in Electrical Circuit Analysis	

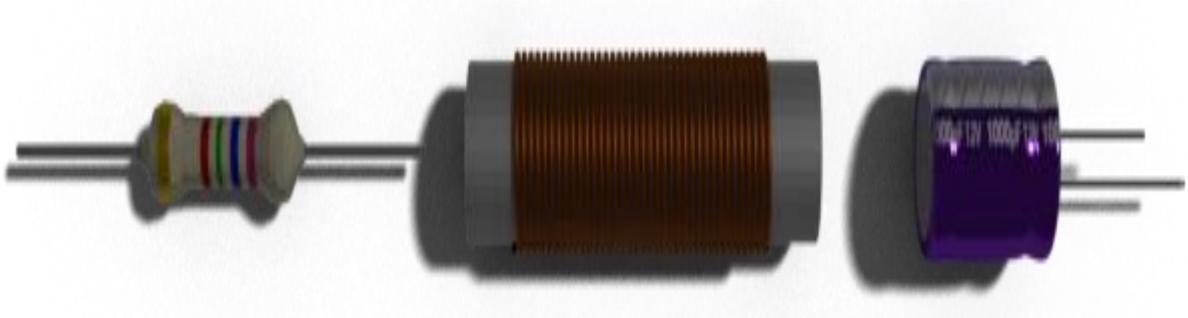
4.3.13.2. Information Sheet No. 4/ LO12

Meaning of passive networks
A passive network is a type of computer network in which each node works on a predefined function or process.
Passive networks don't execute any specialized code or instruction at any node and don't change their behavior dynamically.

Typically, this behavior is related to each network router nod

- Types of Passive network

Resistors
A resistor is taken as a passive element since it cannot deliver any energy to a circuit.



Inductors
An inductor is also considered as passive element of circuit, because it can store energy in it as a magnetic field, and can deliver that energy to the circuit, but not in continuous basis.

Capacitors
A capacitor is considered as a passive element because it can store energy in it as electric field.

Transformers
A transformer is also a passive electronic component. Although this can seem surprising since transformers are often used to raise voltage levels – remember that power is kept constant.

Characteristic impedance in T & pie networks
Transforming from Pi to T and vice versa

Any pi network can be transformed to an equivalent T network. This is also known as the Wye-Delta transformation, which is the terminology used in power distribution and electrical engineering. The pi is equivalent to the Delta and the T is equivalent to the Wye (or Star) form.

The impedances of the pi network (Za, Zb, and Zc) can be found from the impedances of the T network with the following equations:

Za = ((Z1*Z2)+(Z1*Z3)+(Z2*Z3)) / Z2

Zb = ((Z1*Z2)+(Z1*Z3)+(Z2*Z3)) / Z1

Zc = ((Z1*Z2)+(Z1*Z3)+(Z2*Z3)) / Z3

Note the common numerator in all these expressions which can prove useful in reducing the amount of computation necessary.

The impedances of the T network (Z1, Z2, Z3) can be found from the impedances of the equivalent pi network with the following equations:

Z1 = (Za * Zc) / (Za + Zb + Zc)

Z2 = (Zb * Zc) / (Za + Zb + Zc)

Z3 = (Za * Zb) / (Za + Zb + Zc)

Note the common denominator in these expressions.

In the case where all the impedances are reactive (i.e. they are all in the form jX), it is handy to note that the -1 factors from squaring j*j on the top cancels the -1 from bringing the j in the denominator up top.

Synthesis of pi and T networks to transform resistances and create phase shifts

Assuming that the desired port impedances are purely resistive (i.e. real), you can design a T or pi network with purely reactive components both to produce a desired phase shift (beta) and transform the impedances with the following equations. Note that beta can be any value, except for zero or pi.

Z1 = -j * (R1 *cos(beta) - sqrt(R1 * R2))/ sin (beta)

Z2 = -j * (R2 *cos(beta) - sqrt(R1 * R2))/sin(beta)

Z3 = -j * sqrt(R1*R2) / sin(beta)

Za = j *R1*R2 * sin(beta) / (R2 * cos(beta) - sqrt(R1 * R2))

Zb = j * R1*R2 * sin(beta) / (R1 * cos(beta) - sqrt(R1 * R2))

Zc = j * sqrt(R1 * R2) * sin (beta)

Beta is the phase lag passing through the network from either port 1 to port 2 or vice versa. Note that if beta is 0 or pi, these expressions break down, except if R1=R2. If you need to transform resistive impedances and you don't want any phase shift, you have to use a transformer.

In many practical applications, the load or generator impedances may be reactive (i.e. Z (port 1) and Z (port 2) are some general R+jX). This can be accomodated by absorbing the external reactive impedance into the network, reducing or increasing the series or shunt impedance as requred. For instance, if a T network is required to connect between two impedances: 50+j0 and 100-j20 with 45 degrees of phase shift:

First, calculate the Z's assuming resistive impedances: R1=50, R2= 100

Z1 = -j * (50 * .707 - sqrt(50*100))/.707 = +j 50 ohms
Z2 = -j * (100 * .707 - sqrt(50*100))/.707 = 0 ohms
Z3 = -j * sqrt(50 * 100) / .707 = -j 100 ohms
(the example is somewhat contrived, and it winds up creating an L network for the resistive case).

Now, a reactive component is added to Z2 to exactly cancel the external reactive component. This changes Z2 from 0 ohms to +j20 ohms. The final network is then:
Z1 = +j50, Z2= +j20, Z3 = -j100 ohms
If you are working with a pi network, you would want to transform the external impedances into their corresponding shunt forms first, so that the reactive component is a shunt value, which would be absorbed (or combined) with the corresponding shunt component of the pi network.

Cascade ABCD two-port networks

Telephone subscriber lines have become a topic of intense interest for organizations attempting to transmit Internet signals on telephone lines. Basic loop standards exist, and tables of twisted-pair primary constants extending to 20 MHz are in the literature. Asymmetric digital-subscriber lines (ADSLs) are now available for high-speed Internet service. The telephone industry has always used two-port networks in the form of ABCD matrices to cascade sections of telephone cable. These configurations allow you to join the sections by matrix multiplication. However, because the elements in the matrices are complex numbers and several sections make up a chain, you need to organize the process of matrix multiplication. A short computer program performs this task (Listing 1). You enter the number of matrices in the chain and then enter the real and imaginary parts for each A, B, C, and D element. The product then appears on the screen.

A represents the open-circuit transfer function, B represents the short-circuit transfer impedance, C represents the open-circuit transfer admittance, and D represents the short-circuit current ratio. You can find the ABCD matrix for a ladder network composed of RLC elements by slicing the network into series and shunt matrices. You then multiply the product of the first two by the third, and the progression continues with additional subscripts identifying the components. In the final product, the elements A, B, C, and D—with all their component symbols—may become quite cumbersome. To avoid these complicated expressions in the matrix for the ladder network, don't use them. Rather, enter the numerical values for the series and shunt components along with the necessary 0,0s and 1,0s. You can use this concept for any network comprising passive components that you can separate into isolated two-port sections. You can also use the method to predict the degradation a bridged tap produces in a telephone cable.

The progression of entering values for cascaded networks is normally from left to right, or from source to load with the current pointing toward the load. If you reverse the progression, the direction of the current is usually reversed, and the location of elements

A and D is reversed to conform to the reciprocity theorem. The matrices for a single series component and a single shunt component are as follows:

You can use these simple matrices to represent RLC components, transformers, and bridged taps in telephone cables. However, for a telephone cable, you must consider the reflected wave. Thus, you must express the A, B, C, D elements by the following hyperbolic functions:

Where the propagation constant, =+, d is the electrical length of the cable, and Z0 is the characteristic impedance. In the United States, the nominal value for Z0 is 100V, which is also the specified value for the source and load impedance. Because is a complex number, A, B, C, and D are also complex numbers, or the polar equivalent thereof. These numbers are not difficult to calculate; however, the parameters depend on the application (References 1 and 2). The following example shows how to enter the data and read the results:

Within the solid bars, N1 through N4 show the entered data for the components. The bottom line shows the matrix product as it appears on the screen. For this network, the matrix elements are A=43+j0, B=0–j25, C=0+j12, and D=7+j0. The open-circuit voltage ratio is V1/V2=A= 43. The open-circuit transfer admittanceI1/V2=C= 0+j12. The input impedance isZN=A/C=0–j(43/12). Listing 1 uses easy-to-read and-compile QuickBasic. (DI #2455)

4.3.13.3. Self-Assessment

a) Describe passive networks
b) Explain the operation of various types of passive network
c) Explain characteristic impedance in T & pie networks
d) Passive networks don't execute any specialized code or instruction at any node and don't change their behavior dynamically. TRUE OR FALSE?
e) .Asymmetric digital-subscriber lines (ADSLs) are now available for high-speed Internet service. TRUE OR FALSE?
f) Describe Cascade ABCD two-port networks
g) Perform calculations on passive networks
h) What are the applications of passive networks?

4.3.13.4.Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop

4.3.13.5. References

1. James W. Nilsson, Susan Riedel, Electric Circuits, New Jersey: Prentice Hall Press, 2010.

4.3.14. Learning Outcome No. 13. Demonstrate understanding of refrigeration and air conditioning

4.3.14.1. Learning Activities

Learning Outcome No. 13. Demonstrate understanding of refrigeration	
Learning Activities	Special Instructions
• Demonstrate understanding the operation principle of a refrigerator and an air conditioner • Demonstrate understanding of the differences between refrigerator and an air conditioner	

4.3.14.2 Information Sheet No. 4/LO13

Meaning of Refrigeration and Air Conditioning
Key differences in the design and operation.

Supply

A major difference between refrigeration and air conditioning is the point of supply for the gases. Refrigeration systems have gas installed in a series of tubes. Air conditioning systems use built-in chemicals, but also air from the room or rooms being heated.

Circulation

Air conditioners have circulation systems designed to project cool air away from the units while refrigeration units have circulation systems designed to retain coolant in a confined space. Air conditioners, while also employing tubes in the coolant system, have fans for the dispersal of air. Unlike refrigeration systems, which keep gases contained to a pre-determined space, air conditioning systems disperse cool air throughout areas of unknown volume.

Vaporization

Both air conditioning and refrigeration units depend on converting liquid to gas in the cooling process, but the manner in which they achieve this is different for each system. Air conditioners use something called an evaporator to convert a liquid to a gas. Vaporization is the process of converting a liquid to a gas and can be accomplished one of two ways: boiling or evaporation. Thus air conditioning units vaporize liquid through evaporation while refrigeration systems do so through boiling

Operation of Refrigeration and Air conditioning

Refrigeration system

The refrigeration system must have 4 parts. A condenser, an evaporator, compressor and an expansion device. Starting with the compressor, refrigerant gas is compressed to a higher pressure. After passing through the compressor, it passes to the condenser. The high pressure gas transfers its heat to the surrounding air and condenses. It then passes through the expansion device, which is a restriction separating the high side from the low side. After passing through the expansion device, the pressure is reduced because the compressor is removing gas from the end of the evaporator. This lowers the boiling temperature of the refrigerant. The lower temperature absorbs heat from the air passing over the evaporator and boils the liquid to a gas. The gas then passes into the compressor and the cycle repeats.

Air conditioners

Air conditioners use refrigeration to chill indoor air, taking advantage of a remarkable physical law: When a liquid converts to a gas (in a process called phase conversion), it absorbs heat. Air conditioners exploit this feature of phase conversion by forcing special chemical compounds to evaporate and condense over and over again in a closed system of coils.

The compounds involved are refrigerants that have properties enabling them to change at relatively low temperatures. Air conditioners also contain fans that move warm interior air over these cold, refrigerant-filled coils. In fact, central air conditioners have a whole system of ducts designed to funnel air to and from these serpentine, air-chilling coils.

When hot air flows over the cold, low-pressure evaporator coils, the refrigerant inside absorbs heat as it changes from a liquid to a gaseous state. To keep cooling efficiently, the air conditioner has to convert the refrigerant gas back to a liquid again. To do that, a compressor puts the gas under high pressure, a process that creates unwanted heat. All the extra heat created by compressing the gas is then evacuated to the outdoors with the help of a second set of coils called condenser coils, and a second fan. As the gas cools, it changes back to a liquid, and the process starts all over again. Think of it as an endless, elegant cycle: liquid refrigerant, phase conversion to a gas/ heat absorption, compression and phase transition back to a liquid again.

Plant layout of Refrigeration and Air conditioning system
Air conditioner layout

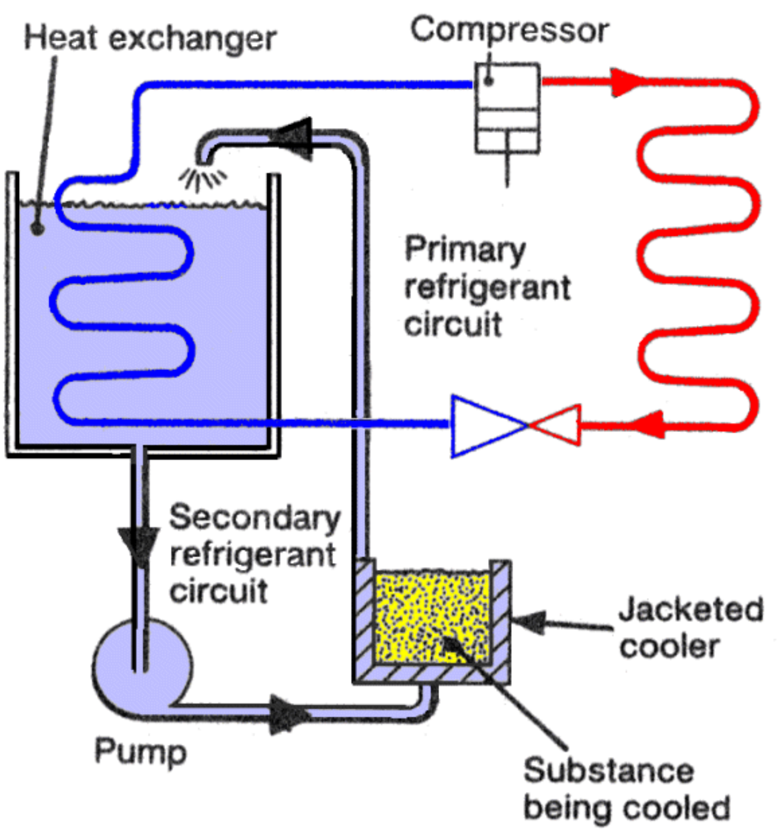


Figure 46: Refrigeration and air conditioning

4.3.15.3 References;

Air Conditioning - Basic Refrigeration Cycle. (n.d.). Retrieved from https://www.swtc.edu/Ag_Power/air_conditioning/lecture/basic_cycle.htm

How Air Conditioners Work. (2011, June 28). Retrieved from https://home.howstuffworks.com/ac1.htm

4.3.14.3. Self-Assessment

a) Define the terms refrigeration systems, air conditioning and vaporization
b) Illustrate various refrigeration plant layouts
c) Describe Refrigeration and Air Conditioning
d) Differentiate between Refrigeration and Air Conditioning
e) Explain operational Principe between a Refrigerator and Air Conditioner
f) What is the importance of Refrigeration and Air Conditioning?
g) Describe Plant layout of Refrigeration and Air conditioning system

h) A major difference between refrigeration and air conditioning is the point of supply for the gases. Refrigeration systems have gas installed in a series of tubes. TRUE OR FALSE?
i) The compounds involved are refrigerants that have properties enabling them to change at relatively low temperatures. TRUE OR FALSE?
j) Define the terms refrigeration systems, air conditioning and vaporization
k) Describe Refrigeration and Air Conditioning
l) Differentiate between Refrigeration and Air Conditioning
m) Explain operational Principe between a Refrigerator and Air Conditioner
n) What is the importance of Refrigeration and Air Conditioning?
o) Describe Plant layout of Refrigeration and Air conditioning system
p) To keep cooling efficiently, the air conditioner has to convert the refrigerant gas back to……..
    a) Solid
    b) Semi solid
    c) Liquid
    d) Gas
q) When hot air flows over the cold, low-pressure………….., the refrigerant inside absorbs heat as it changes from a liquid to a gaseous state.
    a) Condenser coil
    b) evaporator coils
    c) heating coils
r) ………… is the process of converting a liquid to a gas and can be accomplished one of two ways: boiling or evaporation
    a) Circulation
    b) Vaporization
    c) Cooling
s) A major difference between refrigeration and air conditioning is the point of supply for the gases. Refrigeration systems have gas installed in a series of tubes.
    a) True
    b) False
t) The compounds involved are refrigerants that have properties enabling them to change at relatively low temperatures.
    a) True
    b) False

Practical exercise

a) Demonstrate understanding the operation principle of a refrigerator and an air conditioner
b) Demonstrate understanding of the differences between refrigerator and an air conditioner
c) Draw and illustrate various refrigeration plant layouts

4.3.14.2.Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Electrical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

4.3.14.5. References

1. James W. Nilsson, Susan Riedel, Electric Circuits, New Jersey: Prentice Hall Press, 2010.

CHAPTER 5 TECHNICAL DRAWING / PREPARE AND INTERPRET TECHNICAL DRAWING

5.1 Introduction of the Unit of Learning / Unit of Competency

Technical Drawing is the skill of creating a range of plans/ drawings that visually communicate an idea that needs to be constructed or how it functions. Competencies in Technical Drawing are applied in a wide range of areas that include electronics, architecture, manufacturing, engineering, and computer drafting and modelling. This unit covers technical drawing principles, interpretation of technical drawings, drawing equipment and materials, plain geometry, solid geometry, pictorial and orthographic drawings, computer-aided design and drafting, and safe drawing procedures. The essential resources in this course include but not limited to drawing room, computer lab, drawing equipment and materials, computers, CAD package, and a projector. Upon the completion of this course, a trainee should be able to produce a wide range of technical drawings/ designs while following good technical drawing practices. Technical drawing prepares the trainee as a drafting/design technician in the fields of electrical, mechanical and architectural engineering.

5.2 Performance Standard

Drawing equipment and materials are gathered and utilized according to task requirements, waste materials are disposed in accordance with workplace procedures and environmental legislations, drawing lines are used as per standard drawing conventions, different plain geometrical forms are produced according to standard drawing conventions, different solid geometries are produced as per standard drawing conventions, varied pictorial and orthographic drawings are produced according to the standard drawing conventions, and appropriate CAD packages are applied as standard operating procedures.

5.3 Learning Outcomes

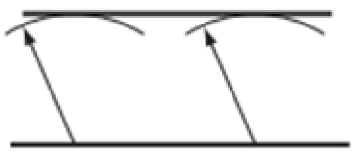
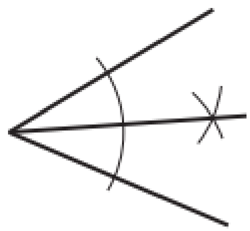
5.3.1. List of Learning Outcomes

a) Use and maintain drawing equipment and materials
b) Produce plain geometry drawings
c) Produce solid geometry drawings
d) Produce pictorial and orthographic drawings of components
e) Apply CAD packages

5.3.2 Learning Outcome No.1: Use and maintain drawing equipment and materials

5.3.2.1 Learning Activities

Select equipment and materials in construction of parallel lines, bisecting angles and lettering.

<table>
<tr><th>Learning Activity</th><th>Special Instructions</th></tr>
<tr><td>Select equipment and materials required draw the illustrated tasks.


Parallel lines ,Bisecting angles

Lettering
Learning Activity
Select equipment and materials required draw the various tasks.</td><td>Provide the trainee with a variety of exercise to build confidence in selecting appropriate drawing equipment and tools.</td></tr>
</table>

5.3.2.2 Information Sheet No 2/LO1: Use and maintain drawing equipment and materials

Introduction

This area of competence covers use and care of technical drawing equipment and materials, overview of ISO technical drawing standards, drawing office procedures, environmental legislations and work place procedures regarding disposal of waste, and the use of personal protective equipment.

Definition of key terms

Drawing.
This is the use of lines, shapes, and sizes to construct objects or structures either in 2-dimesnional or 3-dimensional view.

Technical drawing
Technical drawing a precise detailed representation of an idea using symbols, lines, and signs in creating objects in the manufacturing of engineering articles.

Drafting
This is the act of producing a picture/sketch either in 2-dimesnional or 3-dimensional view and providing dimensions and notes. It is usually a quick sketch/ presentation with details and not to scale.

Designing
This is the act of producing drawings to clearly define the requirements for concepts or products in order to be in line with the expected outcome.

Principles of Engineering Drawing

Engineering drawings should be language-independent in order for drafting/ design technician anywhere in the world can specify a product that can be made and assembled in different countries. Thus, technical drawing serves a language of its own in transmitting information from drafter/designer to the manufacturer and the assembler. Technical Drawing is defined by rules that are embodied in the publications of standards organizations e.g. the British Standards Institution (BSI), the American National Standards Institute (ANSI) and in the International Standards Organization (ISO), which the global body giving guidelines superseding individual countries standards.

Recommended resource for further information

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Watch a 4.11min video on technical drawing tools on the link:
https://youtu.be/k3IhsuJnfh8?t=189

Content

Identification and care of drawing equipment, identification and care of drawing materials, drawing standards and drawing office procedures, workplace procedures, use and maintenance of drawing equipment and materials, and use of Personal Protective Equipment (PPEs).

Conclusion

This outcome covered drawing instruments and materials, ISO drawing rules, drawing office procedures, and use of PPEs in drawing practices.

Trainees' assignment;
- Select different types of drawing sheets as determined by desired quality of a specific job.
- Select drawing pencils required for different drawing features i.e. used in object drawing, outlines, hidden details, and construction lines.

Trainer
- Check that the completed assignments show evidence of understanding of drawing office procedures and housekeeping procedures. Ensure assignments are completed on time. Observe trainee's work behavior from time to time.

5.3.2.3 Self-Assessment

1. The accuracy of the drawing depends on the quality of the instruments used.
   a) True
   b) False

2. Which of the following instrument is made of thin strips of wood arranged in a line to form a rectangle and on which, the drawing is made?
   a) Mini – drafter
   b) Drawing Board
   c) Protractor
   d) Scale

3. Which of the following tools is used to draw horizontal lines?
   a) Mini – drafter
   b) Protractor
   c) T – square
   d) French curve

4. Which of the following instrument can be used to draw accurate perpendicular lines, parallel lines and angular lines?
   a) Mini – drafter
   b) T – square
   c) Protractor
   d) Set square

5. According to the Indian Standard Institute (ISI), which among the following designation has the size 1000 x 700 (in mm)?

a) B0
b) B1
c) B2
d) B3

6. Which is the most common tool used for drawing circles?
a) French curve
b) Mini – drafter
c) Divider
d) Compass

7. For drawing circles with a large radius, which of the following tool is used?
a) Bow compass
b) Lengthening bar compass
c) Divider
d) Protractors

8. The preferred size of the drawing sheets is recommended by the _______
a) B.I.S.
b) ASME
c) ASTM
d) NIST

9. The untrimmed size for ________ sheet is 240 mm x 330 mm.
a) A1
b) A3
c) A4
d) A5

10. SP: 46 (2003) recommends the borders of ________ mm width for the sheet sizes A0 and A1, and ________ mm for the sizes A2, A3, A4 and A5.
a) 10, 20
b) 15, 20
c) 20, 10
d) 15, 10

11. The false statement regarding orientation mark.
a) The orientation mark coincides with one of the centering marks
b) Represents the direction to which sheet is placed
c) Orientation mark can be used for the orientation of drawing sheet on the drawing board
d) Facilitate positioning of the drawing for reproduction purpose

12. The size of the title block is ________ mm x ________ mm.
a) 25 x 10
b) 100 x 25
c) 65 x 185
d) 185 x 65

13. The number of folding methods for folding of various sizes of drawing sheets is __________
a) 1
b) 2
c) 3
d) 4

14. Which of the following is reducing scale?
a) 10:1
b) 10:2
c) 0.5:1
d) 2:1

15. 8. 1:10000 is enlarging scale.
a) True
b) False

16. __________ is not an essential thing for free-hand sketching.
a) A soft-grade pencil
b) French curves
c) A soft rubber-eraser
d) A paper in form of a sketch-book or a pad

17. Which statement is false?
a) Drawing for instruction manual: This is assembly drawing without dimensions. This is also used for explaining the working principle of each part
b) Exploded assembly drawing: This type of assembly drawing is used for explaining the working principle of any machine
c) Drawing for catalogue: Special assembly drawings are prepared for catalogues, with overall and principal dimensions
d) Patent drawing: It is generally assembly drawing either in pictorial form or principal view of orthographic projection of a machine

18. Select and apply different drawing paper holders

5.3.2.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Drawing room
- Computer lab
- Drawing equipment and materials
- CAD packages
- Projector
- Computer

5.3.2.5 References

Heather, S and Shrock, C.R (2019) Begging AUTOCAD Exercise Workbook. Industrial Press, Inc USA

Davies, B. L., Robotham, A. J., & Yarwood, A. (1991). Computer-aided drawing and design. London: Chapman & Hall.

Hubka, V. (2015). Principles of engineering design. Elsevier.

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Morling, K 92012) Geomtric and Engineering Drawing. Routledge, amozon

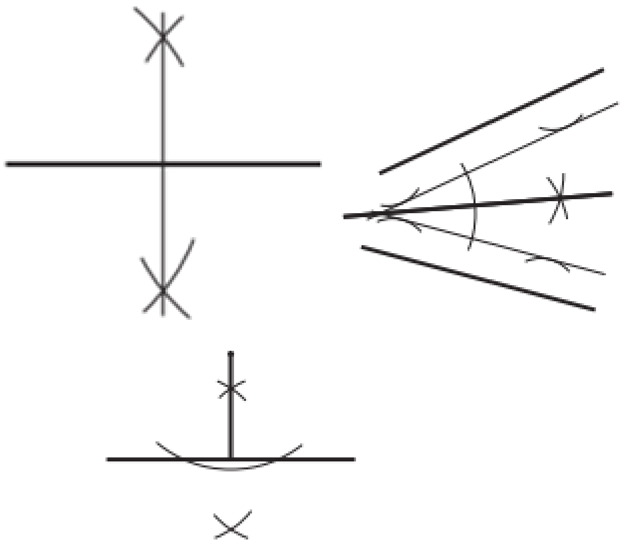
5.3.3 Learning Outcome No. 2: Produce plain geometry drawings
5.3.3.1 Learning Activities

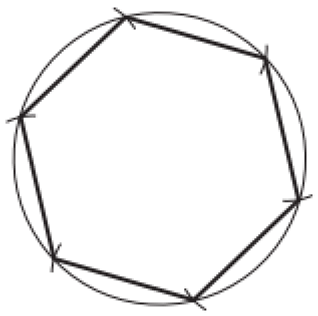
<table>
<tr><td colspan="2">Learning Outcome #2: Produce plain geometry drawings</td></tr>
<tr><td>Learning Activities</td><td>Special Instructions</td></tr>
<tr><td>Activity 1: Produce different types of two- dimensional figures i.e. lines, different angles, bisecting angles, and geometric forms

• Select appropriate equipment and materials for the specific work
• Draw varied lines, different angles, bisect angles, and varied 2-D geometrical forms
Activity 2: Measure different angles, lines, and geometric forms

• Select appropriate equipment and materials for the specific work
Carry out measuring of varied lines, different angles, bisect angles, and varied 2-D geometrical forms

Produce different types of two- dimensional figures i.e. lines, different angles, bisecting angles, and geometric forms
Measure different angles, lines, and geometric forms.

</td><td>Provide feedback and focused instruction to aid trainees to refine their, develop their competencies producing a variety of plain geometries.</td></tr>
</table>

5.3.3.2 Information Sheet No.2/LO2: Produce plain geometry drawings

Introduction

This outcome covers a variety of plain geometry drawings that include lines, triangles, quadrilaterals, polygons, dimensioning and drawing rules.

Definition of key terms

Drawing instruments
These are the tools/equipment that are essential in producing drawings
Drawing materials
These are consumables that are utilized in technical drawing.
Plane geometry
This type of geometry involves production of drawings in two dimensions.
Solid geometry
Solid geometry involves production of drawings in three dimensions.

Plane geometry principle

A line projects as a true length when a view is taken looking perpendicular to the line. A line parallel to the vertical plane will appear as a true length in elevation. A line parallel to the horizontal plane will appear as a true length in plan. Parallel lines appear parallel in every orthographic view. If a line is parallel to any line on a plane, it is parallel to the plane. A line projects as a point when we look along its true length. A plane projects as an edge when any line on the plane projects as a point. The true shape of a plane is seen on a projection plane which is parallel to the plane. Two planes intersect in a line.

Content

Plane geometry: Types of lines, construction of different geometric forms, construction of different angles, measurement of angles, bisection of different angles and lines, polygons, circles, triangles, and drawing symbols and abbreviations.

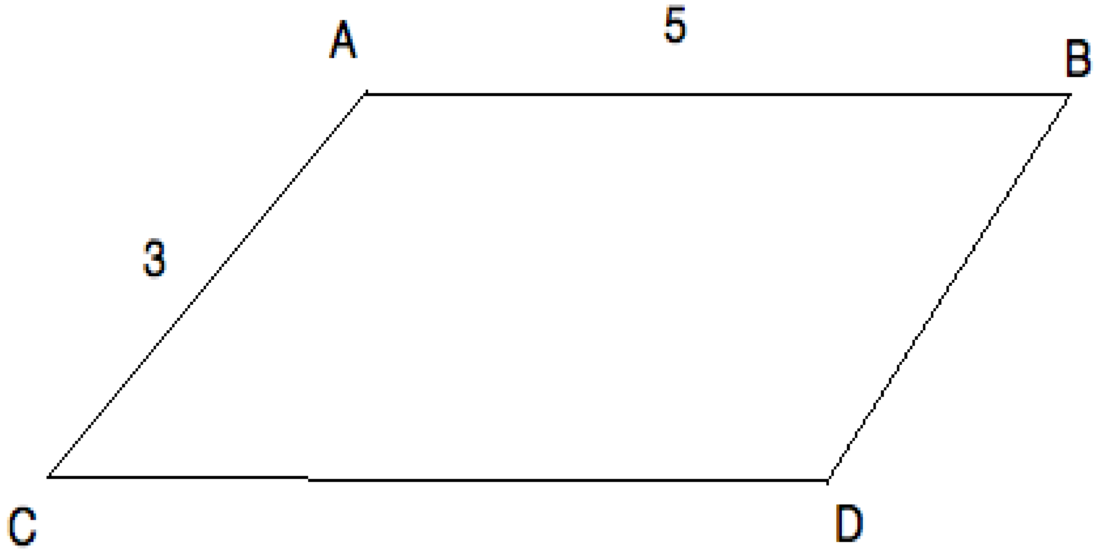


Figure 47: Plane Geometry

Plain geometry can take various shape such as in figure 1 and figure 2

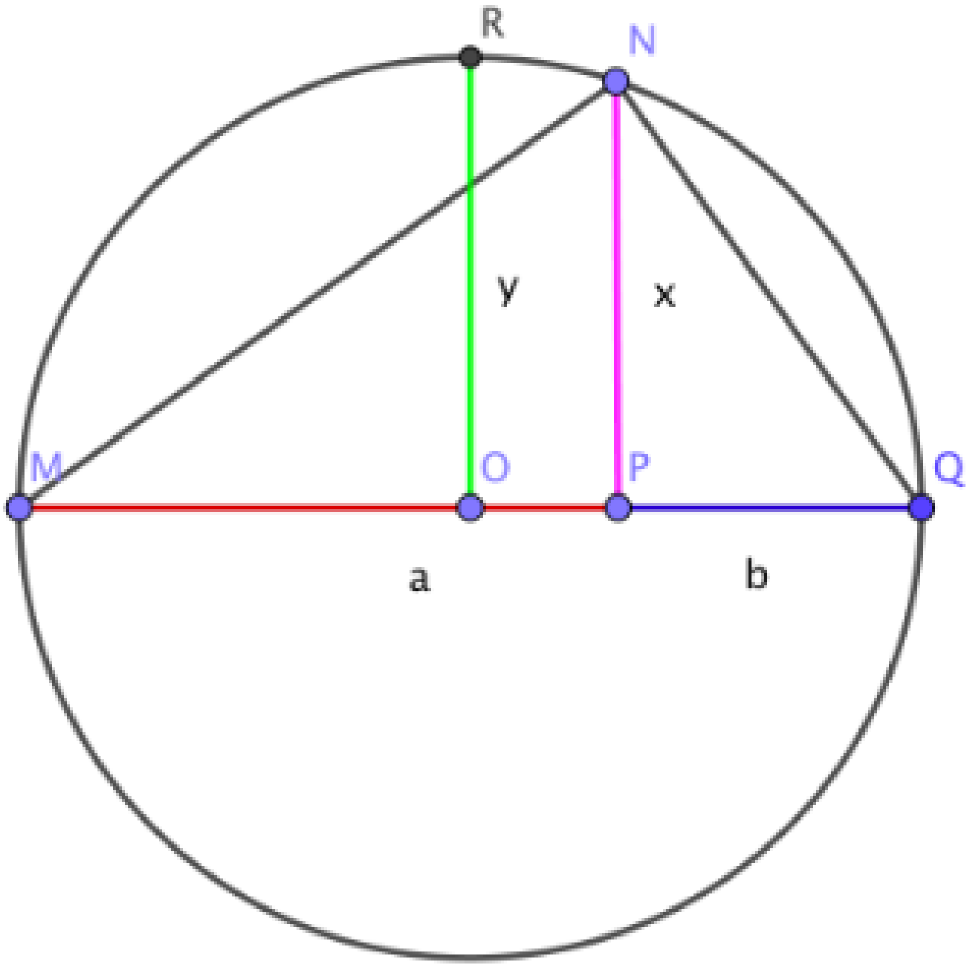


Figure 48: Plane Geometry circle

Conclusion

This outcome covered plane geometries drawings i.e. types of lines, polygons, triangles, quadrilaterals, dimensioning and drawing rules.

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Trainees' assignment;

- Construct an equilateral triangle, given one of the sides, AB = 100.
- Construct a square given the diagonal
- Construct a triangle given the base, the altitude and the vertical angle(base 100mm and vertical angle 65^{o})
- Construct a triangle given the perimeter and the ratio of the sides
- Construct a triangle similar to another triangle but with a different perimeter

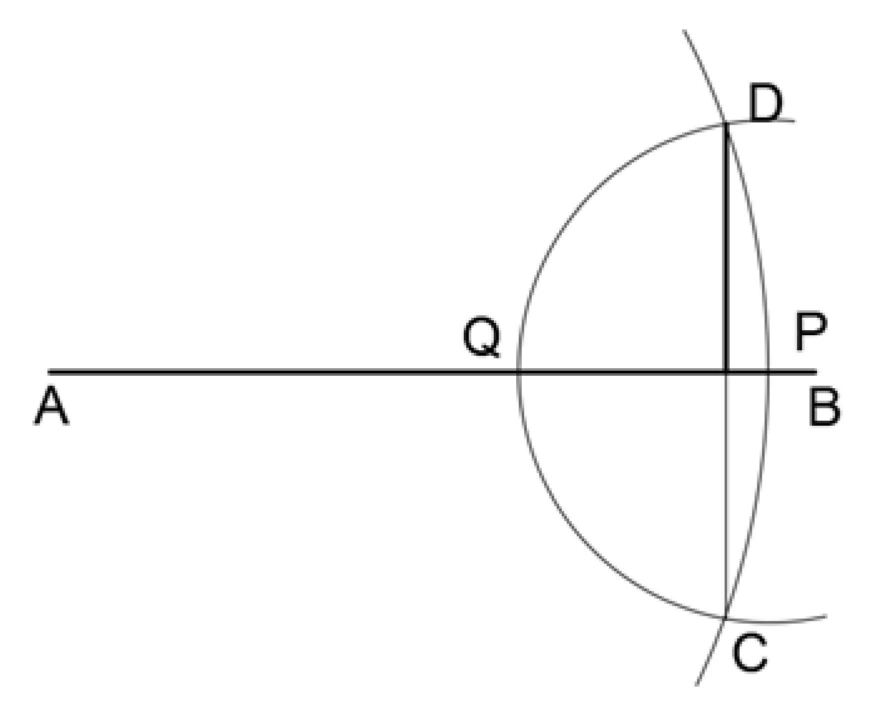
Trainer

- Check that the completed assignments show evidence of understating a variety of plane geometries, drawing rules and housekeeping procedures. Ensure assignments are completed on time. Observe trainees' work from time to time.

5.3.3.3 Self-Assessment

1. While drawing a perpendicular to a line from a point within the line but nearer to the end of the line, all the arcs drawn in the process are of _______
   a) Different radii
   b) Different radii but one
   c) Same radii but one
   d) Same radii

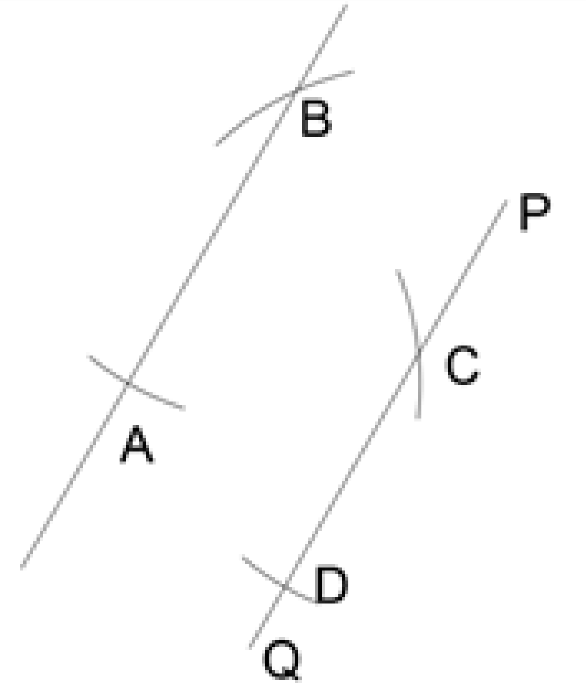
2. In the given figure which of the following construction line is drawn first?



   a) Line AP
   b) Arc DPC
   c) Arc DQC
   d) Line DC

3. For drawing parallel lines to a given line through a given point we make use of ____
   a) Arcs
   b) Triangles
   c) Lines
   d) Quadrilaterals

4. Which of the following arcs is made first to draw a parallel line to the given line PQ?

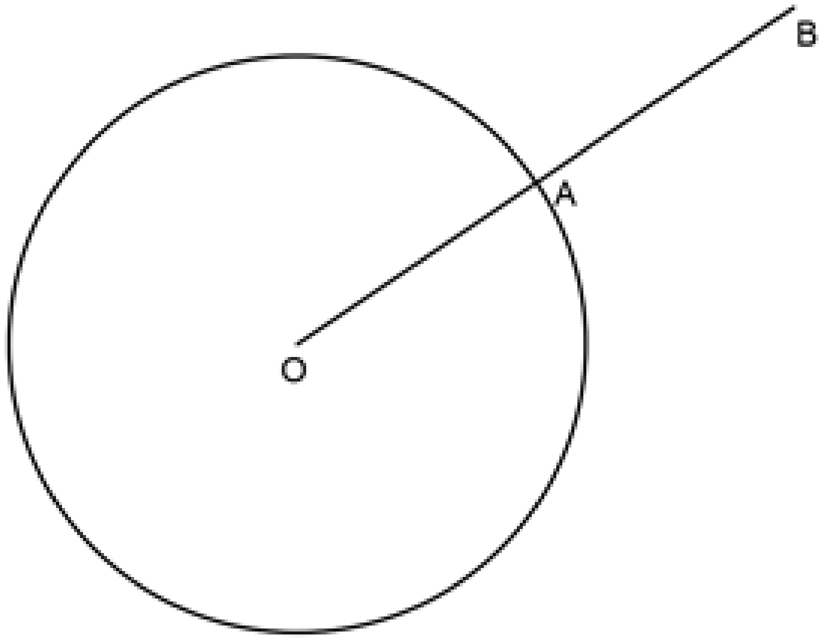


a) A
b) B
c) C
d) D

5. A tangent to a circle is a line which touches the circle at one and only one point.
a) True
b) False

6. The line perpendicular to a tangent and is passing through the point of contact is called as _____
a) Perpendicular bisector
b) Angle bisector
c) Normal
d) Tangent

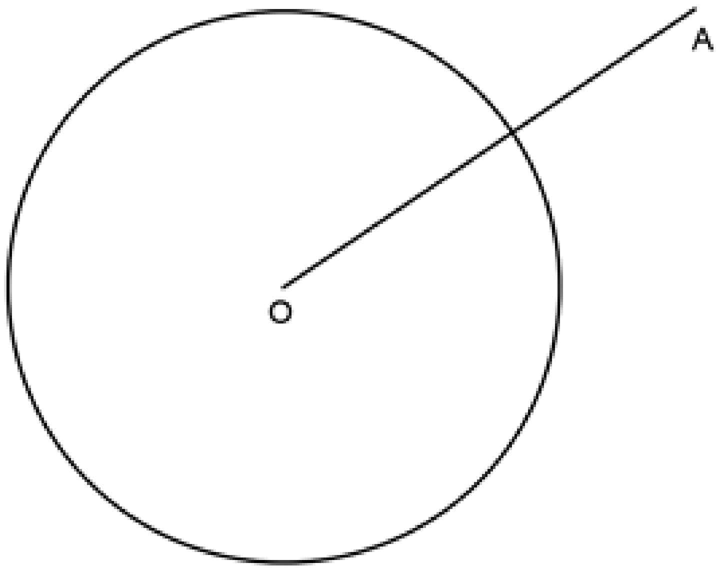
7. In the following figure, the tangent at point A can be drawn by _______



a) Angle bisector
b) Perpendicular bisector
c) Rectangle
d) Arc

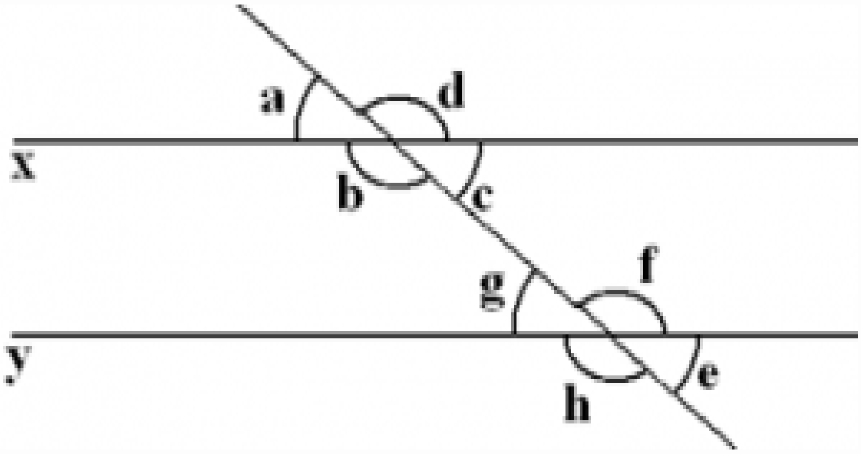
8. How many tangents can be drawn from a point outside a given circle?
a) 4
b) 3
c) 2
d) 1

9. In the following figure, how will make a tangent from the point outside the circle?



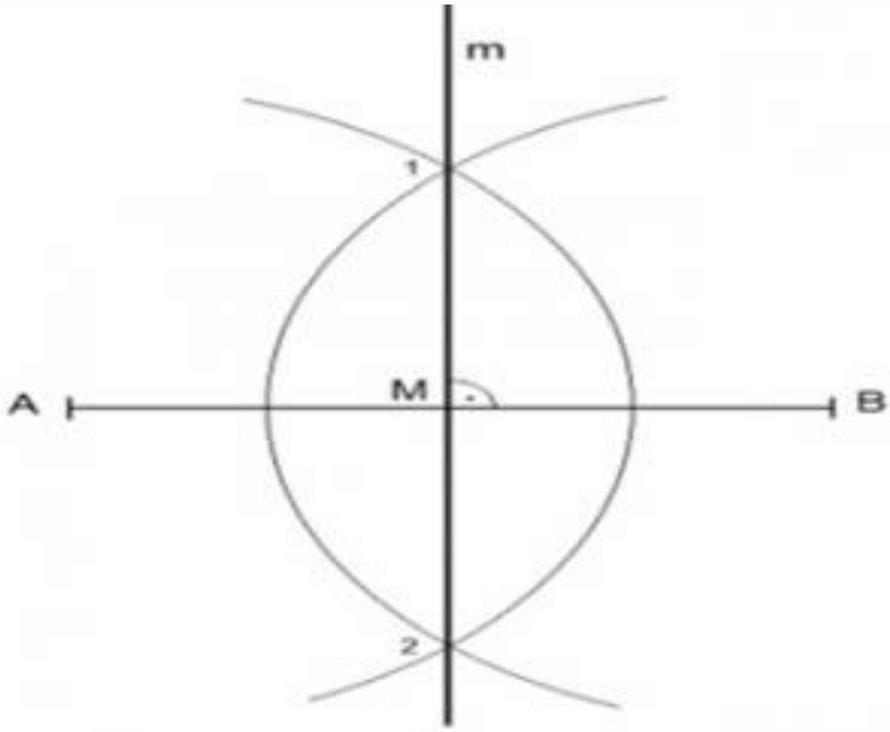
a) By drawing a semicircle with diameter as OA
b) By drawing a perpendicular bisector
c) By drawing an angle bisector
d) By drawing circle with the same radius from A

10. Which geometric principle is used to justify the construction below?



11.
a) A line perpendicular to one of two parallel lines is perpendicular to the other
b) Two lines are perpendicular if they intersect to form congruent adjacent angles
c) When two lines are intersected by a transversal and alternate interior angles are congruent, the lines are parallel
d) When two lines are intersected by a transversal and the corresponding angles are congruent, the lines are parallel

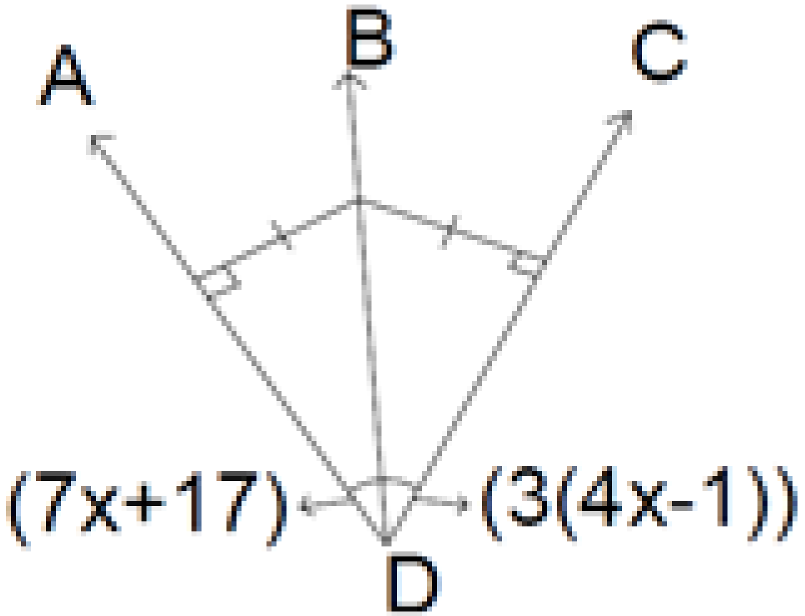
12. The diagram below shows the construction of the perpendicular bisector of AB.



Which statement is not true?
a) AM=MB

b) MB=1/2AB
c) AM=2AB
d) AM+MB=AB

13. Find angle BDC shown in the figure below.



a) 30
b) 65
c) 60
d) 45

15. Construct an isosceles triangle given the perimeter and the altitude (perimeter 150mmand altitude 70mm).
16. Construct a rhombus given the diagonal and the length of the sides
17. Construct a trapezium given the lengths of the parallel sides, the perpendicular distance between them and one angle
18. Construct a regular octagon given the diameter, i.e. within a given square

5.3.3.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Drawing room
- Computer lab
- Drawing equipment and materials
- CAD packages
- Projector
- Computer

5.3.3.5 References

Heather, S and Shrock, C.R (2019) Begging AUTOCAD Exercise Workbook. Industrial Press, Inc USA

Davies, B. L., Robotham, A. J., & Yarwood, A. (1991). Computer-aided drawing and design. London: Chapman & Hall.

Hubka, V. (2015). Principles of engineering design. Elsevier.

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Morling, K 92012) Geomtric and Engineering Drawing. Routledge, amozon

5.3.4 Learning Outcome No. 3: Produce solid geometry drawings

5.3.4.1 Learning Activities

Learning Outcome #4: Produce solid geometry drawings	
Learning Activities	Special Instruction
• Construct two dissimilar square prisms meeting at right angles. • Construct two dissimilar hexagonal prisms meeting at an angle. • Construct two dissimilar hexagonal prisms meeting at an angle. • Construct two dissimilar hexagonal prisms meeting at an angle.	

5.3.4.2 Information Sheet #3: Produce solid geometry drawings

Introduction

In this outcome, these areas are covered interpretation of sketches and drawings of patterns, surface development of interpenetrating solids ad truncated solids, and interpenetration of solids.

Content

Solid geometry: interpretation of sketches and drawings, surface development of prisms, cylinders, truncated prisms, cones, and pyramids. Development of surfaces of interpenetration cylinders and truncated solids, and interpenetration of cylinder to cylinder and cylinder to prism or prism to prism of equal and unequal diameters

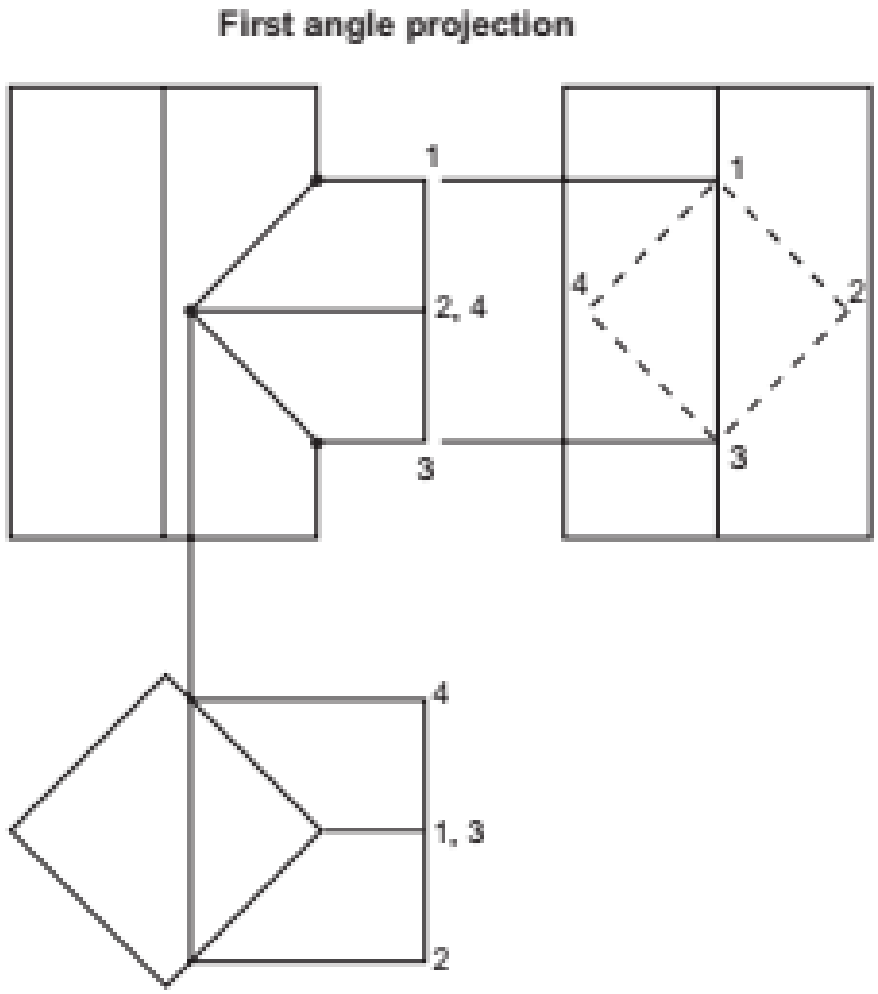


Figure 49: First angle Projection Source: Morling, (2012)

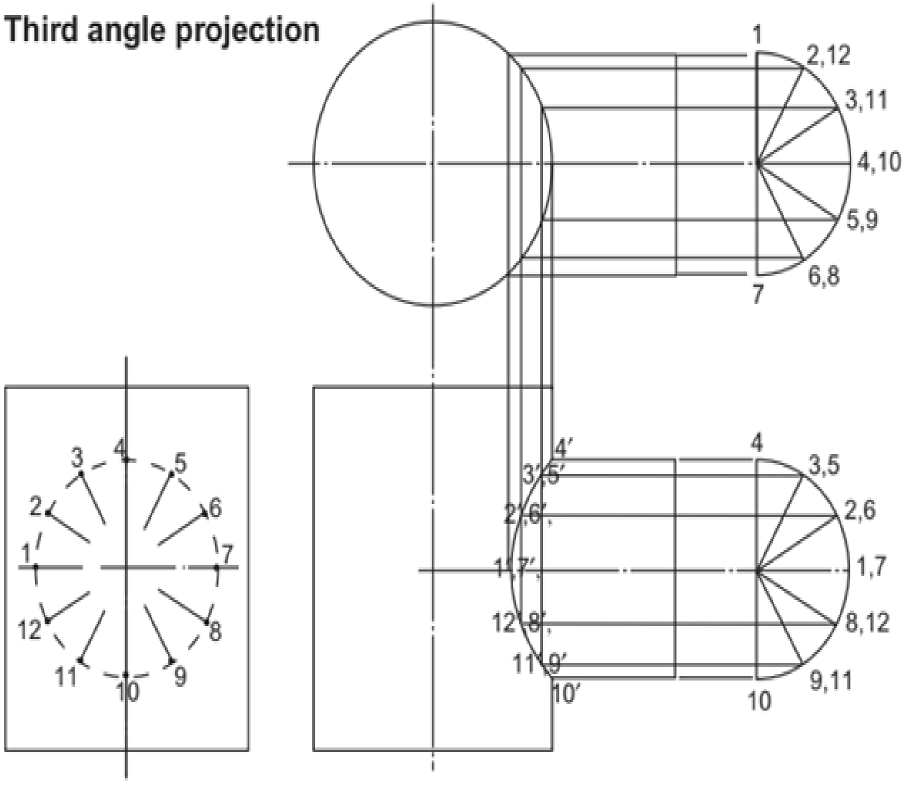


Figure 50: Third and first angle Projection

Watch the video\;htt9UMxr7BT8CEps://www.youtube.com/watch?v=

Conclusion

This outcome covered interpretation of sketches and drawings, surface development of solids, and interpenetration of surfaces.

Trainees' assignment;

- Construct an equilateral triangle, given one of the sides, AB = 100.
- Construct Two dissimilar square prisms meeting at an angle
- Construct a hexagonal prism meeting a square prism at right angles
- Construct a square prism meeting a square pyramid at right angles
- Construct a cylinder meeting a square pyramid at an angle

Trainer

- Check that the completed assignments show evidence of understating a variety of solid geometries, drawing rules and housekeeping procedures. Ensure assignments are completed on time. Observe trainees' work from time to time.

Recommended sources for further information;
Geometric and Engineering drawing Third Edition K Morling.

5.3.4.3 Self-assessment

1. A cylinder is placed on H.P on its base and section plane is parallel to V.P cutting the solid the section gives _______________
   a) parabola
   b) circle
   c) rectangle
   d) ellipse

2. A cylinder is placed on H.P on its base and section plane is parallel to H.P cutting the solid the section gives _______________
   a) parabola
   b) circle
   c) rectangle
   d) ellipse

3. A cylinder is placed on H.P on its base and section plane is inclined to V.P and perpendicular to H.P cutting the solid the section gives _______________
   a) parabola
   b) circle
   c) rectangle
   d) ellipse

4. If a plane is inclined with both the reference plane then the plane come under _____________
   a) auxiliary plane
   b) oblique plane
   c) perpendicular plane
   d) cross planes

5. If a plane is inclined to both the reference planes then the traces would meet at _________ line except the plane perpendicular to picture plane.
   a) XY reference
   b) Vertical reference
   c) Above the XY reference plane

d) Below the XY reference plane

6. When a surface of the plane is inclined to the H.P and an edge is parallel to the H.P and inclined to V.P. The projections are drawn in 2 stages.
a) True
b) False

7. Draw a radial element (0, 1) in one of the orthographic views. Find the points on the line of interpenetration (ie, p & q) and project them to the other views.

8. Repeat with more radial elements until you have enough points to draw the lines of interpenetration

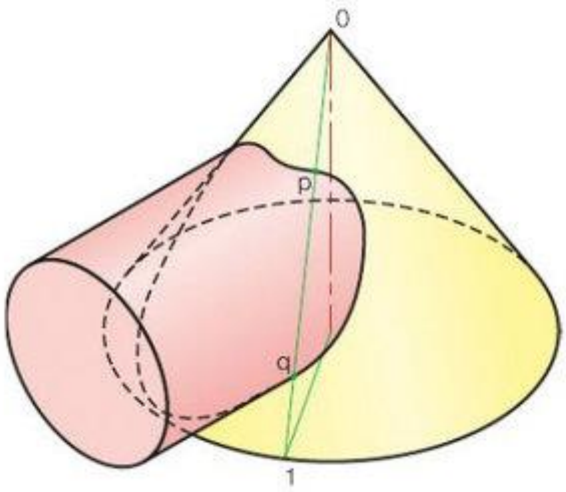


Figure 51: Cylinder intersecting a cone

9. Given pyramid is cut by plane, ⊥ to the frontal plane and inclined at 70o to the top plane. The cutting plane cuts the axis of the pyramid at 15mm from the apex. Draw the projections of the remaining part of the pyramid and the true shape of the cut section

5.3.4.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Drawing room
- Computer lab
- Drawing equipment and materials
- CAD packages
- Projector
- Computer

5.3.4.5 References

Heather, S and Shrock, C.R (2019) Begging AUTOCAD Exercise Workbook. Industrial Press, Inc USA

Davies, B. L., Robotham, A. J., & Yarwood, A. (1991). Computer-aided drawing and design. London: Chapman & Hall.

Hubka, V. (2015). Principles of engineering design. Elsevier.

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman

Group UK Ltd, London

Morling, K 92012) Geomtric and Engineering Drawing. Routledge, amozon

5.3.5. Learning Outcome No 4: Produce pictorial and orthographic drawings of components

5.3.5.1. Learning Activities

- Produce orthographic views in first angle and third angle elevations.
- Isometric Projection (Isometric Drawing).
- Produce Circles and Curves Drawn in Isometric Projection.
- Produce components in oblique projection.

Learning Outcome #4: Produce pictorial and orthographic drawings of components	
Learning Activities • Produce orthographic views in first angle and third angle elevations	Special Instructions
• Produce isometric projection (isometric) drawing of the above components.	
• Produce Circles and Curves Drawn in Isometric Projection	
• Produce the above component in oblique projection.	

5.3.5.2 Information Sheet #4: Produce pictorial and orthographic drawings of components

Introduction

This outcome covers meaning of pictorial and orthographic drawings and sectioning, symbols and abbreviations, drawing of isometric, oblique, axonometric, auxiliary and perspective views, drawing of first and third angle projections, sectioning of components, and free hand sketching of tools, equipment, components, geometric forms and diagrams.

Definition of key terms

- Orthographic projection
- Oblique projection

Recommended resources

Engineering Drawing with CAD Applications by O.OSTROWSKY

Geometric and Engineering drawing Third Edition K Morling

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Solid geometry principles

All views presented in a solid geometry are assumed to be from the same object, and only the particular object but from different points of view and that all views are at the same scale. All the visible edge are depicted by a line and assumptions are made that those edge progress away from the viewer to form faces that are flat abd at right angles. The true angle between a line and a plane is seen in a view showing the line as a true length and the plane as an edge. All horizontal sections of an upright or inverted right cone are circles. A sphere appears as a circle in every view. A sphere and cone in contact will have a common tangent plane. When two spheres touch one another: the point of contact lies on the line joining the two centres, the distance between their centres is equal to the sum of the radii, and the point of contact can be located in any view, by dividing the line in the ratio of the radii. The vertical trace of a plane is the line in which the plane meets the vertical lane. The horizontal trace of a plane is the line in which the plane meets the horizontal plane.

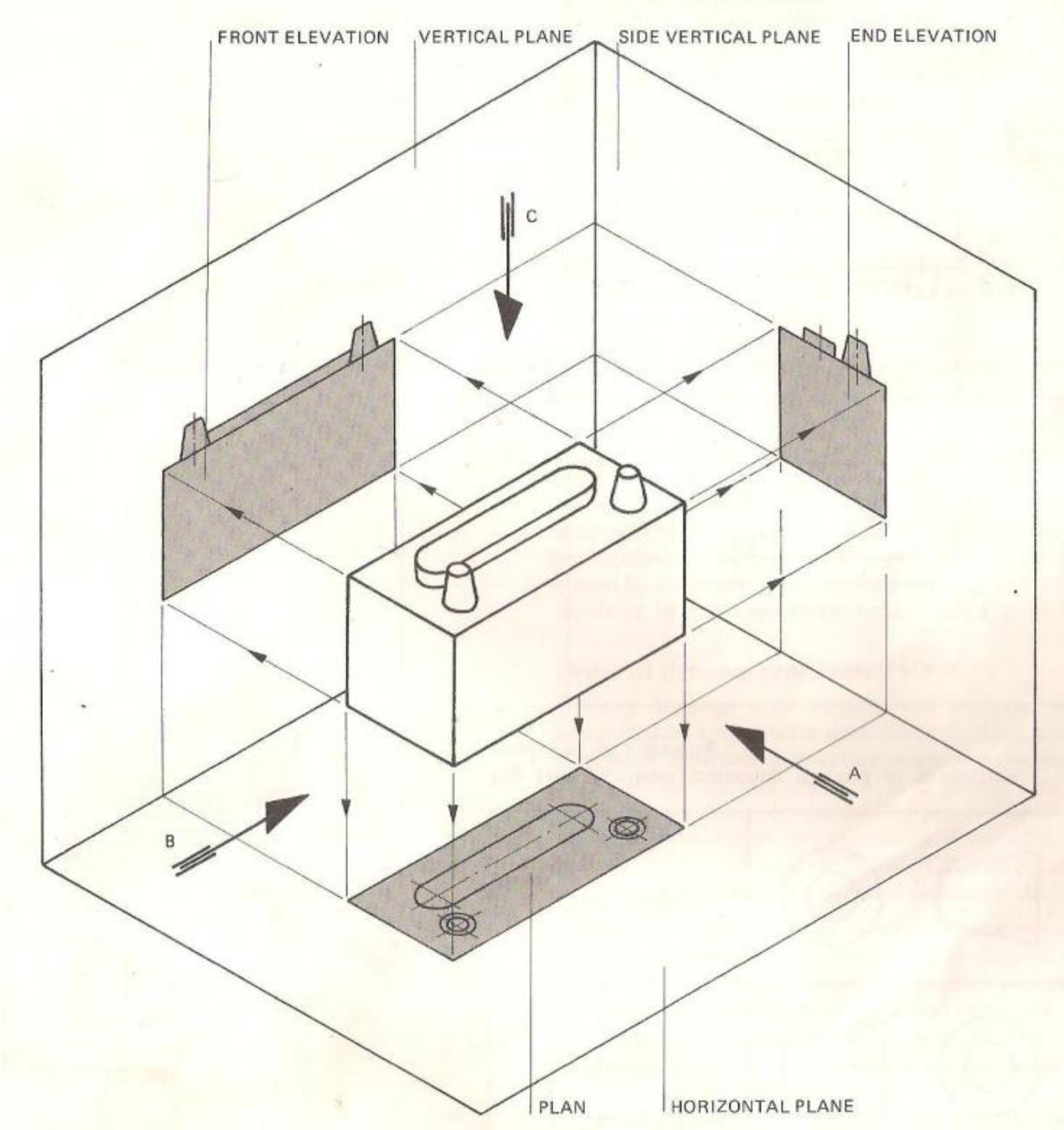
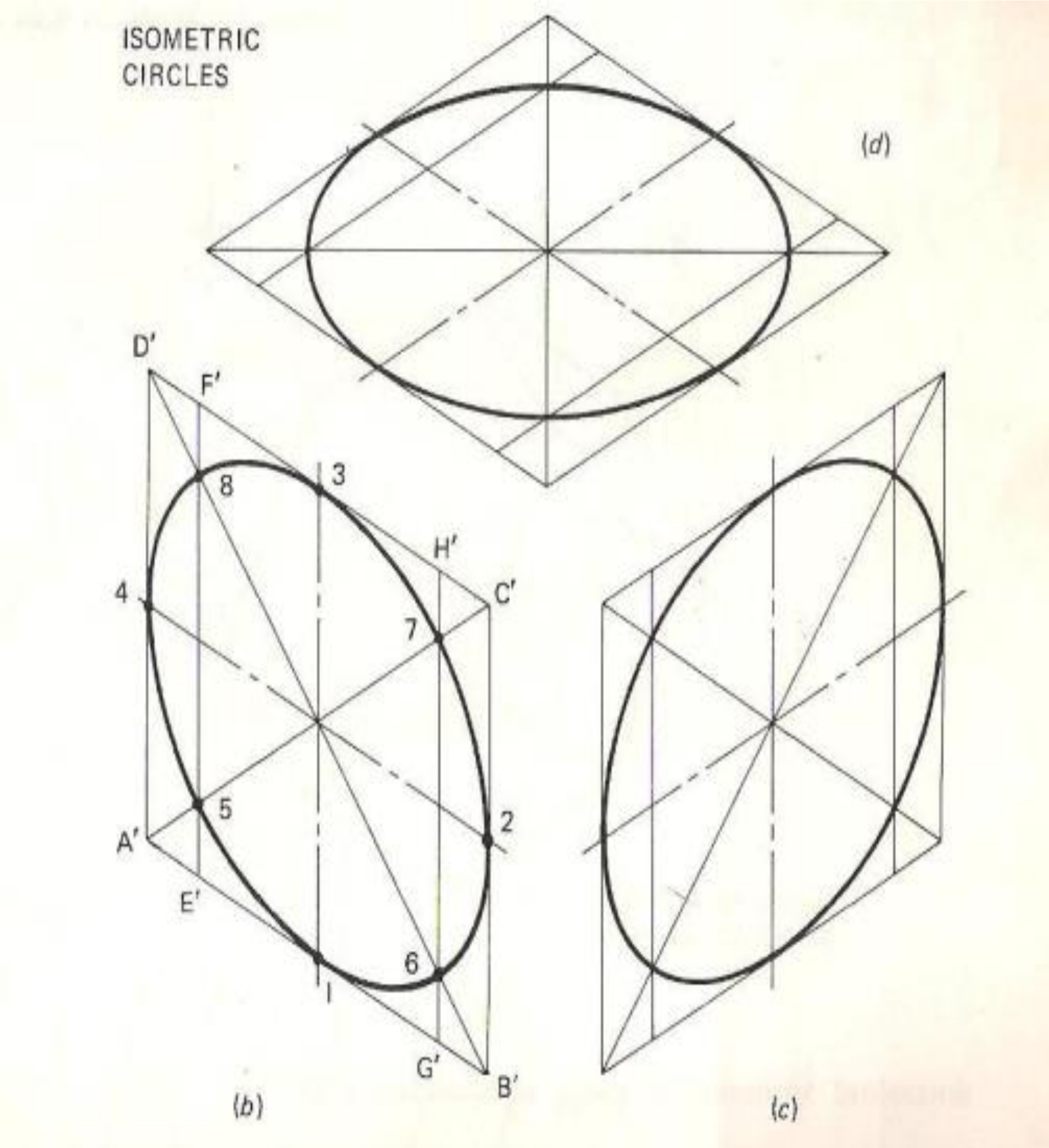


Figure 52: Isometric drawing

Content

Solid geometry: orthographic drawings, oblique projections, pictorial projections, axonometric, auxiliary and perspective views, drawing of first and third angle projections, sectioning of components, and free hand sketching of tools, equipment, components, geometric forms and diagrams.



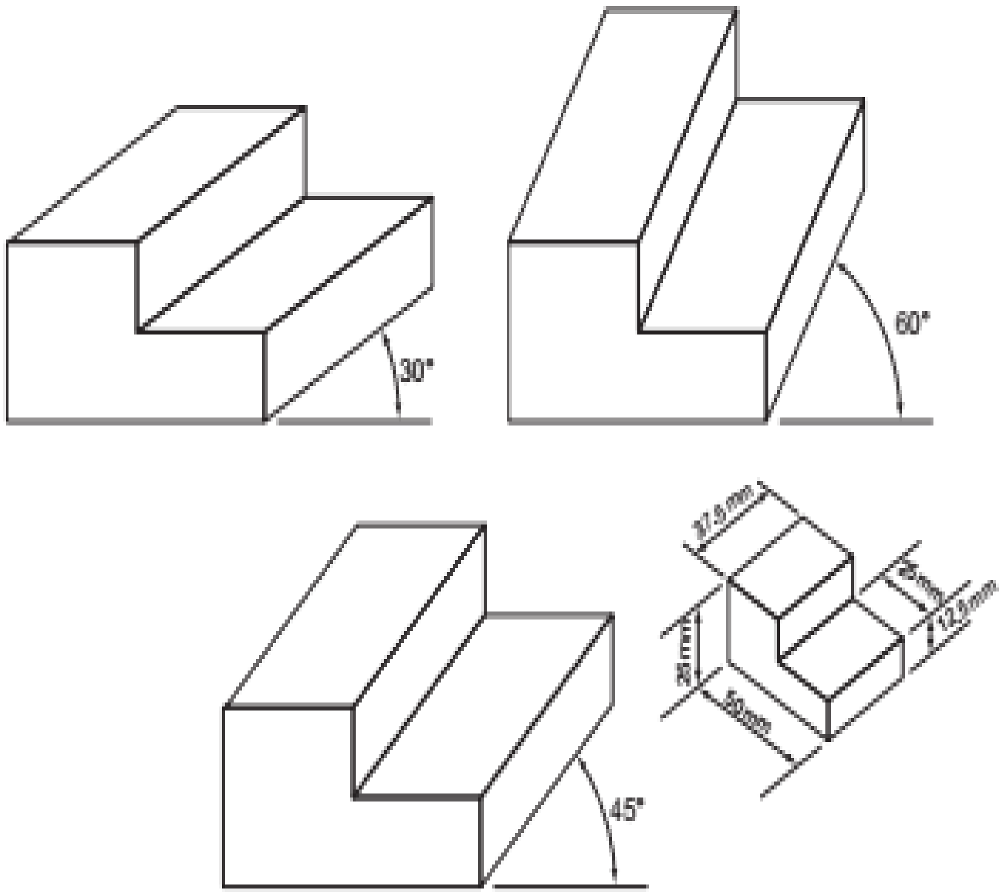


Figure 54: Oblique Projection

Illustrations on dimensioning

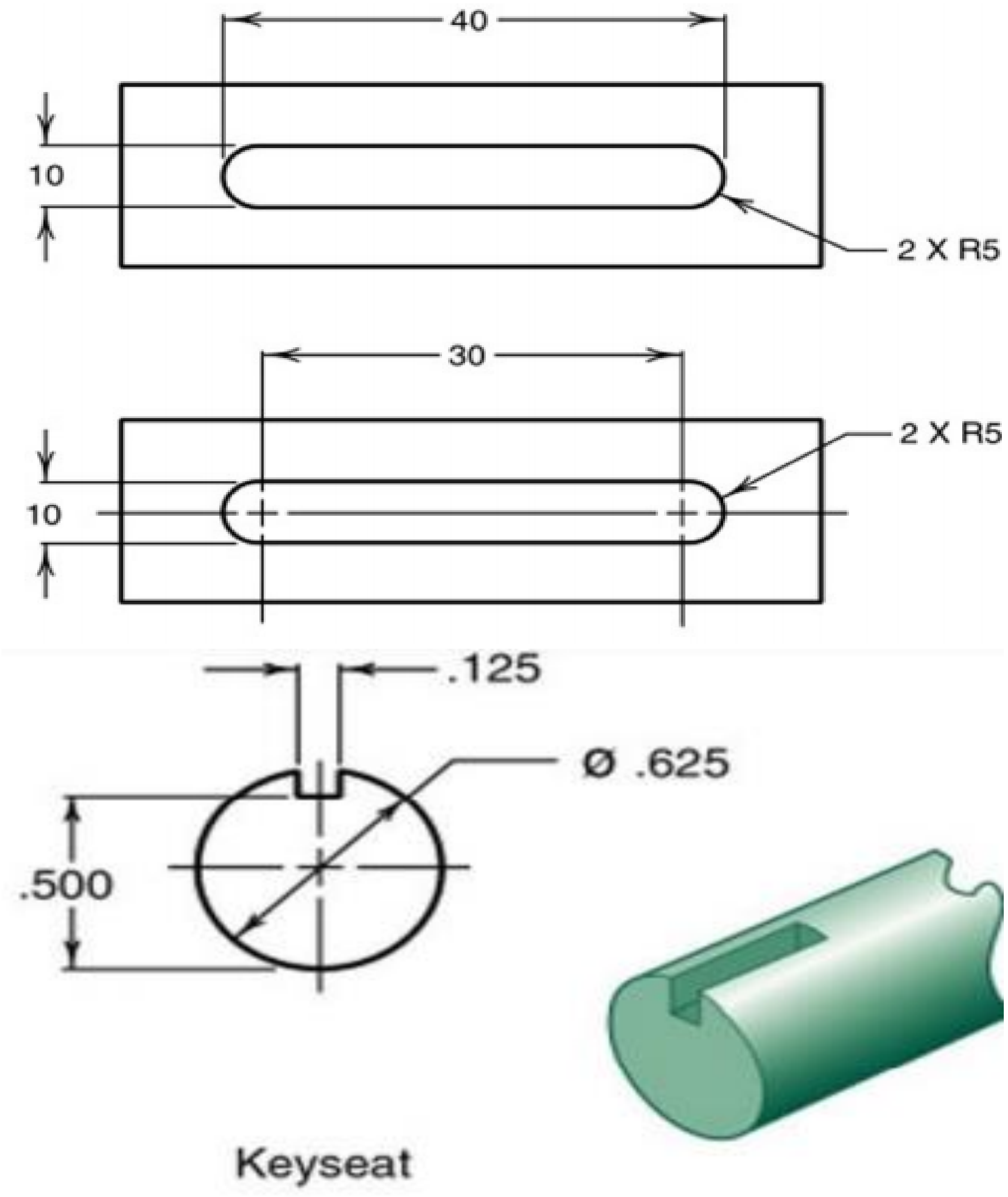


Figure 55: Technical drawing key seat Slots Keyway

Conclusion

This outcome covered orthographic views, pictorial drawing, oblique drawings, sectioning, axonometric, auxiliary first, and third angle projections, and free hand sketching.

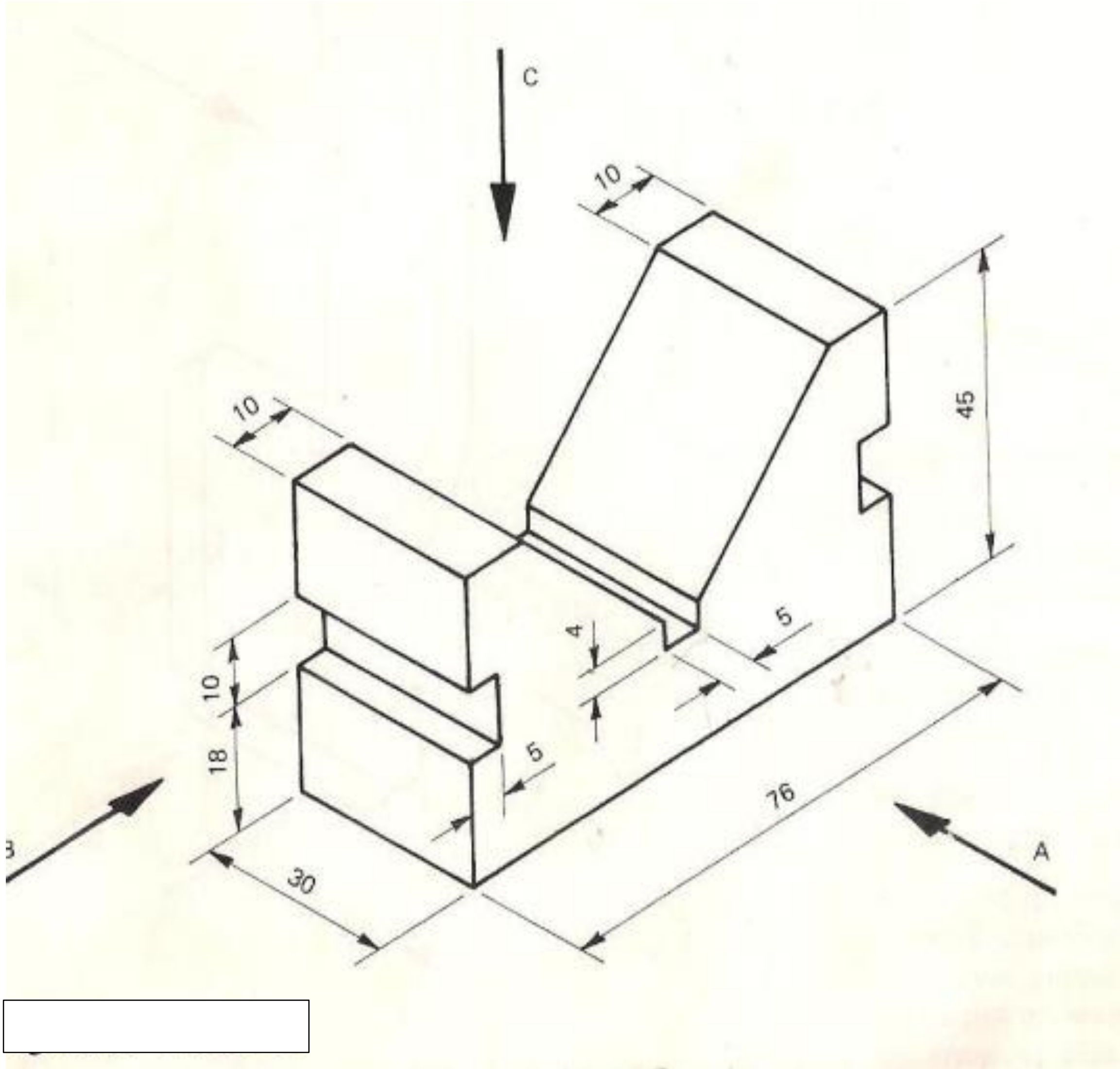


Figure 56: Vee Block, (source, Morling, 2012)

Trainees' assignment;

Draw the following views of the stub below in first angle projection.

a) Front elevation looking from the direction arrow A
b) End elevation looking from the direction arrow B
c) A plan

Show all the hidden detail and fully dimension the finished drawing

The casting is symmetrical about the vertical centre line and both lugs are identical
Construct Two dissimilar square prisms meeting at an angle

Draw twice full size of the front elevation looking in the direction of arrow A. from this front elevation, project an end elevation and plan looking in the direction of the arrows B and C respectively. Insert five main dimensions and add the title block and the scale.

Trainer

- Check that the completed assignments show evidence of understating a variety of solid geometries, drawing rules and housekeeping procedures. Ensure assignments are completed on time. Observe trainees' work from time to time.

Recommended sources for further information;

Geometric and Engineering drawing Third Edition K Morling.
Engineering Drawing with CAD Applications by O.OSTROWSKY

2.3.5.3 Self-Assessment

1. Orthographic projection is drawn using two methods which is ___________
a) Second angle and third angle method
b) First angle and third angle method
c) First angle and fourth angle method
d) Second angle and fourth angle method

2. The method in which the object is placed in the first quadrant is known as __________ method.
a) third angle
b) second angle
c) first angle
d) fourth angle

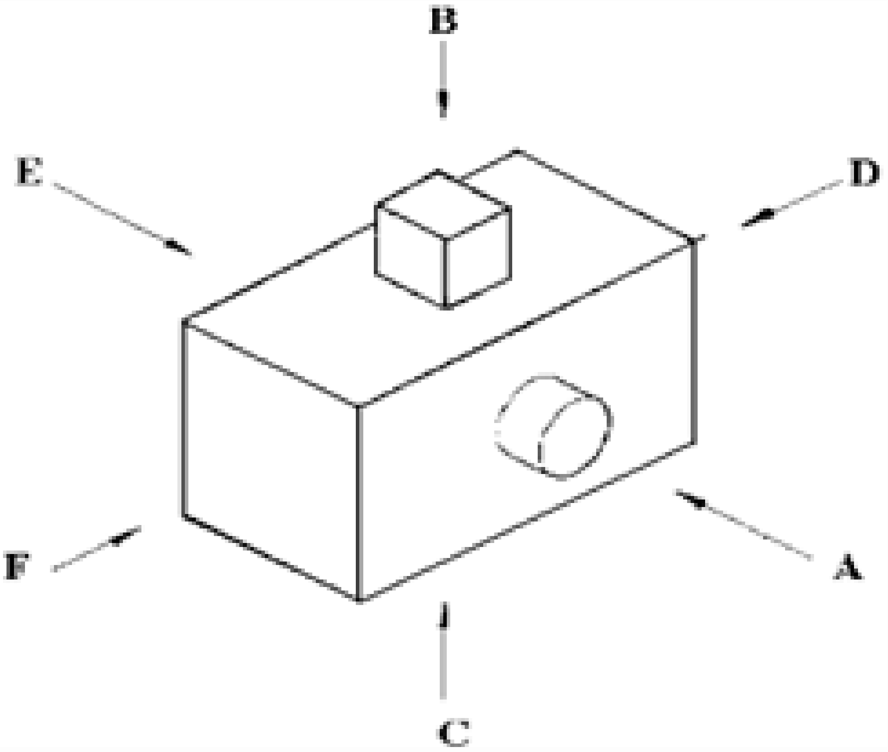
3. In first angle method the top view is drawn _______ of the front view.
a) above
b) right Side

c) left side
d) bottom

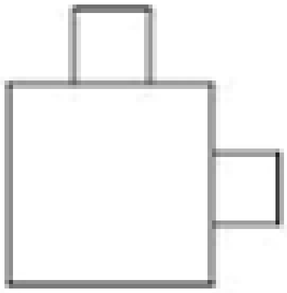
4. The method in which the object is placed in the third quadrant is known as __________ method.
a) third angle
b) second angle
c) first angle
d) fourth angle

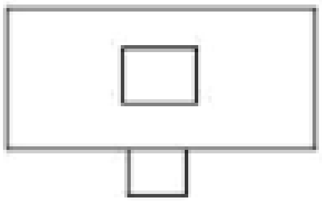
5. In third angle method the top view is drawn _______ of the front view.
a) above
b) right Side
c) left side
d) bottom

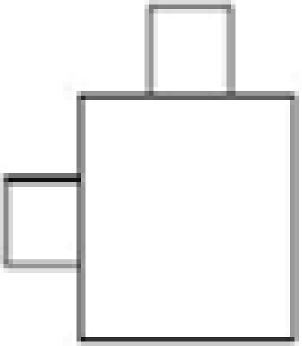
6. **Question 6 to 11 is for the diagram drawn below:-**

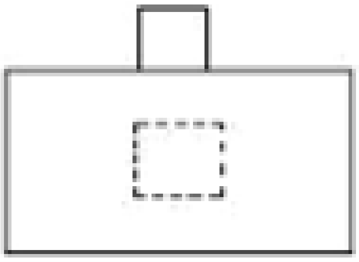


7. Taking 'A' as the FRONT VIEW. Which view will letter 'D' represent?

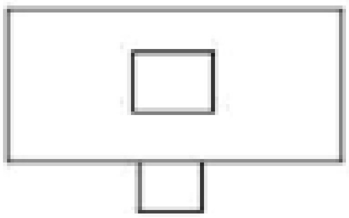
a) 

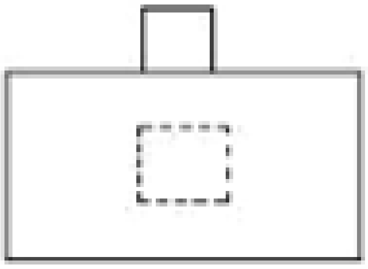
b) 

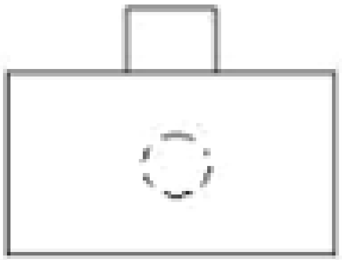
c) 

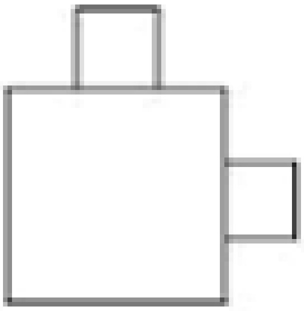
d) 

8. Which view will letter 'C' represent?

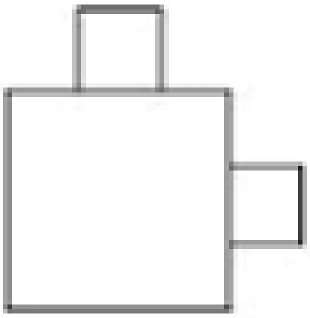
a) 

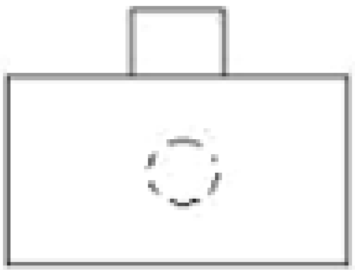
b) 

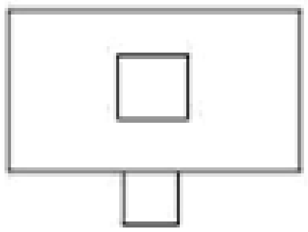
c) 

d) 

9. Which view will letter 'E' represent?

a) 

b) 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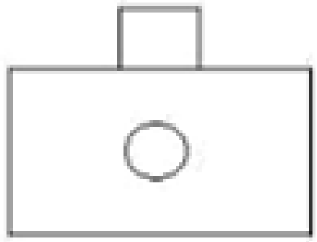
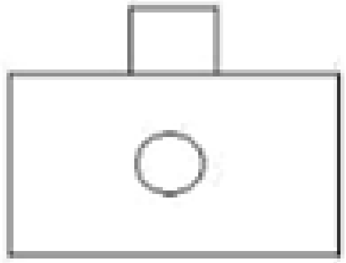
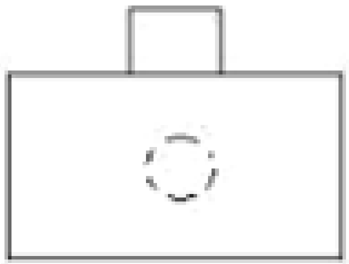
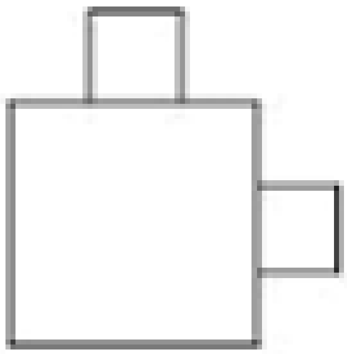
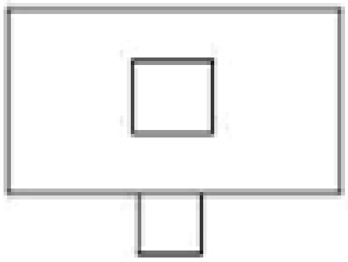

d)

10. Which view will letter 'B' represent?

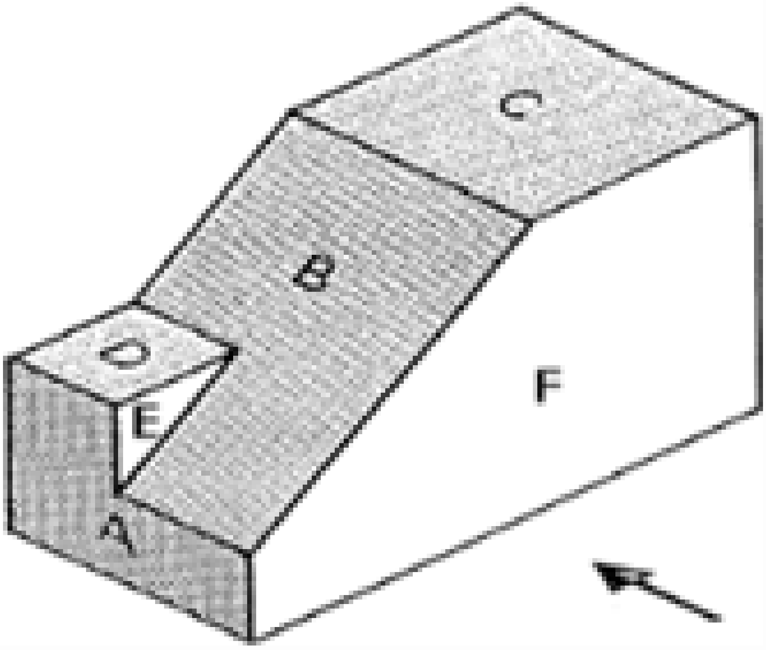

a)


b)

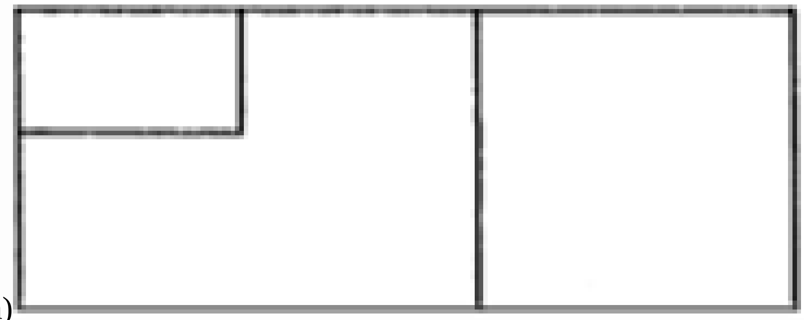

c)

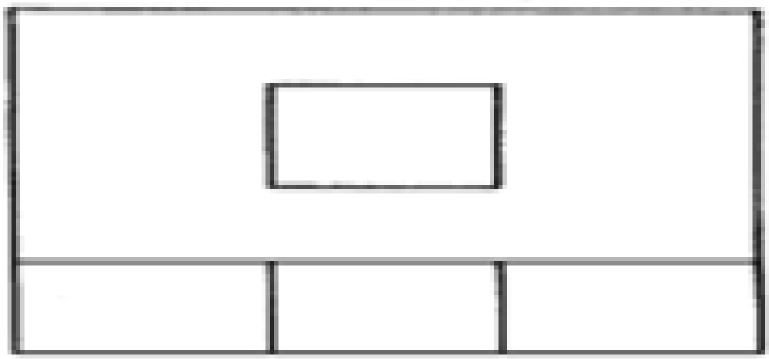
d) 

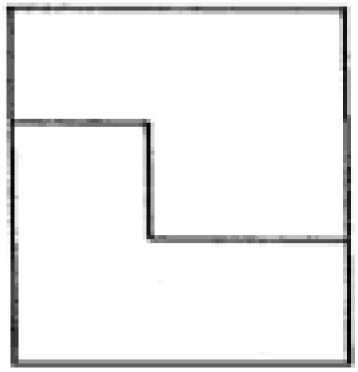
11. **Questions 12 and 13 are for the diagram drawn below:-**



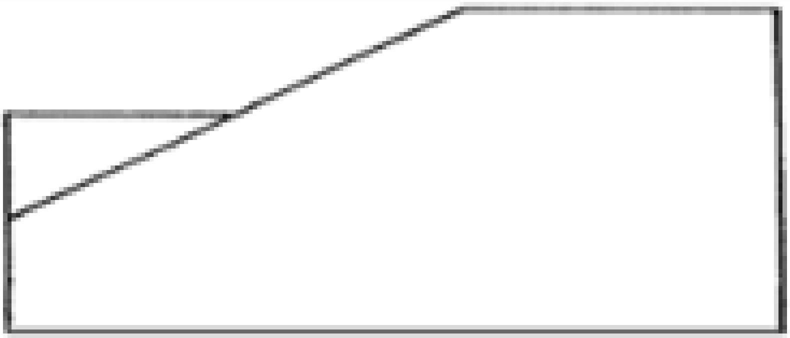
12. 'A', 'B' view will be represented by which figure?

a) 

b) 

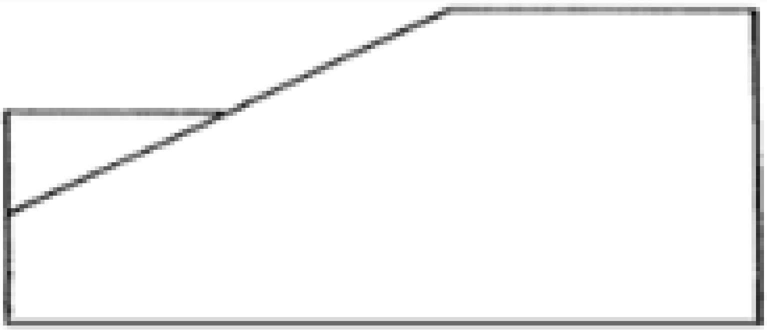


c)

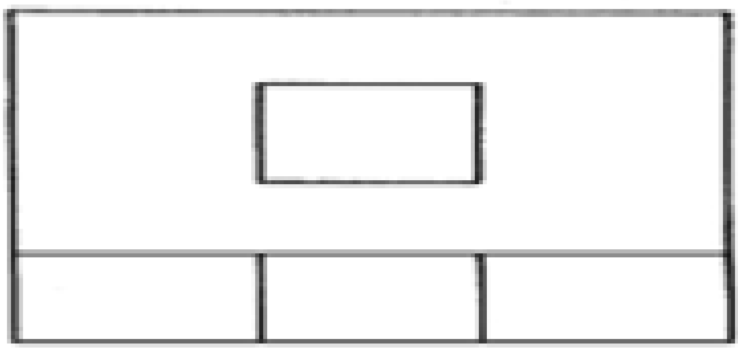


d)

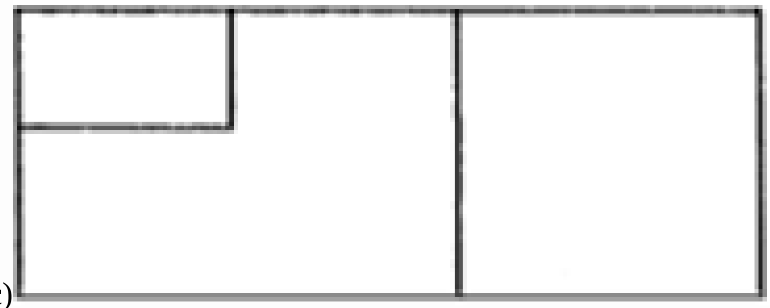
13. 'F', 'E' view will be represented by which figure

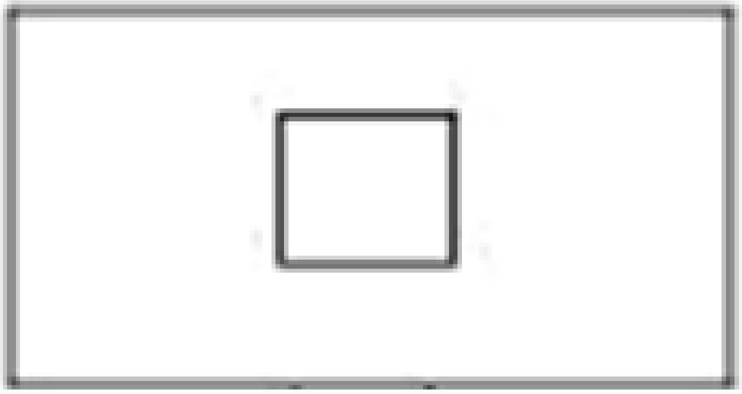


a)



b)

c) 

d) 

14. Any object can be viewed from__________ mutually perpendicular views.

a) Two

b) Four

c) Three

d) Six

2.3.2.4 Tools, Equipment, Supplies and Materials for the specific learning outcome

- Drawing room
- Computer lab
- Drawing equipment and materials
- CAD packages
- Projector
- Computer

2.3.4.5 References

Heather, S and Shrock, C.R (2019) Begging AUTOCAD Exercise Workbook. Industrial Press, Inc USA

Davies, B. L., Robotham, A. J., & Yarwood, A. (1991). Computer-aided drawing and design. London: Chapman & Hall.

Hubka, V. (2015). Principles of engineering design. Elsevier.

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Morling, K 92012) Geomtric and Engineering Drawing. Routledge, amozon

5.3.6. Learning Outcome No. 5: Apply CAD packages in drawing

5.3.6.1 Learning Activities

Learning Outcome #5: Apply CAD packages in drawing	
Learning Activities	Special Instructions
• Draw a drawing the views of the various figures using CAD application and save on the desktop. • Draw a variety of figures using CAD applications • Draw 2 dimensional objects of the given views. • Draw 2 dimensional objects of the given views.	Make sure your computers have CAD packages. understand

5.3.6.2 Information Sheet #5: Apply CAD packages in drawing

Introduction

This outcome covers use of CAD applications to draw pictorial and orthographic drawings and sectioning, symbols and abbreviations, drawing of isometric, oblique, axonometric, auxiliary and perspective views, drawing of first and third angle projections, sectioning of components.

Definition of key terms

- 2D and 3Ddrafting technique
- Computer aided design

Content

Solid geometry: application of CAD technology in orthographic drawings, oblique projections, pictorial projections, axonometric, auxiliary and perspective views, drawing of first and third angle projections, and sectioning of components.

Illustrations on dimensioning

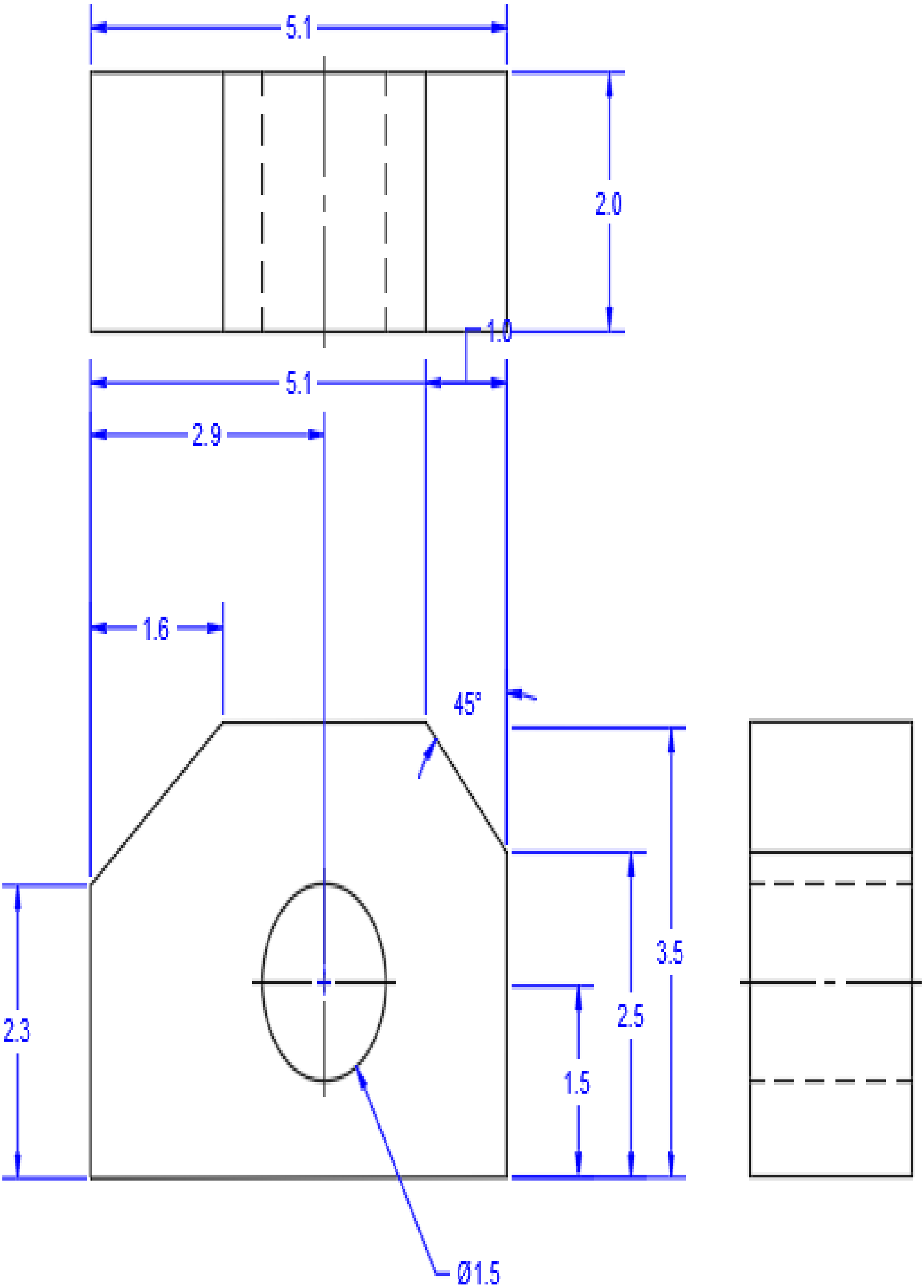


Figure 57: Dimensioning

Conclusion

This outcome covered application of CAD in orthographic views, pictorial drawing, oblique drawings, sectioning, and axonometric, auxiliary first, and third angle projections.

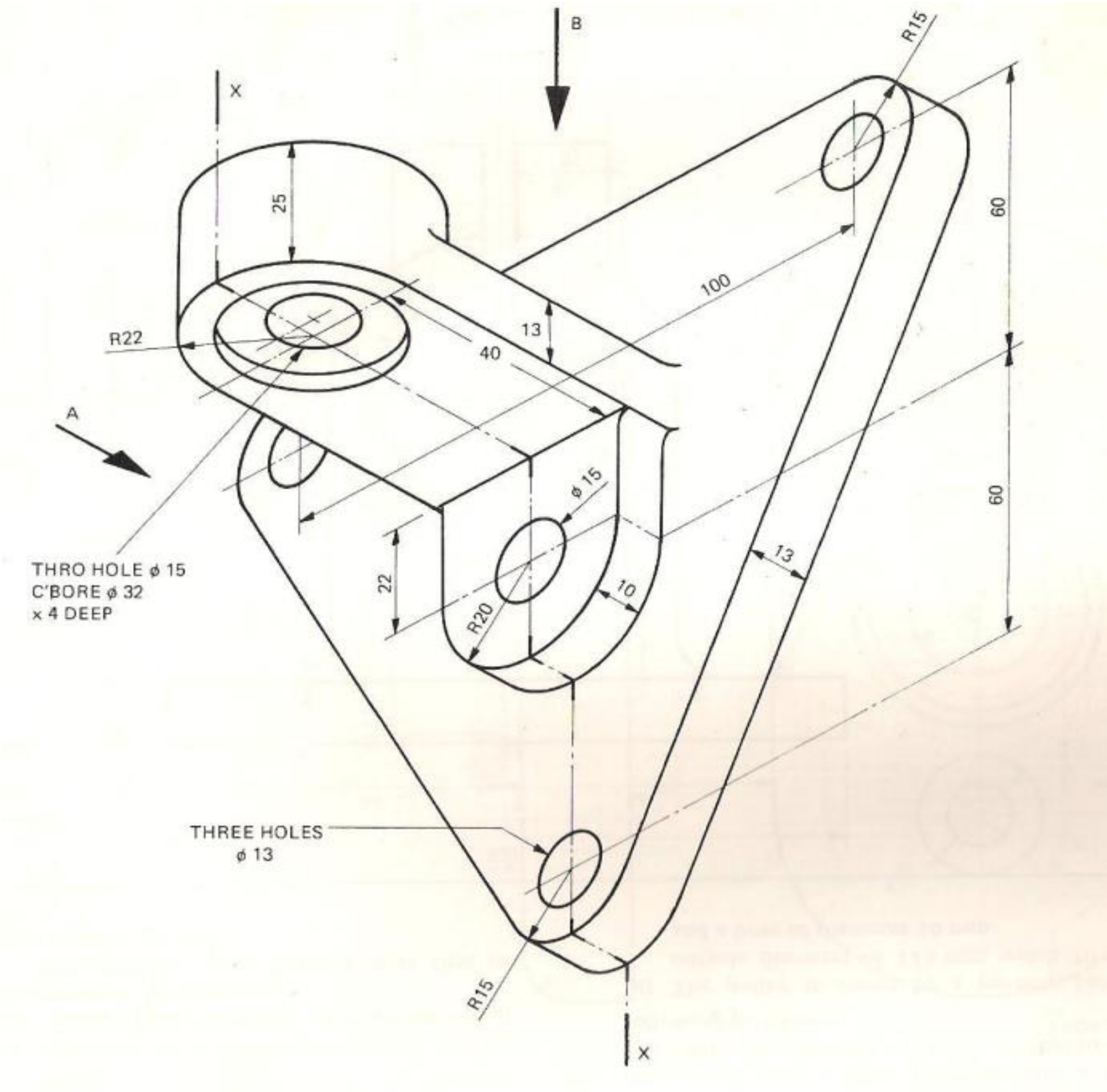
Trainees' assignment;

i. Use CAD application to draw the following views of the figure below in first angle projection.

a) Front elevation looking from the direction arrow A

b) End elevation looking from the direction arrow B

c) A plan



Trainer

Check that the completed assignments show evidence of understating a variety of solid geometries, use of CAD technology, safe use of computers and housekeeping procedures. Ensure assignments are completed on time. Observe trainees' work from time to time.

5.3.6.3. Self-Assessment

1. The computer-aided design (CAD) hardware doesn't include.
   a) Graphic display terminals
   b) Computer
   c) Computer programmes
   d) Keyboard

2. How many types of CAD are there?
   a) 6
   b) 4
   c) 2
   d) 5

3. Modem CAD systems are based on:
   a) ICG
   b) GCI
   c) GIF
   d) IFG

4. The computer communicates with the user via:
   a) CPU
   b) CRT
   c) Graphics
   d) Display button

5. The process of designing consists of __________ identifiable steps.
   a) 8
   b) 5
   c) 4
   d) 6

6. Implementing CAD improves communications.
   a) True
   b) False

7. The functionality areas of CAD application can be grouped into __________ categories.
a) 2
b) 3
c) 4
d) 5

8. The colour on CRT screen is obtained by the combination of:
a) Red, yellow, blue
b) Red, green, blue
c) Green, black, yellow
d) Red, black, yellow

9. The input devices in CAD can be divided into:
a) 2
b) 5
c) 3
d) 4

10. An orthographic projection map is a map projection of __________
a) Sphere
b) Earth
c) Cartography
d) Top view

5.3.6.4. Tools, Equipment, Supplies and Materials for the specific learning outcome

- Drawing room
- Computer lab
- Drawing equipment and materials
- CAD packages
- Projector
- Computer

5.3.6.5. References

Davies, B. L., Robotham, A. J., & Yarwood, A. (1991). Computer-aided drawing and design. London: Chapman & Hall.

Hubka, V. (2015). Principles of engineering design. Elsevier.

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Morling, K 92012) Geomtric and Engineering Drawing. Routledge, amozon

CHAPTER 6: APPLY MECHANICAL SCIENCE PRINCIPLES

6.1 Introduction of the Unit of Learning / Unit of Competency

In this unit the competencies required by a trainee in order to apply a wide range of Mechanical science principles in their work are addressed, while adhering to occupational safety and health procedures relevant to specific workplace. The following areas have been considered: determining forces in a system, demonstrating knowledge of moments, understanding friction principles, understanding motions in engineering, describing work, energy and power, performing machine calculations, demonstrating gas principles, applying heat knowledge, applying density knowledge and applying pressure principles.

This unit is a common unit that lays foundation to acquire knowledge, skill and competence required in welding and fabrication. The resources required to implement this unit of competence includes but not limited to; access to relevant workplace or appropriately simulated environment, measuring tools and equipment and sample materials. The trainee is expected to apply mechanical science principles in their field of work.

6.2 Performance Standard

Apply a wide range of mechanical science principles as per the given work specifications while observing safety as per workplace procedures and related OSHA standards.

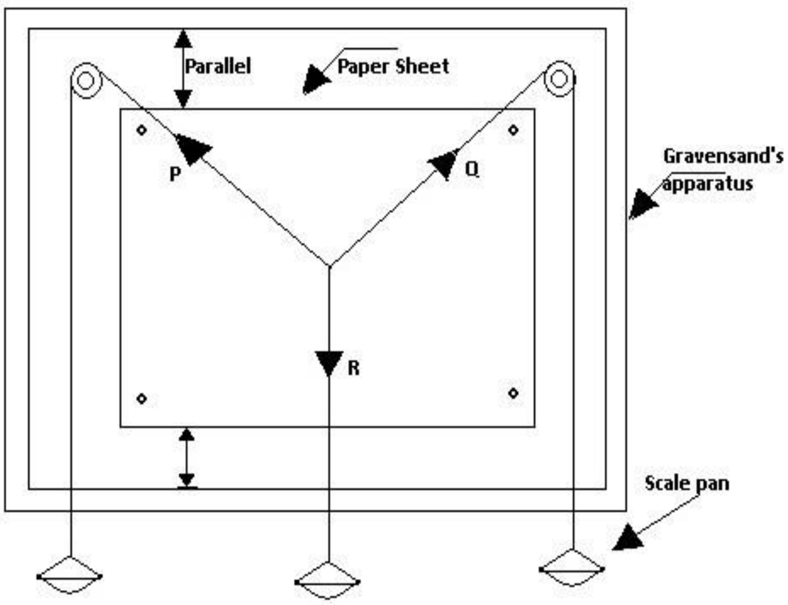
6.3 Learning Outcomes

6.3.1 List of Learning Outcomes

a. Determine forces in a system
b. Demonstrate knowledge of moments
c. Understand friction principles
d. Understand motions in engineering
e. Describe work, energy and power
f. Perform machine calculations
g. Demonstrate gas principles
h. Apply heat knowledge
i. Apply density knowledge
j. Apply pressure principles

6.3.1.1 Learning Outcome No 1: Determine forces in a system

Learning Activities

Learning Outcome No 1: Determine forces in a system	
Learning Activities	**Special Instructions**
Activity 1; The trainee to carry out an experiment to verify triangle and parallelogram law of forces with the help of Gravesands's apparatus **Apparatus required;** Gravesand's apparatus, paper sheet, weight, thread, pans, set square, pencil, drawing pin etc **Procedure:** Refer to fig. 1.1  Fig. 1.1 Fix the paper sheet with drawing pin on the board set in a vertical plane such that it should be parallel to the edge of board.	Pans/weights should not touch the vertical board There should be only one central knot on the thread which should be small

Pass one thread over the pulleys carrying a pan at its each end. Take a second thread and tie its one end at the middle of the first thread and tie a pan at its other end.

Add weights in the pan in such a manner that the small knot comes approximately in the centre.

Displace slightly the pans from their position of equilibrium and note if they come to their original position of rest. This will ensure the free movement of the pulleys.

Mark lines of forces represented by thread without disturbing the equilibrium of the system and write the magnitude of forces,

i.e. Pan Weight + Added Weight.

Remove the paper from the board and produce the line to meet at O.

Use Bow's notation to name the force P, Q, R as AB, BC, and CA.

Select a suitable scale and draw the line *ab* parallel to force P and cut it equal to the magnitude of P. From *b* draw the line *bc* parallel to force Q and cut it equal to the magnitude of Q (Fig. 1.2).

Calculate the magnitude of *ca* i.e., R_1 which will be equal to the third force R which proves the triangle law of forces.

If R_1 differs from original magnitude of R, the percentage error is found as follows:

Percentage error = $\frac{R-R1}{R} * 100$

TRIANGLE LAW OF FORCES

Graphical Method

Fig. 1.2(b), draw *ab* parallel to force P in suitable scale with the use of set square and then from *b* draw *bc* parallel to force Q. The closing side of triangle represents the force R_1 which should be equal to force R. Note, the difference in R_1 and R shows the graphical error.

(a) Space diagram (b) Vector diagram

Analytical Method

Measure angles α, β and γ and by using Lami's theorem check the followi

$$\frac{P}{Sin\ \alpha} = \frac{Q}{Sin\ \beta} = \frac{R2}{Sin\ \gamma}$$

PARALLELOGRAM LAW OF FORCES

Graphical Method

Fig. 1.3, cut OA=P and OB=Q in suitable scale. From A draw AC' parallel to OB and BC' parallel to OA.

R_1 represents the resultant of force P and Q. As the system is in equilibrium it must be equal to R.

Note that R and R_1 are in opposite direction.

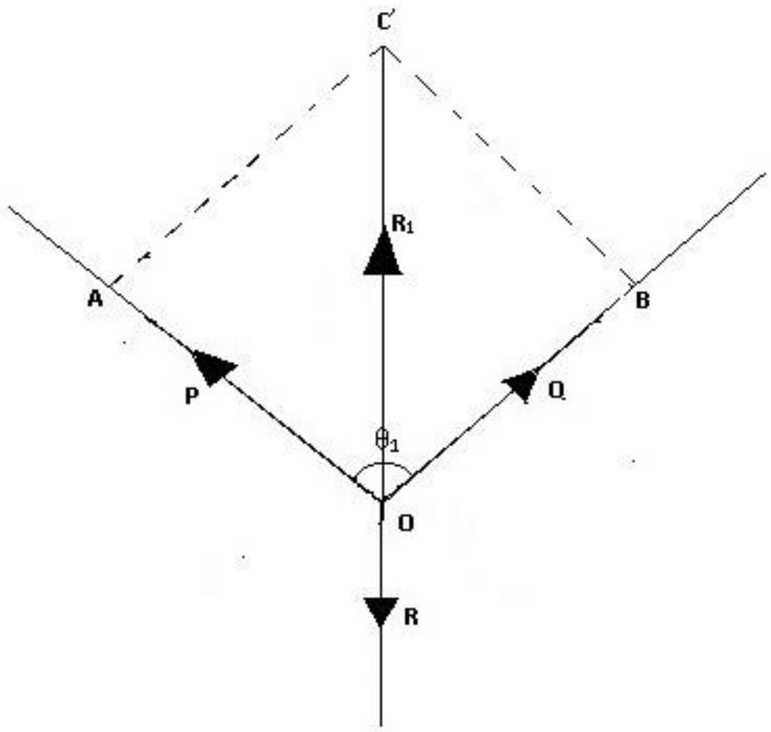


Fig. 1.3 **Analytical Method**

Measure angles θ_1 and by using resultant formula, calculate R_1

$R_2=\sqrt{(P^2+Q^2+2\ PQ\ \text{cosine}\ \theta_1)}$

OBSERVATION **Scale ……….N: …….mm**	

Information Sheet: 4.3.1.1
Introduction

By the end of this learning outcome, the trainee should be able to determine forces in an engineering system.

Definition of force

Force changes or tends to change a body's state of rest or state of uniform motion in a straight line.

A force has the following characteristics;

Magnitude

Direction (line of action and sense)

Point of application

Force is a *vector quantity* since it possesses both magnitude and direction. It can be represented by a straight line drawn to scale from the point of application along the line of action of the force. An arrowhead is used to indicate the direction of the force.

Forces acting at a point

Terms frequently used in forces acting at a point;

Equilibrium

When two or more forces act at a point and are so arranged to balance each other, the forces are said to be in equilibrium.

Resultant

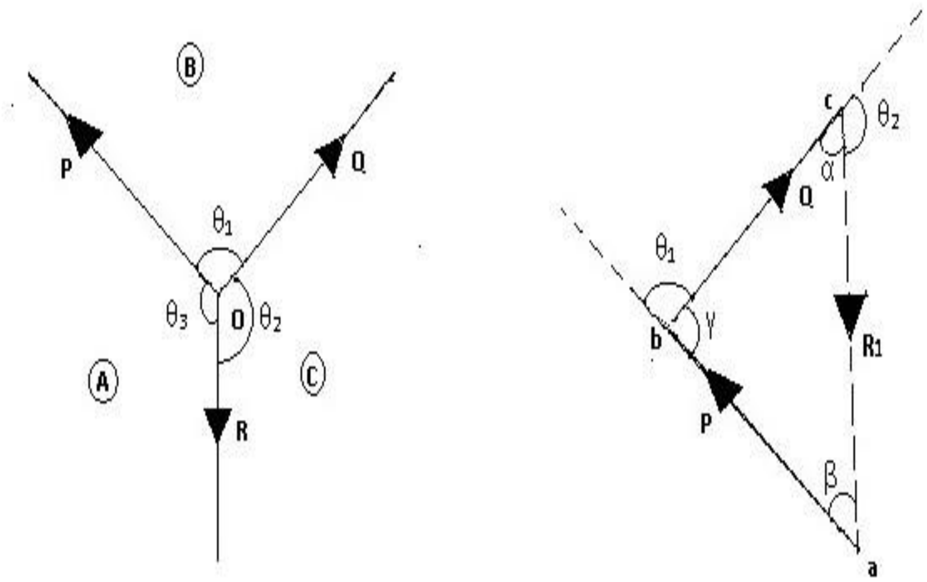
The resultant of a number of forces acting at a point is that single force which would have the same effect if it replaced those forces.

Equilibrant

The equilibrant is a single force which, if added to a system of forces acting at a point, would produce equilibrium. The equilibrant neutralizes the other forces. The equilibrant is equal in magnitude and direction, but opposite in sense to the resultant.

Coplanar forces
These are forces which are all acting in the same plane.

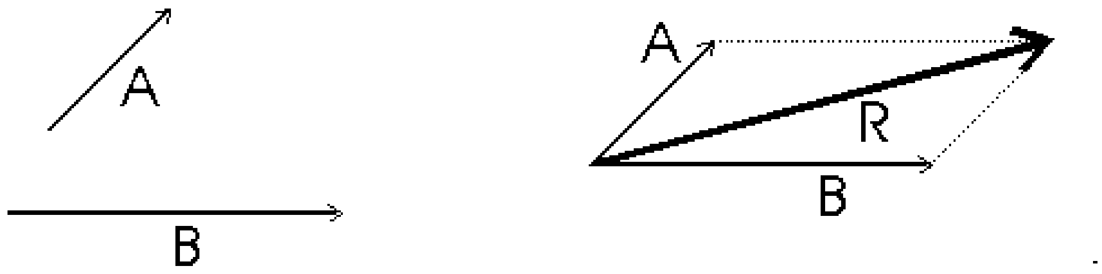
Concurrent forces
These are forces whose lines of action meet at the same point.



Forces Theorems

Parallelogram of forces
If two forces acting at a point are represented in magnitude and direction by the adjacent sides of a parallelogram, then their resultant will be represented in both magnitude and direction by the diagonal of the parallelogram drawn from that point. This is known as the *parallelogram of forces rule,*
which is a graphical means of determining the resultant of two forces acting at a point.

The method is illustrated by the following figure.



Example 1. *The forces on a cutting tool are 2600 N vertically downward and 2100 N horizontally. Determine the resultant force acting on the tool and the angle at which it acts*.

Solution:

Choose a suitable scale and draw the vectors representing the forces acting at a point. Complete the parallelogram.

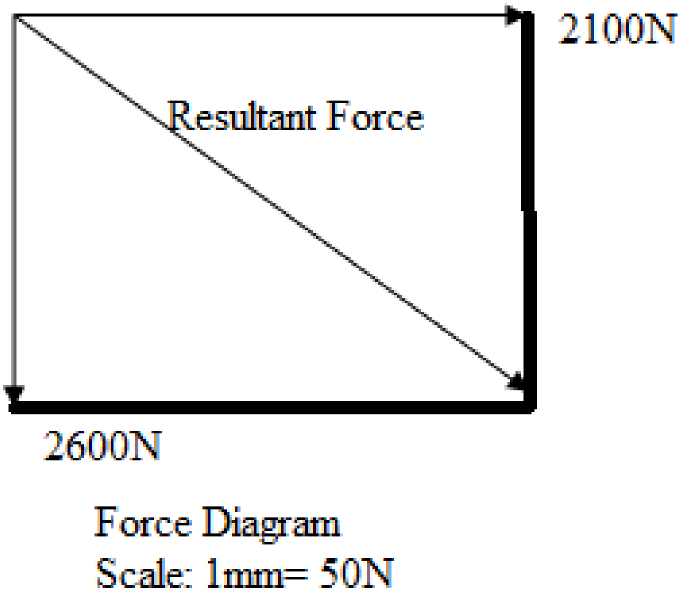


Figure 60: Parallelogram diagram

Resultant: Draw the diagonal through the point and measure it.
Resultant = 3340 N
Measure the angle of inclination to the horizontal with a protractor.
Angle at which resultant acts = 51° 5' to horizontal.

Triangle of forces

If three coplanar forces acting at a point are in equilibrium, they can be represented in magnitude and direction by the sides of a triangle taken in order. This is known as the *triangle of forces rule*.

The words ‘taken in order’ mean that the direction of the forces follow each other round each side of the triangle in either a clockwise or an anticlockwise order.

Suppose three forces, *F*, *F2* and F3, acting at a point O, are in equilibrium and suppose the lines of action of these three forces to be as shown in the *space diagram*, Fig. (a) below.

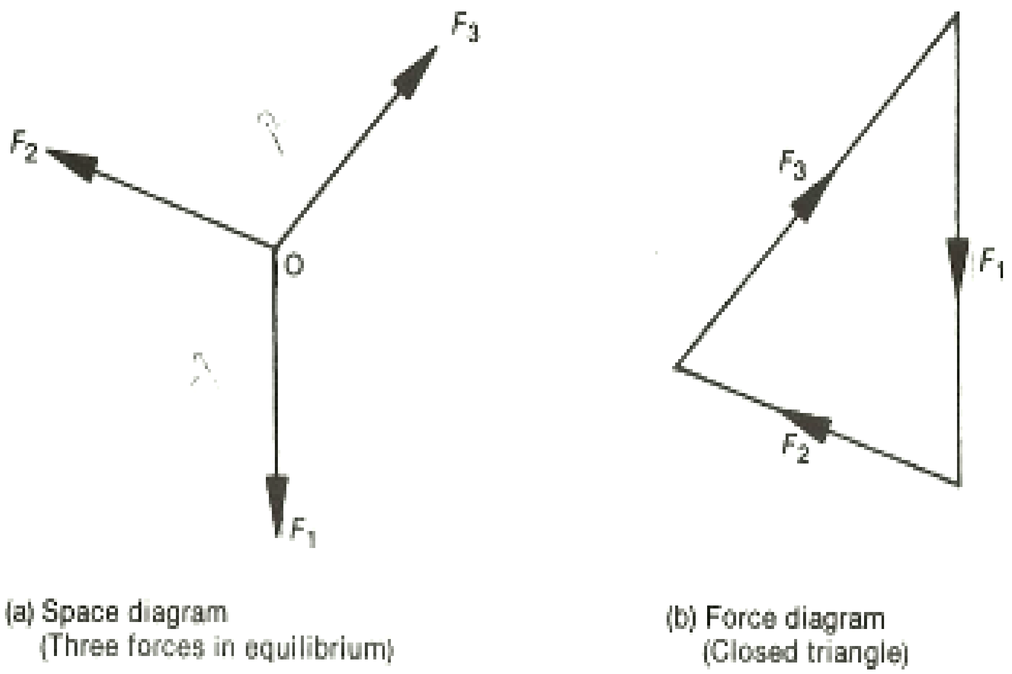


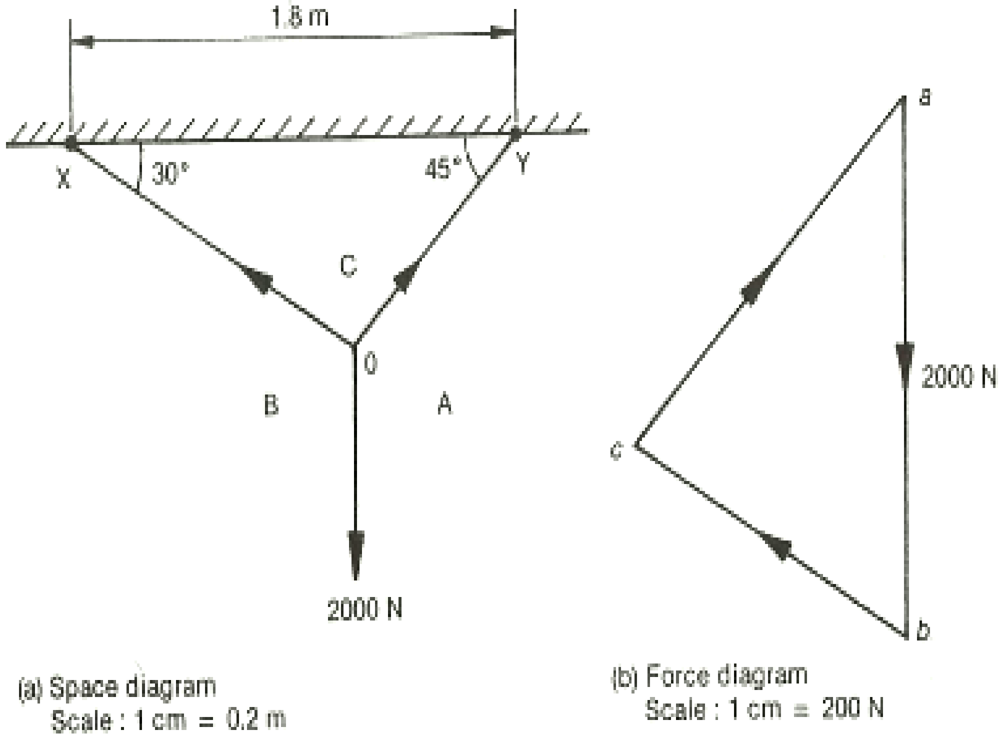
Figure 61: Space Diagram Source: Zammit (1987)

The corresponding *force (vector) diagram* is shown, in Fig. (b) Which must be drawn accurately to a suitable scale so that the sides of the triangle represent the magnitude and direction of the three forces.
The sense of direction of each force is indicated by the arrowhead placed on the respective vector.

In the example above, notice that the force diagram has been drawn by taking the forces in a clockwise cyclic order around the point O.

Example 2; *An electric motor having a weight of 2000 N is suspended by two ropes, OX and OY, attached to a horizontal beam at X and Y, 1.8 m apart. If the ropes OX and OY make angles of 30° and 45° respectively with the beam, find graphically the tension in each rope when the system is in equilibrium.*

Solution;



Source: Zammit (1987)

The space diagram showing the load and the directions of the unknown forces (tensions) in the ropes is drawn to a suitable scale e.g. 1 cm = 0.2 m, and the spaces between the forces around the junction O are lettered in accordance with Bow's notation.

The force diagram, is drawn to a suitable scale e.g. 1 cm = 200 N and is constructed as follows:
Draw vector *ab* vertically and 10 cm long to represent the magnitude and direction of the force AB of 2000 N exerted by the load. Since the system is in equilibrium, the vector triangle of forces must close.

Hence, from *b* draw a line parallel to the line of action of force BC, and from *a* draw another line parallel to the line of action of force CA so that the two lines meet at c. Insert arrowheads *in order* round the triangle, as shown.

The magnitude of the forces BC and CA (i.e. the tensions in the ropes OX and OY) can be found by measuring the sides *be* and *caf* respectively, of the vector triangle of forces and multiplying by the scale factor.

By measurement, *be* = 7.3 cm and *ea* = 9.0 cm. Thus:
Tension in rope OX = 7.3 x 200 = 1460 N
Tension in rope OY = 9.0 x 200 = 1800 N

Bow's notation

Bow's notation is a system that ensures that the forces are taken in order.

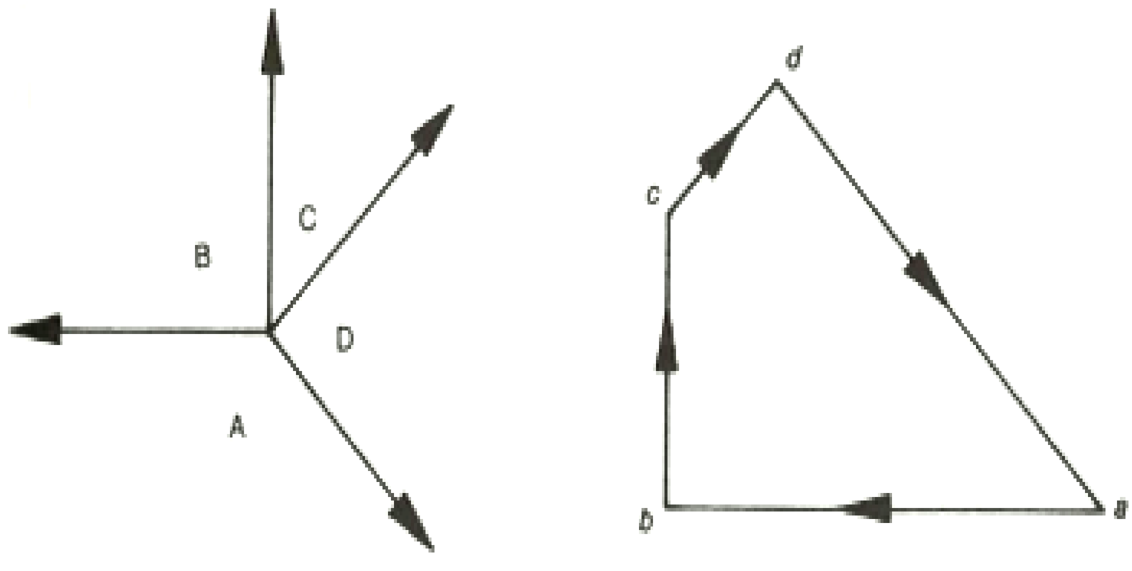
The spaces between the forces in the space diagram are lettered with capital letters. A force is then identified by the spaces to it, lower-case letters being used.

When the force diagram is drawn, the forces are drawn in order, going around the point through which they act in a clockwise or an anticlockwise direction.

As each vector is drawn it is lettered so that the order of the letters will give the direction in which the force acts on the body.

Polygon of forces

The *polygon of forces rule* is an extension of the triangle of forces rule. It states that, if four or more coplanar forces acting at a point are in equilibrium, they can be represented in magnitude and direction by the sides of a polygon taken in order.

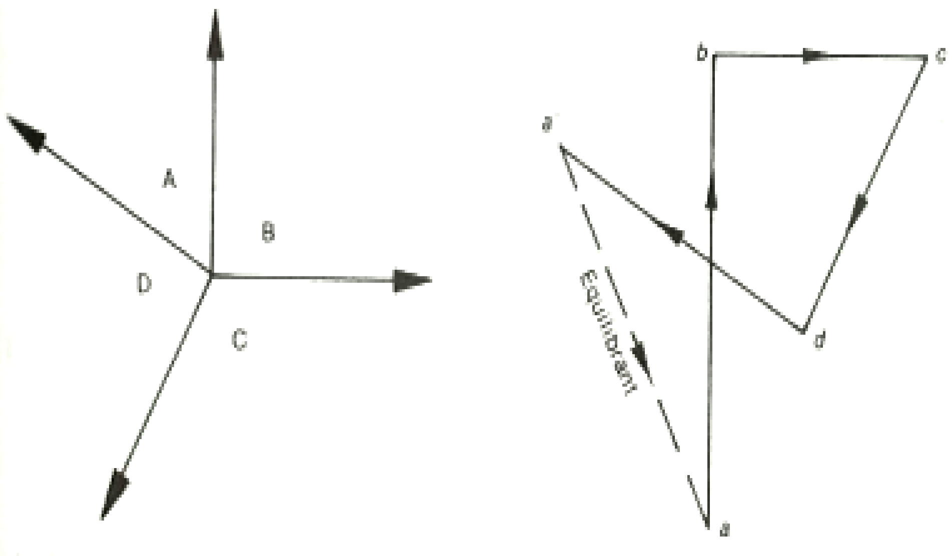


(a) Space diagram
(Four coplanar forces acting at a point in equilibrium)

(b) Force diagram
(Closed polygon)

Source: Zammit (1987)

If a system of several coplanar forces meets at a point and that system is not in equilibrium, then the polygon does not close and the force required to produce equilibrium in the system is represented by the vector which joins the open ends of the incomplete polygon.



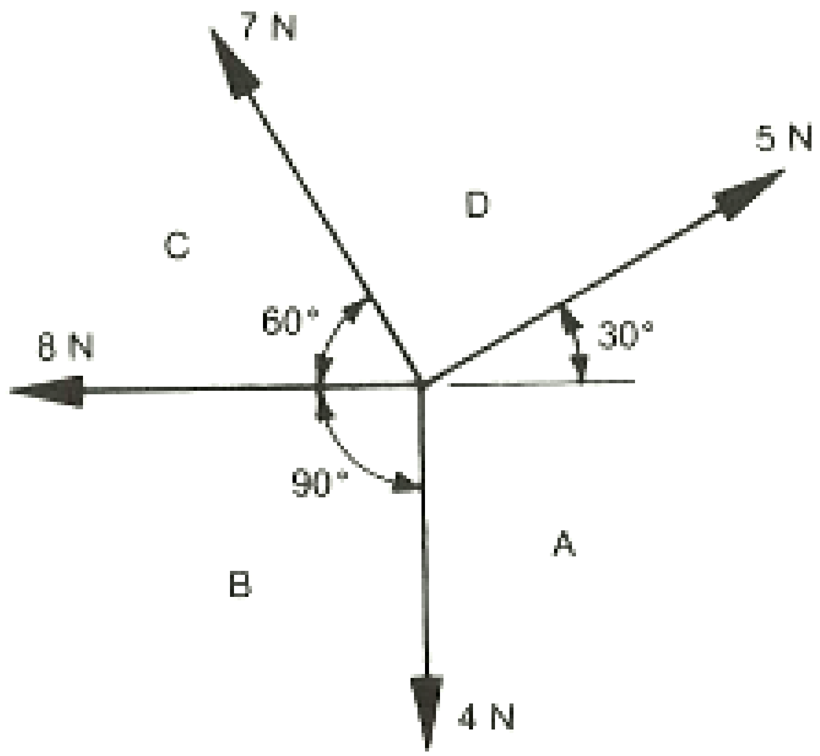
(a) Space diagram

(b) Force diagram

Source Zammit (1987)

In the figure above, the equilibrant is represented by the vector *a'a* (dotted), its direction being taken from *a* ' to a. Notice that the resultant of the force system is represented by the same vector, but its direction
is from *a* to *a'*.

Example 3; *Four coplanar forces act at a point as shown in below. Determine their resultant in magnitude and direction.*



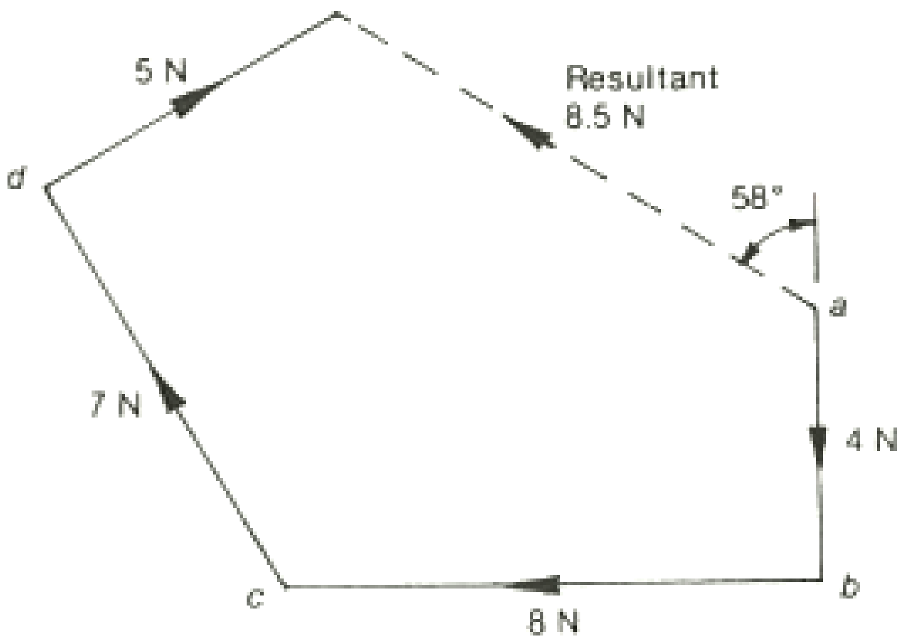
Solution;

Using Bow's notation, put capital letters in the spaces between the forces in the space diagram, as shown in figure above.

Taking a suitable scale, say 1 cm represent 1 N, draw the force diagram, as shown if figure below.

Start by drawing vector *ab 4* cm long, parallel to and in the same direction as force AB in the space diagram. Continue by drawing, in the same order, vectors *be* (8 cm long), *cd* (7 cm long) and *da'* (5 cm long) parallel to forces BC, CD and DA respectively, as shown. Join *aa'*.

Then the vector *aa*' , taken in the sense from *a to a'* , represents the resultant force. By measurement, this is found to be 8.5 N acting in the direction 58° to the vertical, as shown in the force diagram, figure below.



(b) Force diagram
Scale : 1 cm = 1 N

Source: Zammit (1987)

Self-Assessment

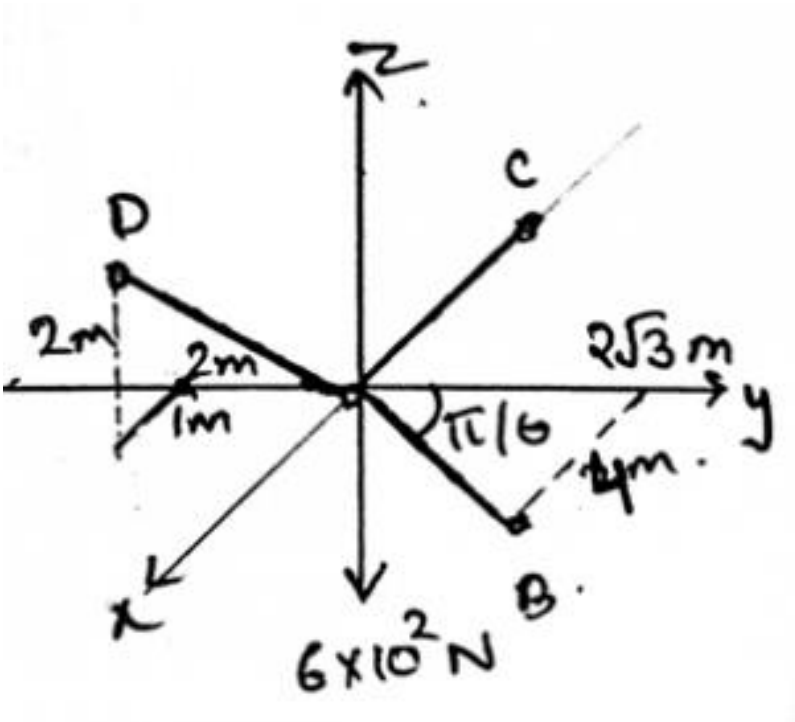
1. Which one of the following is not the condition for the equilibrium in three dimensional system of axis.
   a) ∑Fx=0 b) ∑Fy=0 c) ∑Fz=0 d) ∑F≠0

2 We first make equilibrium equations and then the free body diagram and then solve the question.
   a) True b) False

3. In the diagram given below, coordinates of D is (1, -2, 2), C (-2, 0, 0) and B are

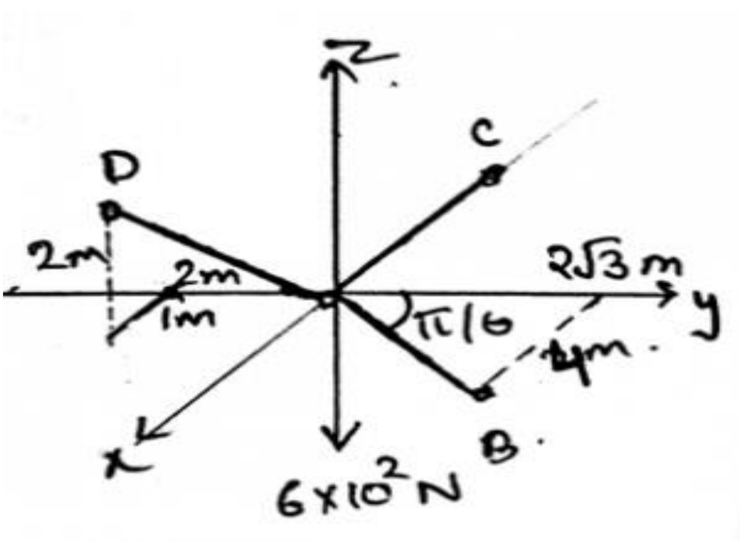
as shown. The dark region is the cables holding the weight of 600N at the origin.

Find the tension in the AD section.



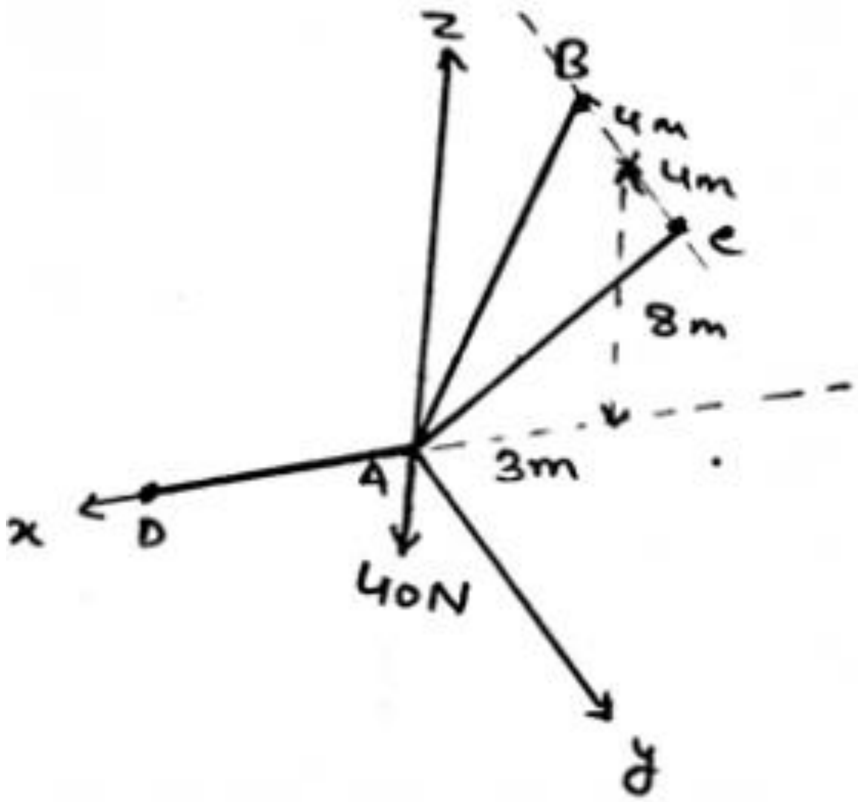
900 N b) 693 N c) 646 N d) 0 N

4 In the diagram given below, coordinates of D is (1, -2, 2), C (-2, 0, 0) and B are as shown. The dark region is the cables holding the weight of 600N at origin. Find the tension in the AB section.



900N b) 693N c) 646 N d) 0N

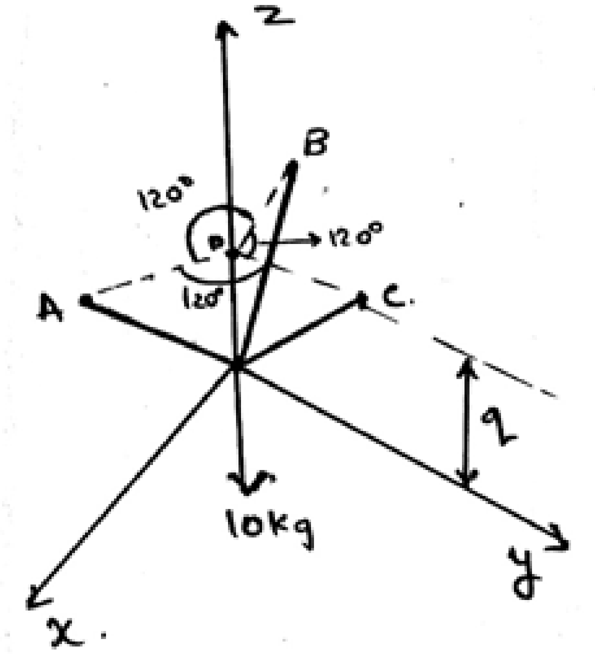
5 Find the tension in the cable AC.



23.6N b) 55 N c) 89 N d) 29 N

6. Determine the value of the q, parallel to the z-axis. That is the point of intersection of the projections of the points A, B and C parallel to the xy plane. With the distance between the tri-section point and the points A, B and C be equal to 0.6m.

51.9 cm b) 51.9 mm c) 51.9 m d) 5.19 mm



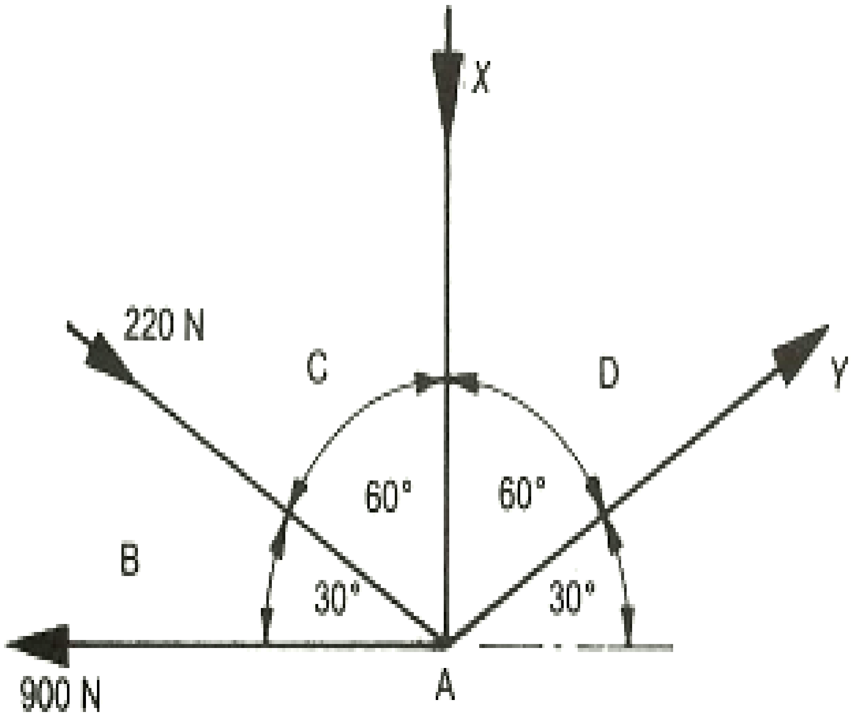
7 $\sum Fx=0$, $\sum Fy=0$ and $\sum Fz=0$ are vector equations.

a) True
b) False

8 When the body is in equilibrium then which of the following is true?
a) We equate all the components of the forces acting on the body equal to their resultant vector's magnitude
b) We equate all the components of the forces acting on the body equal to their resultant vector's magnitude square
c) We equate all the components of the forces acting on the body equal to their resultant vector's magnitude square root
d) We equate all the components of the forces acting on the body equal to zero

1. Define and describe Forces in a system
2. Describe Forces theorems
3. Determine Resultant of coplanar forces.

4. Two forces of 300 N and 500 N act at a point O and are inclined at 60° to each other. Determine, graphically, the magnitude and direction of the resultant force.
5. An electric motor having a weight of 2500 N is suspended by two ropes attached to its lifting eyebolt. The ropes make angles of 30° and 25° with the horizontal respectively. Find the tension in each rope.
6. Four members of a frame structure meet at a joint, as shown in the figure below. If the joint is in equilibrium, determine graphically the magnitude of the forces X and Y in the members shown.



Tools, Equipment, Supplies and Materials for the specific learning outcome

- Forces diagram chats and figures
- Scientific Calculators
- Relevant reference materials
- Stationeries
- Mechanical workshop
- Relevant practical materials
- Dice
- Computers with internet connection

References (APA)

Hurlow J W & Lake J (1969), Examples in engineering science for mechanical engineering technicians, Bell and Bain Ltd, Glasgow

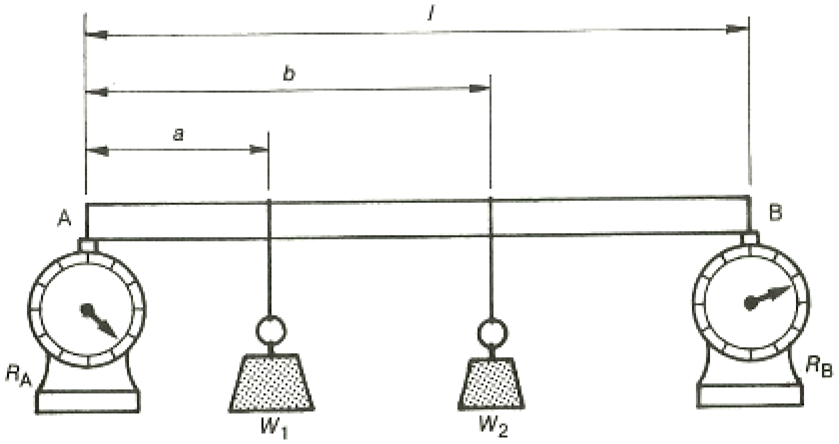
Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Bigelow, J. 1829. *Elements of Technology*. Boston: Boston Press,

Calvert, M. A. (1967). *The Mechanical Engineer in America, 1830-1910.* Baltimore, MD: John Hopkins Press.

6.3.1.2 Learning Outcome No 2: Demonstrate knowledge of moments

Learning Activities

Learning Outcome No 2; Demonstrate knowledge of moments	
Learning Activities	**Special Instructions**
The trainee to calculate values of the reaction at the support of a loaded beam and then conduct an experiment to compare the values. Using the following apparatus, standard weights, a metre rule, and a wooden beam of uniform section supported horizontally at its ends on two 'clock-type' spring balances, determine experimentally the reactions at the supports of the loaded beam.  The experiment can be repeated using three or more weights. In each case check that; (i) the sum of the spring balance readings is equal to the sum of the loads (ii) the sum of the clockwise moments about a support is equal to the	provide dimensions for the loaded beam and appropriate weights **Procedure** Before placing any loads on the beam, adjust the spring balances so that they both read zero. This will eliminate the weight of the beam.

sum of the anticlockwise moments about that support.	

Information Sheet
Introduction

By the end of this learning outcome, the trainee should be able to define and calculate moments, describe principles of moments and apply couples in engineering systems.

A *beam* is any structural member which is subjected to external forces along its length. Usually the beam is horizontal and the external forces vertical; these forces will consist of the *loads* applied to the beam and the *reactions* at the supports.

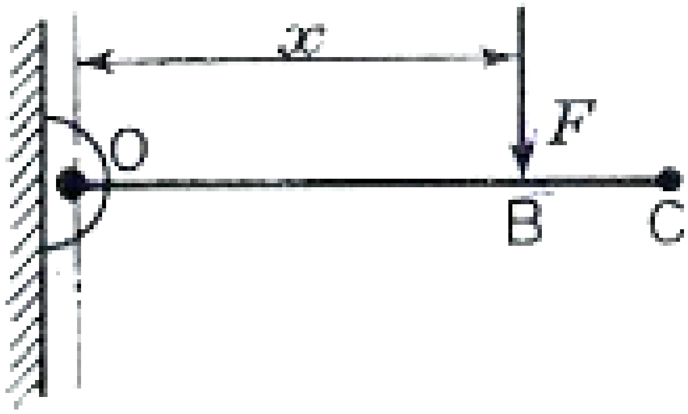
In general, the loads applied to a beam are the forces exerted by gravity on masses supported by the beam, and hence will act downwards.

A *uniform beam* is one which has the same density of material and the same cross-sectional area throughout its length. The weight of a uniform beam is considered to act through its centre. The weight of a beam is usually small compared with the loads it carries, and should therefore be neglected unless a definite value for it is given.

The moment of a force; is the turning effect of the force about a fixed point or *fulcrum* and is measured as the product.

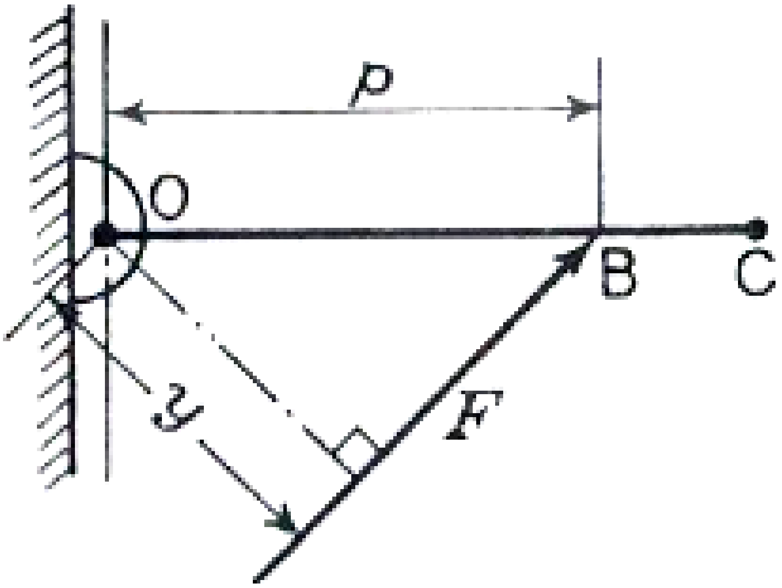
Moment of force = force x perpendicular distance from point to line of action of force

The direction of this turning effect should be specified, i.e. clockwise or anticlockwise.



In figure above the moment of force *F* applied at B about O is

F x **x** in a clockwise direction



In the figure above the moment of force F applied at B about O is

F x *y* in an anticlockwise direction

N.B. The moment is not F x *p*.

Units for moment of a force

SI units: Nm.

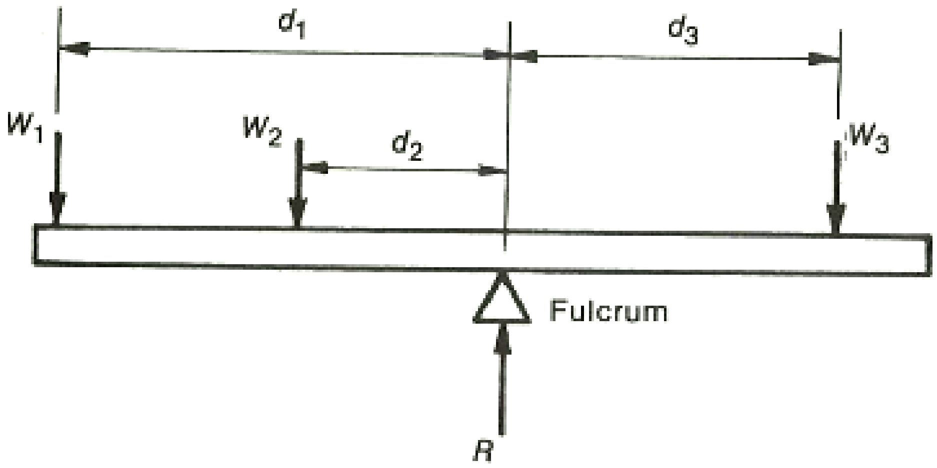
The principle of moments

If a body is in equilibrium,

Then the sum of the clockwise moments acting on it about any point is equal to the sum of the anticlockwise moments about that point.

The resultant of all the forces on it is zero.

These two conditions of equilibrium are separate and both must be fulfilled if equilibrium exists.



Consider a uniform beam to be pivoted at its centre on a fulcrum.

Suppose the beam is carrying point loads of W_1, W_2 and W_3 at distances d_1, d_2 and d_3 respectively from the fulcrum, as shown in figure above.

Now, for the resultant force on the beam to be zero, the upward force provided by the reaction R at the fulcrum must equal the downward forces, i.e.

R = W_1, +W_2 + W_3

For the algebraic sum of the moments of the forces to be zero, the total anticlockwise moment produced by W_1, andW_2 about the fulcrum must equal the total clockwise moment produced by W_3 about the fulcrum.

Thus, for equilibrium to be maintained,

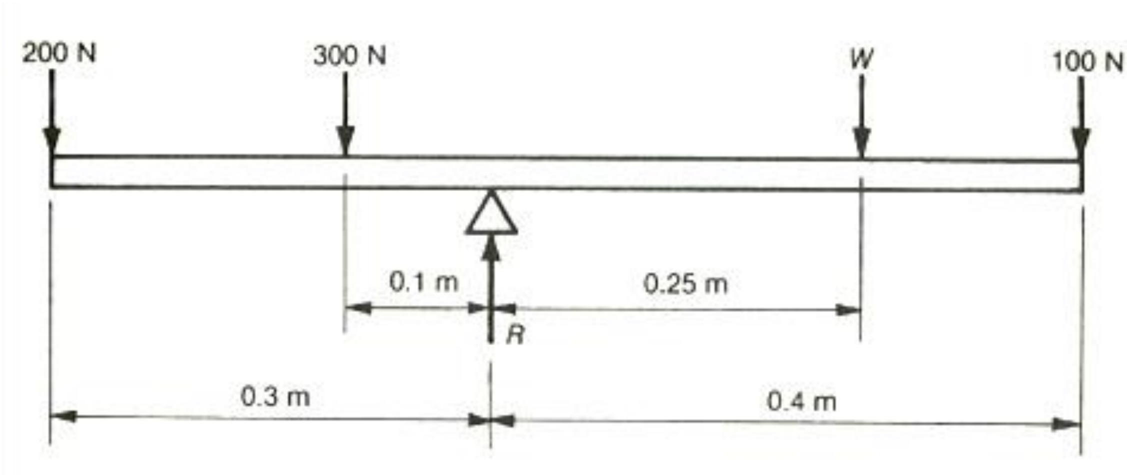
$W_1d_1 + W_2d_2 = W_3d_3$

Example 1; *A uniform horizontal lever is supported on a fulcrum and loaded as shown in the figure below. Calculate:*

(a) the magnitude of the load W required to maintain equilibrium

(b) the magnitude of the reaction R at the support.

Neglect the mass of the lever.



Solution

(a) Taking moments about the support, and working throughout in units of N and m,

Total anticlockwise moment = (200 x 0.3) + (300 x 0.1)
= 60 + 30 = 90 Nm

Total clockwise moment = (W x 0.25) + (100 x 0.4)
= (0.25 W + 40) Nm

For the lever to remain horizontal, the total anticlockwise moment about the support must equal the total clockwise moment about the support. Thus:

$$90 = 0.25W + 40$$

or $0.25\,W = 90 - 40$

and $W = 50/0.25 = 200\text{N}$

(b) At equilibrium, the resultant vertical force must be zero. Hence,

the reaction at the support (acting upwards) must be equal to the sum of the loads (acting downwards), i.e.

R = 200 + 300 + 200 + 100 = 800 N

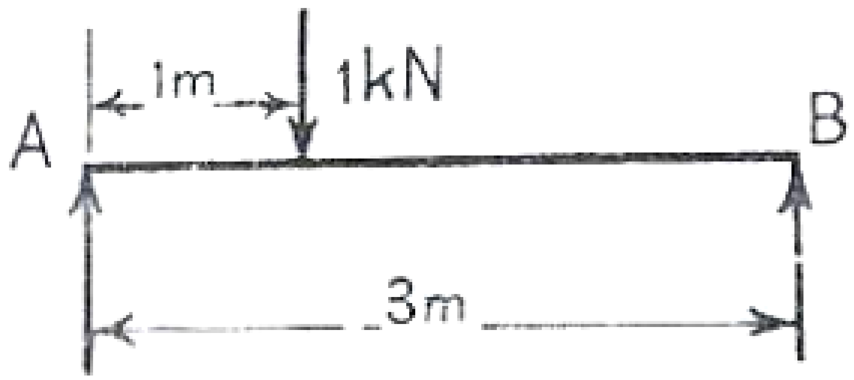
Answer: (*a*) Magnitude of load W = 200 N
(*b*) Reaction at the support = 800 N

Simply supported beams

A *simply supported beam* is one which rest on two knife-edge or roller supports and is free to move horizontally. For a simply supported beam to be in equilibrium, both the conditions in the principle of moments must be satisfied. The resultant force acting on the beam must be zero, and the algebraic sum of the moments about either of the supports must also be zero. These two facts enable the value of the reactions at the supports to be determined when the loading of the beam is known.

Example 2; *A 3m girder rests on two supports, one at each end. A weight of 1 kN is placed 1 m from one end. Calculate the reactions at the supports, neglecting the weight of the girder.*

Solution



The figure above shows the arrangement. Using the principle of moments, moments may be taken about any point along the beam.

Usually the best point about which to take moments is one through which an unknown force acts, as the moment for the unknown force about this point will then be zero.

Taking moments about A,

sum of clockwise moments = sum of anticlockwise moments

1000 N x 1m $= R_B$ x 3m

$$\frac{1000\text{ N x 1m}}{3\text{m}} = R_B$$

∴ Reaction at B = R_B = 333 N

To find R_A take moments about B;

clockwise moments = anticlockwise moments

R_A x 3m = 1000 N x 2m

$$R_A = \frac{1000\ \text{N x 2m}}{3\text{m}}$$

∴ Reaction at A = R_A = 667 N

A check may be made, since the forces are in equilibrium and their resultant is zero; consequently sum of vertically upward forces = sum of vertically downward forces

Upward forces:

$R_A + R_B$ = 667 N + 333 N = 1000 N

Downward forces:

applied load = 1000 N

Hence answers are correct.

Further reading and the experimental determination of beam reaction can be found on

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London, pg 136

Self-Assessment

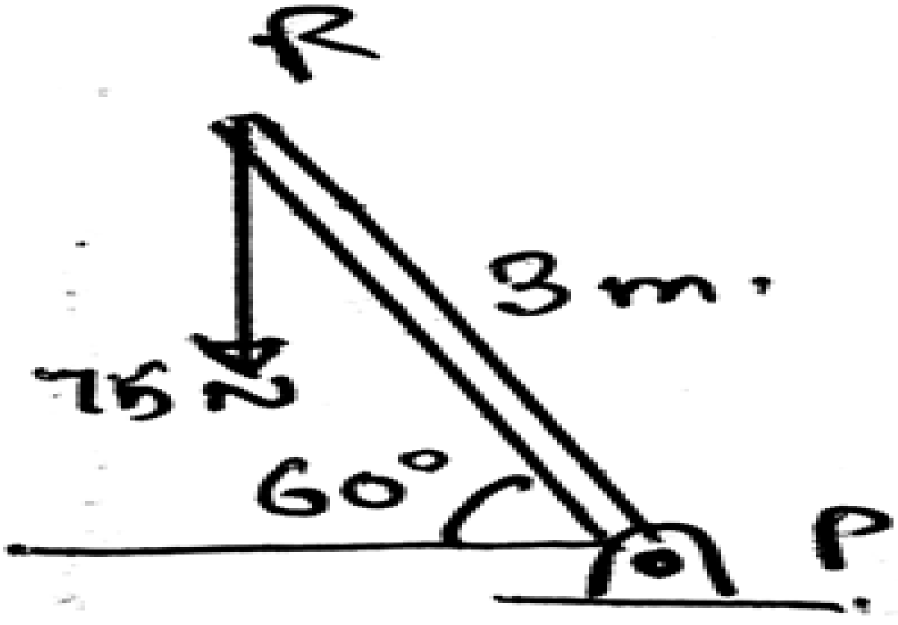
1. Determine the smallest force applied at R which creates the same moment about P as by 75N.

a. 37.5N

b. 112.5N

c. 60N

d. 0N



2. What does the moment of the force measure?
a) The tendency of rotation of the body along any axis
b) The moment of inertia of the body about any axis
c) The couple moment produced by the single force acting on the body
d) The total work is done on the body by the force

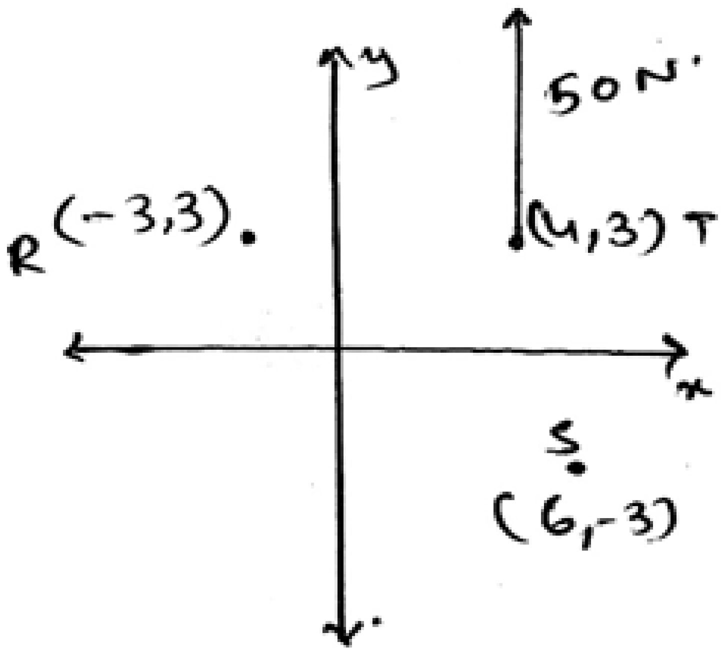
3. If a car is moving forward, what is the direction of the moment of the moment caused by the rotation of the tires?
a) It is heading inwards, i.e. the direction is towards inside of the car
b) It is heading outwards, i.e. the direction is towards outside of the car
c) It is heading forward, i.e. the direction is towards the forward direction of the motion of the car
d) It is heading backward, i.e. the direction is towards the back side of the motion of the car

4. The tendency of rotation of the body along any axis is also called ___________
a) Moment of inertia
b) Moment of couple
c) Torque
d) Force

5. The moment of the force is the product of the force and the perpendicular distance of the axis and the point of action of the force.

a) True
b) False

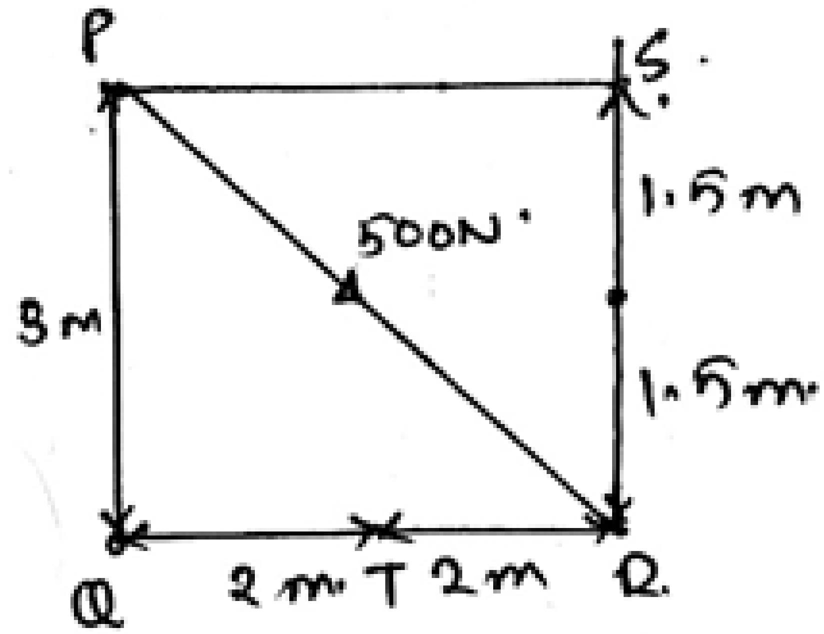
6. Determine the moment about the point T.



a) 0Nm
b) 350Nm
c) 100Nm
d) 200Nm

7. The moment axis is in the direction perpendicular to the plane of the force and the distance.
a) True
b) False

8 Find the moment along T.



a) 1200Nm
b) 600Nm
c) 0Nm
d) 1400Nm

9. If you are getting to know about the direction of the moment caused by the force applied on the body by using your wrist and curling it in the direction of the rotation then which of the following is not right?
a) The thumb represents the direction of the force
b) The thumb represents the direction of the moment
c) The fingers represent the direction of the force
d) The direction in which you curl your wrist is towards the direction of the distance from point of contact of force to the axis of rotation.

10. The moment axis, force and the perpendicular distance in the moment of the force calculation is lying in____________
a) Two planes perpendicular to each other
b) A single plane in the direction of the force
c) A single plane in the direction of the perpendicular distance
d) A single line in the direction of the force

11 State the two conditions necessary for the equilibrium of a body acted on by a number of parallel forces.

12 Describe an experiment for determining the reactions of a simply supported beam.

13 A uniform beam, 4 m long, is simply supported at two points A and B, point A being 0.5 m from the left-hand end and point B 1.5 m from the right-hand end. The beam carries loads of 600 N at the left-hand end, 800 N at its centre and 400 N at the right-hand end.

14 Determine the magnitude of the support reactions at A and B. At what point should the load of 800 N be applied to make the support reactions equal?

15 A motor vehicle has a wheelbase of 3 m. The load on the front axle is 12 kN and that on the rear axle is 16 kN. The vehicle rests on a simply supported bridge of span 7.5 m, the front axle being 1.5 m from the left-hand support. Calculate the magnitude of the reactions of the bridge supports.

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Weights/ masses
- Simply supported beams
- Scientific Calculators
- Relevant reference materials
- Stationeries
- Mechanical workshop
- Relevant practical materials

References (APA)

Hurlow J W & Lake J (1969), Examples in engineering science for mechanical engineering technicians, Bell and Bain Ltd, Glasgow

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Hurlow J W & Lake J (1969), Examples in engineering science for mechanical engineering technicians, Bell and Bain Ltd, Glasgow

Zammit S.J (200), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Bigelow, J. 1829. *Elements of Technology*. Boston: Boston Press,

Calvert, M. A. 1967. *The Mechanical Engineer in America, 1830-1910.* Baltimore, MD: John Hopkins Press.

6.3.1.3 Learning Outcome No 3: Understand friction principles

Learning Activities

Learning Outcome No 3; Understand friction principles	
Learning Activities	**Special Instructions**
Trainee to perform an experiment to measure the coefficients of static friction between several combinations of surfaces using a heavy block and a set of hanging masses in the workshop. The trainee to measure the coefficient of kinetic friction between two of the combinations of surfaces used in the static friction part of this experiment. *Equipment:* Wooden Flat Plane Large Steel Block Hanging Mass Set Pulley Alternative surfaces: Plastic/ Wood Laptop	Coefficient of surface frictions

Information Sheet: 6.3.1.3

Introduction

By the end of this learning outcome, the trainee should be able to calculate the force to overcome friction on a plane.

Force of friction

Whenever one surface moves (or attempts to move) over another, a resisting force, acting tangentially to the surfaces, is set up so as to oppose the motion. This resisting force is called the *force of friction.*

The force of friction is usually slightly greater before one surface starts to move over the other than after this movement has started. In other words, it requires a slightly greater force to overcome the friction of rest, known as *static friction,* than it does to overcome the friction of motion, known as *sliding* or *dynamic friction.*

Laws of friction for dry surfaces

The sliding frictional force opposing motion, once motion has started, is directly proportional to the normal force between the surfaces.

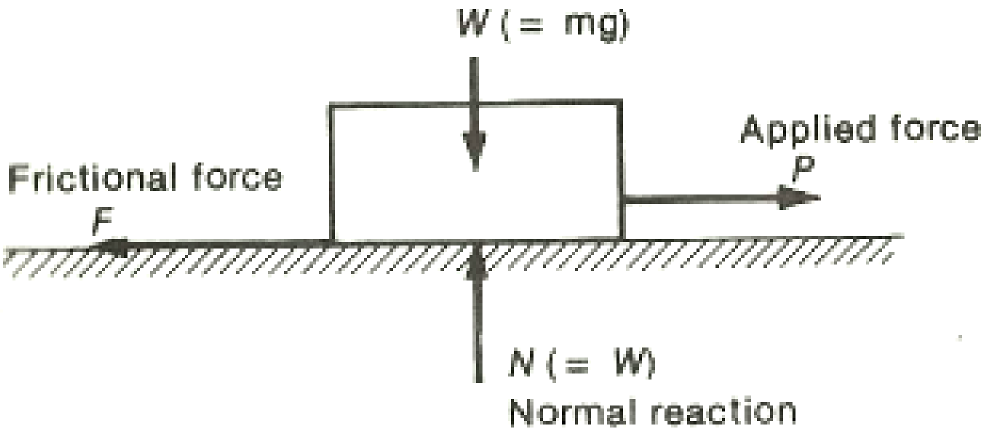
The sliding frictional force is dependent upon the nature of the surfaces in contact.

The sliding frictional force is dependent upon the physical properties of the materials involved.

The sliding frictional force is independent of the area of the surfaces in contact.

For low speeds of relative motion of the surfaces, the frictional force is independent of the speed of sliding.

Static friction



The figure above shows a body of mass *m* resting on a flat horizontal surface. The weight *W* of the body (equal to *mg)* acts vertically downwards, for equilibrium, there will be an equal and opposite reacting force *N*, acting vertically upwards. Suppose now a horizontal force *P* is applied to the body, tending it to move to the right. A frictional force *F* (equal to *P)* will be created between the surfaces to act in opposition to P, i.e. to the left. As *P* is increased in magnitude, F also increases and will reach an upper limiting value when the body is just about to move. This limiting or maximum value of F is called the *force of static friction* between the surfaces under these conditions.

Sliding or dynamic friction

Once the body has started to move, it will be found that the magnitude of the applied force *P* can be reduced slightly to keep the body moving at a steady speed along the surface. This is because sliding or dynamic friction (i.e. the friction of motion) is less than static friction (i.e. the friction of rest). This particular value of *P* is then equal to the force of sliding friction.

The coefficient of friction

By the first law of friction given in above, the sliding frictional force is directly proportional to the reaction force normal to the surfaces in contact. Thus:

$$F \propto N$$

or

$$\frac{F}{N} = \text{Constant}$$

The constant is called the *coefficient of friction* between the two surfaces concerned, and is denoted by *μ*. (the Greek letter 'mew').

$$\therefore \text{Coefficient of friction, } \mu = \frac{F}{N}$$

Since the forces *F* and *N* are expressed in the same units, *μ* is just a number and has no units of its own.

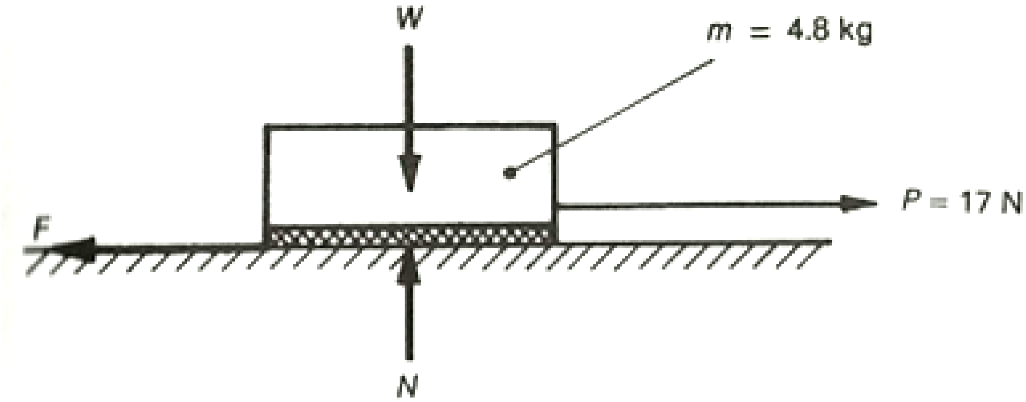
Advantages and disadvantages of friction

Advantageous application of friction include; in a motor vehicle when applied to such units as tyres, clutches and brakes, in which instances the surfaces must be dry and free from oil or grease.

However, it is disadvantageous in bearings and other moving parts, however, and systems of lubrication must be used to reduce friction to a minimum.

Example 1; *A metal block lined with a ceramic material and having a mass of 4.8 kg requires a horizontal pull of 17 N to move it at a steady speed along a horizontal steel surface. Calculate the coefficient of friction for the ceramic material on steel.*

Solution



Referring to the figure above,
Total weight of block, W = mg
= 4.8 [kg] x 9.81 [m/s^2] = 47.1 N

∴ Normal reaction N between ceramic and steel surface = 47.1 N
Since the block is moving at a steady speed, then:

Frictional force, F = Applied force, P
= 17 N

Coefficient of friction, μ = $\frac{F}{N}$

$= \frac{17 (N)}{47.1 (N)} = 0.36$

Answer: Coefficient for friction for the ceramic material on steel = 0.36.

The trainee is advised to do further reading on friction on an inclined surface.

Self-Assessment

1. The maximum value of the frictional force is called _________

a. Limiting Friction
b. Non-Limiting Friction
c. Limiting Action Friction
d. Non-Limiting Action Friction

Answer: a

Explanation: The friction is the phenomena that define that there is a resistance which is present there between the two surfaces. The two surfaces are in contact and the friction applies at that surface only, resisting the motion of the surface. Thus the maximum values are called as limiting friction.

2. When the body which is applied forces come in the stage of the limiting friction then the body is termed as to come in ___________ equilibrium.

a) Unstable
b) Stable
c) Non-stable
d) Improper Stable

Answer: a

Explanation: As the limiting friction is the maximum value of the frictional forces. Thus if more force is applied to the body then the body is going to move forward. Because the two surfaces are in contact and the friction applies at that surface only, resisting the motion of the surface. Thus the name unstable equilibrium.

3. The frictional force is directly proportional to the ____________

a) Applied load
b) Type of surface used
c) The normal force
d) The horizontal load

Answer: c

Explanation: The frictional force is directly proportional to the vertical force that is being applied normal to the surface of the body. The force of friction is not dependent on the type of the surface. Thus the only thing the frictional force does depend is the normal force.

4. The constant in the equation F = µN is called?
a) Knew
b) Proprietary Constant
c) Coefficient of dry friction
d) Coefficient of static friction

Answer: d
Explanation: The constant in the equation F = µN is known as the coefficient of static friction. This is the proportionality constant and is generally used to express the equation of the frictional force. The value of this constant is generally from 0 to infinite, depending on the surface.

4. The coefficient of static friction does depend upon the surface on which the body is being slid.
   a) True
   b) False

Answer: a
Explanation: The constant in the equation F = µN is known as the coefficient of static friction. This is the proportionality constant and is generally used to express the equation of the frictional force. The value of this constant is generally from 0 to infinite, depending on the surface.

6. The coefficient of friction is generally determined by _____________
a) Written over the Body
b) Experiments
c) Weighing the body
d) Measuring length of the body

Answer: b
Explanation: The coefficient of friction is generally determined by the help of experiments. Many experiments are done on the body. Try and error methods are involved. And the final observations are being taken out. Then the average of all the final answers resulted in the experiments is done.

7. We have two types of a coefficient of friction, one is coefficient of static friction and the other one is the coefficient of the kinetic friction.
a) True
b) False

Answer: a
Explanation: The constant in the equation F = μN is known as the coefficient of static friction. This is the proportionality constant and is generally used to express the equation of the frictional force. And in the same equation the constant is sometimes called a coefficient of kinetic friction, when the limiting value of static friction is passed over.

8. The angle of the inclination of wedge over which the block is sliding is determined by which of the following trigonometric function?
a) Tangent Inverse
b) Cosine
c) Sine
d) Secant

Answer: a
Explanation: The angle of the wedge over which the block is being slided is generally taken out by the help of the tangent inverse trigonometric function. It is the ratio of the frictional force to the normal force. This ratio is kept inside the inverse function.

9. The coefficient of kinetic friction is _____________ than coefficient of static friction.
a) Smaller
b) Larger
c) Significantly larger
d) Highly larger

Answer: a
Explanation: The coefficient of kinetic friction is smaller than the coefficient of static friction. The main thing about the kinetic one is that it is applied by the surface when the body is in motion. The static one is applied to the body when the body is static and is about to move.

10. The kinetic friction is applied when the body is ___________
a) Moving
b) Stopped
c) Just stopped
d) Just started to move

Answer: a
Explanation: The kinetic friction is applied to the body by the surface when the body is moving. This means there is friction present and the coefficient of that friction is smaller than the static one. The main observation is that this is applied when the static friction attends its maximum value.

11. The angle of the inclination of wedge over which the block is sliding and is experiencing the kinetic friction is determined by which of the following trigonometric function?
a) Tangent Inverse
b) Cosine
c) Sine
d) Secant

Answer: a
Explanation: The angle of the wedge over which the block is being slided is generally taken out by the help of the tangent inverse trigonometric function. Whether it may be the static or the kinetic friction, the ratio is the frictional force to the normal force. And this ratio is kept inside the inverse function.

12.The value of a coefficient of friction is taken at that moment when the block is at the verge of moving.
a) True
b) False

State any three laws which govern the effect of friction between dry surfaces.

A casting has a mass of 30 kg and requires a horizontal force of 70 N to drag it at constant speed along a level surface. Determine:

(a) the normal reaction between the casting and the surface

(b) The coefficient of friction.

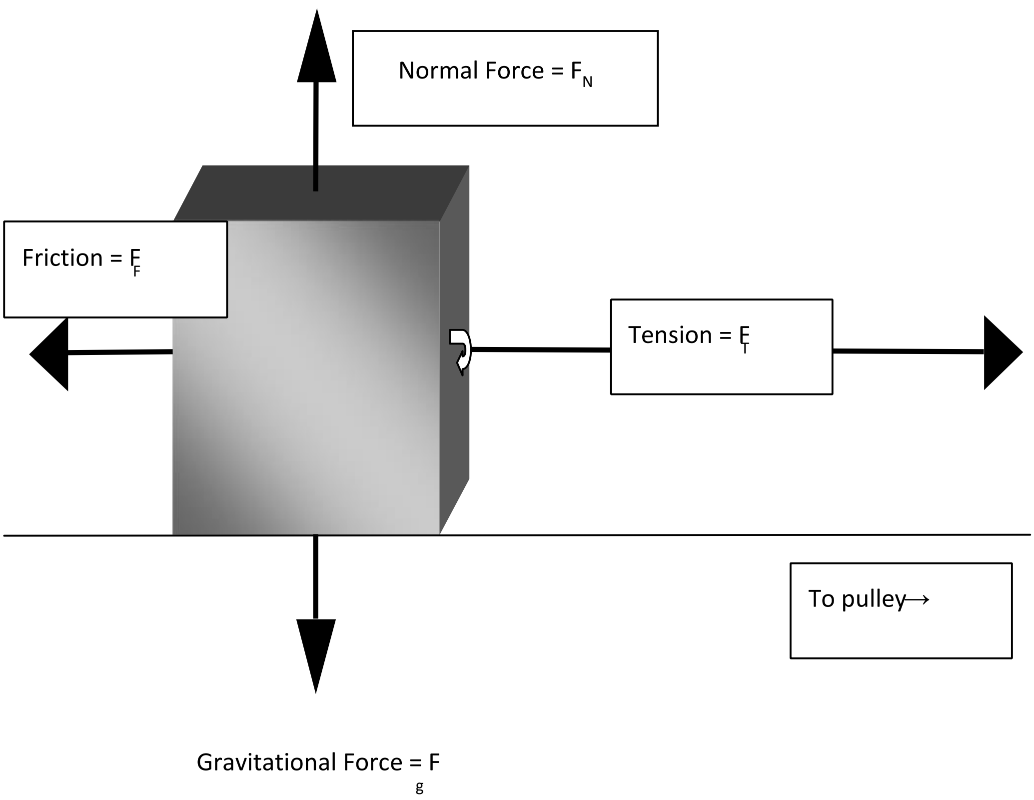
13 Determine the maximum load that may be moved across a horizontal surface by an effort of 175 N when the coefficient of friction between the materials in contact is 0.5.

Kinetic and static friction coefficient detector: Devise a means of measuring the coefficient of kinetic friction. It may be possible to modify the static coefficient experiment to accomplish this project.

The trainee to measure the coefficient of kinetic friction between two of the combinations of surfaces used in the static friction part of this experiment.

Equipment:

Wooden Flat Plane	Pulley
Large Steel Block	Alternative surfaces: Plastic/ Wood
Hanging Mass Set	laptop



Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials

- Stationeries
- Mechanical workshop
- Relevant practical materials

References (APA)

Hurlow J W & Lake J (1969), Examples in engineering science for mechanical engineering technicians, Bell and Bain Ltd, Glasgow

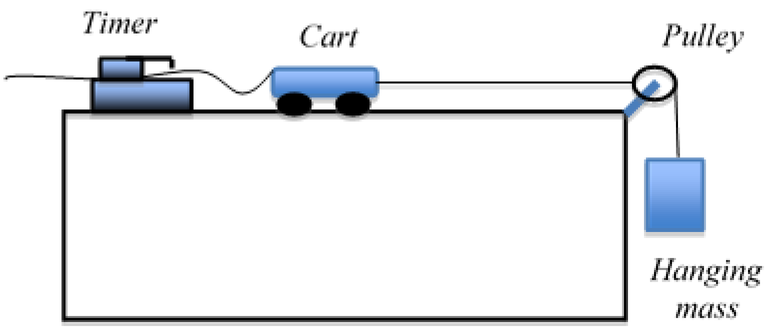
Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Bigelow, J. 1829. *Elements of Technology*. Boston: Boston Press,

Calvert, M. A. 1967. *The Mechanical Engineer in America, 1830-1910.* Baltimore, MD: John Hopkins Press.

6.3.1.4 Learning Outcome No 4: Understand motions in engineering

Learning Activities

Learning Outcome No 4; Understand motions in engineering	
Learning Activities	**Special Instructions**
Trainee to carry out a lab test analyse motion using a ticker timer and present results in motion graphs. **Set-up;** First, attach a pulley to the *Ticker-Tape Motion* edge of the lab tables. Use a string to tether together the motion cart and the hanging mass. Drape the string over the pulley as shown. This will create a system that causes the cart to move when you drop the hanging mass from a certain height above the ground. Finally, tape a long piece of "ticker-tape" to the motion cart, and allow this tape to be pulled through a "ticker-tape timer". This will allow analysis of the motion of the motion cart and give valuable data that can be used to create a motion graph. 	It is important to understand how the ticker-tape timer works, and what each dot means on your tickertape. The first important thing to remember is that each DOT on the ticker tape was made 1/60th of a second after the previous DOT.

Information Sheet: 6.3.1.4

Introduction

By the end of this learning outcome, the trainee should have the ability to perform calculations on motion.

Linear motion

Linear motion is the motion a straight line and the movement in a direction where forwards is positive and backwards is negative.

Kinematics is the section of physics which studies the motions of objects without considering the effects that produce the motion. The study generally involves the analysis of the position of an object in relation to time. Dynamics is the section of physics which studies the causes of motion of an object.

Distance, d and Displacement, s

Distance, d is how far a body travels during a motion without considering any particular direction or the length of the path of an object.

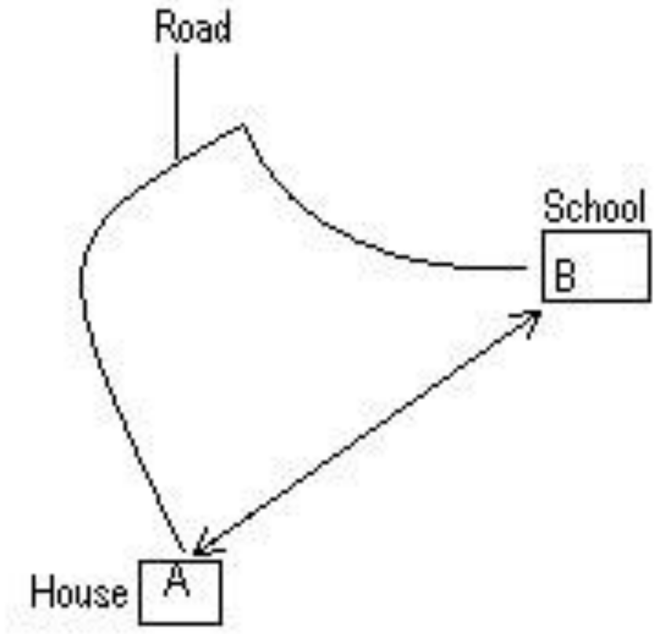
Distance is a scalar quantity and the value always positive.

The unit of distance is metre (m)

Displacement, s is distance traveled in a particular direction.

Displacement, s = final position – initial position Displacement is a vector quantity and the value can be positive and negative depend on their directions. The unit of displacement is meter (m)

Diagram below shows the difference between distance and displacement.



Distance = Length of the road

Displacement = Length of the line AB

If the motion in a straight line and in one direction, the magnitude of distance is same as the magnitude of displacement.

Speed and Velocity, v

Speed is the rate of change of distance.

$$\text{Speed} = \frac{\text{distance travelled}}{\text{Time taken}}$$

$$\text{Average speed} = \frac{\text{total distance traveled}}{\text{Total time taken}}$$

Speed is a scalar quantity and the value always positive.
The unit of speed is meter per second (m s^{-1})

Velocity is the rate of change of displacement.

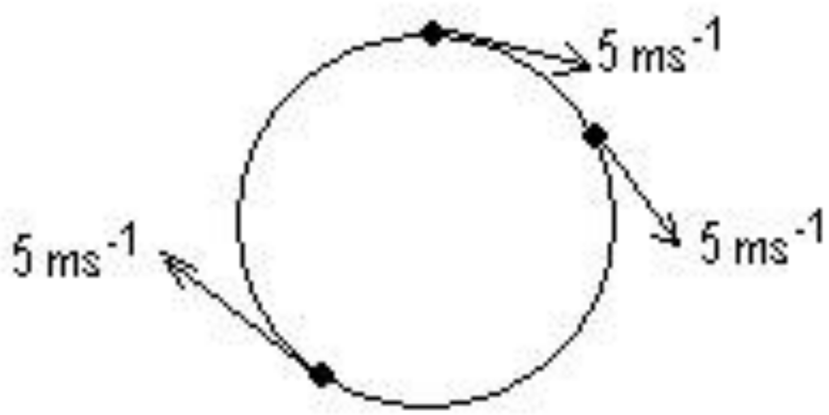
$$\text{Velocity} = \frac{\text{displacement}}{\text{Time taken}}$$

$$v = \frac{s}{t}$$

$$\text{Average velocity} = \frac{\text{total displacement}}{\text{Total time taken}}$$

Velocity is a vector quantity and the value can be positive and negative depend on their directions. The unif of velocity is meter per second (m s^{-1})

If an object moves in a circle with constant speed, it has different velocities at different points along the circle because the direction and hence the velocity of the object is always changing as shown in the following diagram.



Acceleration, a and Deceleration (Retardation)

Acceleration is the rate of change of velocity.

Acceleration = change in velocity time taken

Acceleration = final – initial (velocity) time taken

$$a = \frac{v - u}{t}$$

Negative acceleration is called as deceleration (retardation)

Acceleration is a vector quantity the unit of acceleration or deceleration is Meter per second per second (ms^{-2})

Extra notes

uniform = constant = same

increasing velocity = acceleration

decreasing velocity (slow down) = deceleration

zero velocity = the object is stationary (at rest)

negative velocity = the object moves in opposite direction

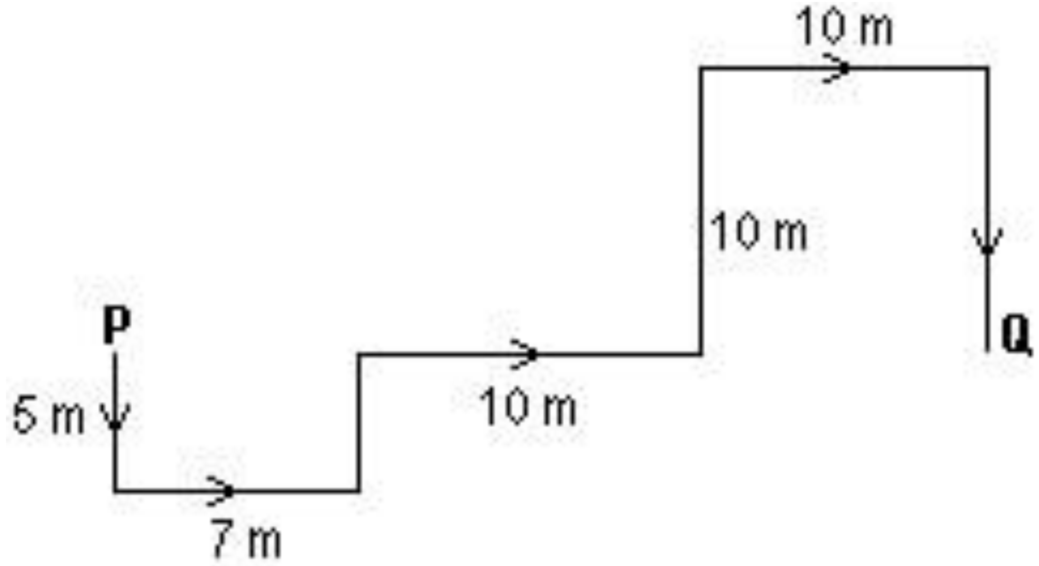
uniform velocity = zero acceleration

negative acceleration = deceleration

(Retardation)

Example 1

A boy walks finish the following path AB**.**



Find
total distance traveled
displacement

Example 2

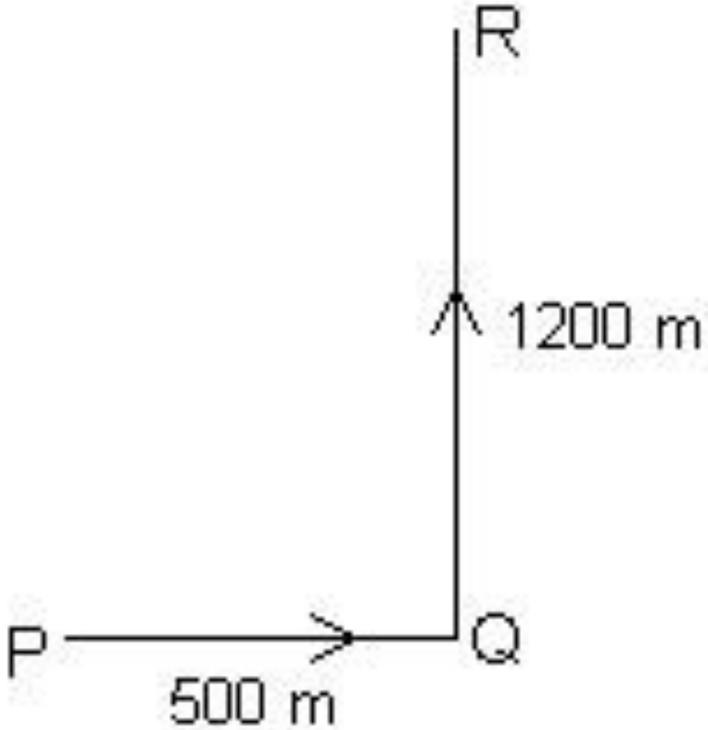


Figure above shows runner runs 500 m towards east in 2 minutes and 1200m towards north in 4 minutes.
Calculate his
average speed
average velocity

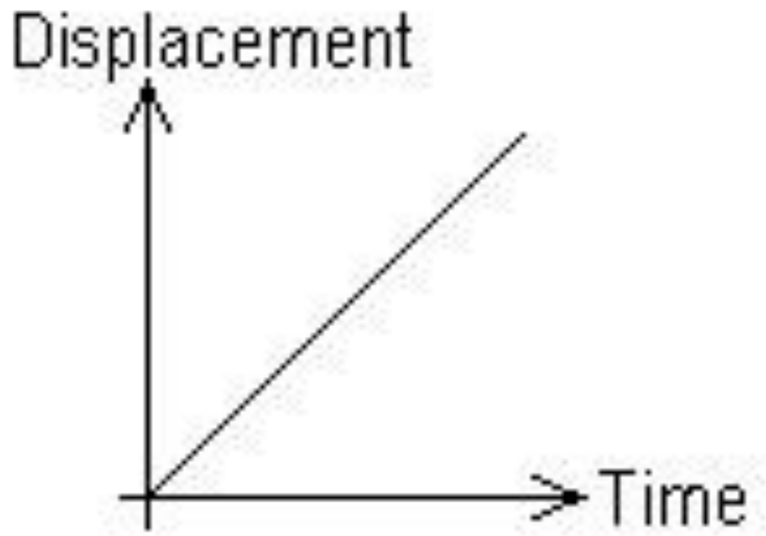
Example 3

An object accelerates uniformly along a straight line from a velocity of 10 m s^{-1} until 25 m s^{-1} in 5 s.
Calculate
the acceleration of the object
the velocity of the object during the first 10 s of motion
the time taken to reach a final velocity 50 ms^{-1}

Analyzing motion graphs

The motion graphs is a useful method of summarizing the motion of an object. In the graph the nature of the motion can be seen quite clearly.

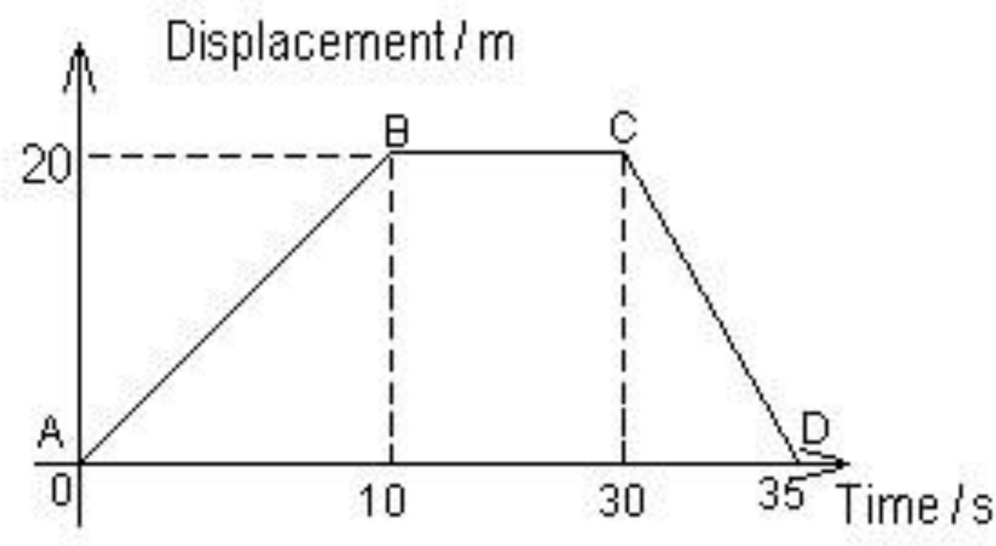
<u>Displacement – time graphs</u>



Gradient = Velocity

<u>Example 1</u>

The following figure shows displacement – time graph of an object.



Based on the graph:

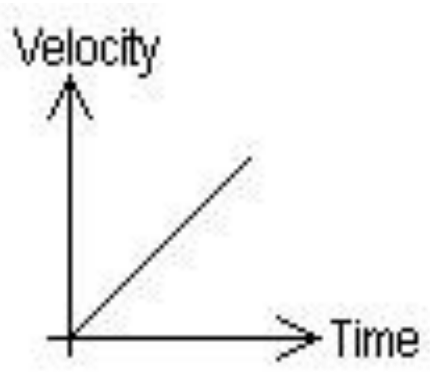
Calculate the velocity of the object between

i. AB,
ii. BC,
iii. CD

Describe the motion of the object between

i. AB
ii. BC
iii. CD

Velocity – Time graphs



Gradient = acceleration

Area under the graph = displacement

Newton's laws of motion

Definition of force

Force is defined as anything that changes the state of rest or motion of an object moving in a straight line.
Force is a vector quantity which has both direction and magnitude
The S.I. unit for force is N or kg ms^{-2}
Force is measured by using a Spring Balance

The effects of a force

A force can

i. move a stationary object
ii. stop a moving object
iii. accelerate a moving object
iv. decelerate a moving object
v. change the direction of a moving object
vi. alters the size of the object
vii. alters the shape of the object

NEWTON'S LAWS OF MOTION

Newton's First Law:

An object will remain at rest or continue with a constant speed in a straight line unless acted on by an unbalanced force.

Newton's Second Law:

The acceleration of a body, a, is directly proportional to the net force acting on it, F, and inversely proportional to its mass, m**.**

Newton's Third Law:

For every action there is an equal and opposite reaction.

The relationship between the acceleration, a, the net force, F and the mass, m.

Based on the Newton's Second Law of motion,

$a \propto F$

$a \propto \frac{1}{m}$

we obtain $a \propto \frac{F}{m}$

$a = \frac{kF}{m}$

$F = k\,ma$

In S.I. units , the definition of a force of 1 N is given as the amount of force which is applied on a mass of 1 kg and which causes it to experience an acceleration of 1 ms^{-2}

Thus,

$1\ N = k\ (1\ kg)\ (1\ ms^{-2})$

Thus $k = 1$

Therefore $\mathbf{F = ma}$

Where F = net force

m = mass

a = acceleration

Self-Assessment

1. If a block moves from a height h above the ground then the work done is given by________

a) $-\int_0^h W dy$

b) $\int_0^h W dy$

c) $-\int_{-h}^h W dy$

d) $\int_{-h}^h W dy$

2.If any external conservative force also is applied on the distributed loading then?

a) The net force will act at the centroid of the structure only

b) The net load will not be formed as all the forces will be cancelled

c) The net force will act on the base of the loading horizontally

d) The net force will not to be considered, there would be a net force of the distribution, rest will be the external forces

3. Which object has more inertia and why? A bowling ball at rest or a high-speed soccer ball?

a. Soccer ball. Because it is moving with a high velocity

b. Soccer ball. Because it has a greater volume than the bowling ball.

c. Bowling ball. Because it is not moving

d. Bowling ball. Because it is more massive

4. According to Newton's __________ law of motion, an object with less mass will experience a greater acceleration if a constant force is applied to the object
    a. First
    b. Second
    c. Third
    d. Fourth

5. A 1.50 kg ball is kicked and accelerates at a rate of 4.25 m/s^2. What is the force that was applied to the ball?
    a. 5.75 N
    b. 2.83 N
    c. 6.38 N
    d. 0.353 N

5. A car accelerates from rest to 25 m s-1 in 4 s. Find the acceleration of the car.
   Plan three simple experiments using objects you have test relationships between mass, acceleration, and force.

6. Design an experiment to test the relationship between mass and acceleration. What will be the independent variable in your experiment? What will be the dependent variable? What controls will you put in place to ensure force is constant?

7. Design a similar experiment to test the relationship between mass and force. What will be the independent variable in your experiment? What will be the dependent variable? What controls will you put in place to ensure acceleration is constant?

8. Design a similar experiment to test the relationship between force and acceleration. What will be the independent variable in your experiment? What will be the dependent variable? Will you have any trouble ensuring that the mass is constant?

9. A construction worker accidentally knocks a brick from a building so that it falls in 4 s to the ground. Calculate:
   the velocity of the brick as it hits the ground

   the distance fallen of the brick

Tools, Equipment, Supplies and Materials for the specific learning outcome

Scientific Calculators

Relevant reference materials

Stationeries

Mechanical workshop

Relevant practical materials

References (APA)

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Internet, https://www.yuhuaphysics.com/notes

Hurlow J W & Lake J (1969), Examples in engineering science for mechanical engineering technicians, Bell and Bain Ltd, Glasgow

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6.3.1.5 Learning Outcome No 5: Describe work, energy and power

Learning Activities

Learning Outcome No 5; Describe work, energy and power	
Learning Activities	**Special Instructions**
The trainee to perform an experiment to determine the work done on a frictionless cart and show that; The work done is equal to the increase in kinetic energy of the cart; The increase in energy of the cart is equal to the decrease in potential energy of the falling weight that supplies the force on the cart. **Apparatus** A cart accelerated along a linear track A cord	Make sure you understand and have checked the operation of the photo gate timers. To simulate a frictionless system, tip the track until the cart rolls toward the pulley at a constant speed. (No forces should be acting on the cart!)

Mass Photo gate timers spaced along the track	

Information Sheet: 6.3.1.5
Introduction

By the end of this learning outcome, the trainee should be able to solve problems related to work, energy and power.

Work
Work is said to be done when a force is applied to a body and causes it to move in the direction of the force. If the applied force is constant, the amount of work done is measured by the product of that force and the distance moved by the body.

Let a constant force *F* act on a body through a distance s. Then:
Work done = Force x Distance moved in the direction of the force
i.e. Work done = *Fs*

The unit of work is the *joule* (J), and this is defined as the amount of work done when a force of one newton acts through a distance of one metre in the direction of its application.

Hence, one joule is equal to one newton metre of work. In symbols, 1 J = 1 N m.

Work done in lifting objects
When an object is lifted at a steady speed, the direct force applied to raise the object is simply the upward ‘force to overcome the downward gravitational pull on the object, which is the weight of the object.
The gravitational force acting on an object of mass *m* kg is *mg* newtons, where *g* is the acceleration due to gravity having the value of 9.81 m/s^2.

When the object is lifted through a certain height, the work done is given by the product of the force to
overcome the downward gravitational pull and the vertical distance moved by the object.

Example 1; *Find the amount of work done by a hydraulic hoist in lifting a vehicle of mass 1500 kg to a height of 2 m.*

Solution
Force to overcome when lifting the vehicle
= mg
= 1500 [kg] x 9.81 [m/s^2]
= 14 715 N
Work done = Force x Vertical distance moved
= 14715 [N] x 2 [m]

= 29 430 J = 29.43 kJ
Work done in lifting vehicle = 29.43 kJ

Energy
Energy is defined as the capacity for doing work, and is measured in the same unit, i.e. the joule (J).

It exists in many forms such as mechanical energy, electrical energy, heat energy, chemical energy and
so on.

Potential energy (PE)
The *potential energy* of a body is the energy it possesses due to its position in a gravitational field, i.e. due to its height above the ground (or any convenient reference level).
If a body of mass *m* kg is lifted through a vertical distance of *h* metres above the ground, work is done because the body is being lifted against the gravitational force which acts on the body.

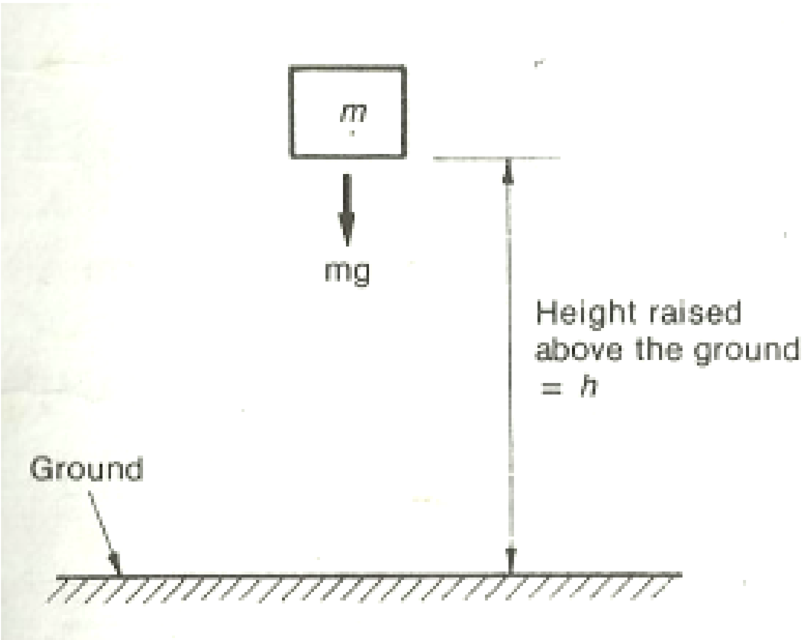


Figure 62: Mgh

Source Zammit (1987)

Work done = Force x Vertical distance
= mg x h

= *mgh* joules

This amount of work done will be stored in the body as potential energy by virtue of its position relative to the ground. In other words, the body will be capable of doing *mgh* joules of work if allowed to fall back to the ground. Thus, energy is transferred to a body when it is lifted.
Potential energy (PE) = *mgh* joules

Kinetic energy (KE)
The kinetic energy of a body is the energy it possesses due to its velocity. This energy can be made available to do work against a resistance if the moving body is brought to rest.
Kinetic energy (KE) $= \frac{1}{2}mv^2$ joules

Where *m* is mass of the body in kg and *v* is velocity in m/s.

Work is the process by which energy is transferred to a body, and the energy thus gained by the body could be in the form of either potential energy or kinetic energy.

Example 2; A body of mass 5 kg is supported 12 m above the ground. Determine the potential energy possessed by the body due to its position with respect to the ground.

Solution
PE possessed by body = *mgh*
where $m = 5$ kg; $g = 9.81$ m/s^2 ; $h = 12$ m
PE = 5 x 9.81 x 12 = 588.6 J

Example 3
A motor vehicle of mass 2 tonne is travelling at 50.4 km/h. Determine the kinetic energy of the vehicle at this speed.

Solution
KE of vehicle $= \frac{1}{2}mv^2$
where m = 2 tonne = 2000 kg
v =50.4 km/h = 14 m/s
KE $= \frac{1}{2} \times 2000 \times 14^2$ *= 196000 J = 196 kJ*

Principle of conservation of energy
The *principle of conservation of energy* states that energy can neither be created nor destroyed. Energy can be readily converted from one form to another, but it is found that a loss of energy in any one form is always accompanied by an equivalent increase in another form. In all such conversions, therefore,

the total amount of energy remains constant.

There are many cases in which the potential energy of a body is converted into kinetic energy (and vice versa). When a motor vehicle freewheels down an incline, it gives up some of its potential energy but at the same time, it gains an equal amount of kinetic energy. Hence, the total energy possessed by the vehicle at any instant on (he incline remains constant. In practice, friction is always present and work has to be done in overcoming the frictional resistances (this amount of work done is dissipated as heat). In such cases:

Final energy = Initial energy - Work done against friction

Let us consider again the body of mass *m* kg raised to the height *h* metres above the ground. We have seen that the potential energy possessed by the body due to its position with respect to the ground is *mgh* joules. If the body is allowed to fall freely from that height until it is just about to strike the ground, all its available potential energy will be given up. Assuming no external work is done on or by the body during its time of fall then, by the principle of conservation of energy, the body will gain kinetic energy equal in amount to the initial potential energy.

Suppose the body reaches a speed of *v* m/s just before contact with the ground. Then, since energy is conserved, we may write:
KE on reaching the ground = Initial PE

Power
Power is defined as the rate of transfer of energy. If the energy transfer is in the form of mechanical work, then:

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}}$$

$$= \frac{\text{Force x Distance moved}}{\text{Time taken}}$$

But $\frac{\text{Distance moved}}{\text{Time taken}}$ is the velocity of the body. Hence;
Power = Force x Velocity = *Fv*

The unit of power is the *watt* (W), which is the rate of doing one joule of work every second. Thus:

1 W = 1 J/s = 1 N m/s

Example 4; *A vehicle hauls a trailer at 72 km/h when exerting a steady pull of 800 N at the tow-rope. Calculate the power required.*

Solution

Power required = Force x Velocity
= F x v from equation
where F = 800 N and v = 72 km/h = 20 m/s
Power required = 800 [N] x 20 [m/s]
= 16 000 W = 16 kW

Self-Assessment

1.Principle of virtual work was developed by mohr. State whether the above sentence is true or false.

a) True

b) False

2. What is the relation between work done by external loads and work done by internal loads.

   a) They are unequal

   b) They are equal

   c) Can’t say

   d) Depends upon load

3. Dummy unit load method and virtual work method are two different approaches. State whether the above statement is true or false.

   a) True

   b) False

4. The total energy of the universe is constant.

   a) True

   b) False

5. How much mass is converted into energy per day in Tarapur nuclear power plant operated at 107 kW?

   a) 10g

   b) 9g

   c) 9.6g

   d) 2g

6. A machine gun fires 60 bullets per minute, with a velocity of 700m/s. If each bullet has a mass of 50g, find the power developed by the gun.

   a) 1225W

   b) 12250W

   c) 122.5W

   d) 122W

7. For a collision to occur, the actual physical contact is necessary.

   a) True

   b) False

8. Which of the following is an example for inelastic collision?
   a) Collision between two vehicles
   b) Collision between glass balls
   c) A bullet fired into a wooden block
   d) Collision between two railway compartments

9. Mud thrown on a wall and sticking to it is an example for
   a) Inelastic collision
   b) Elastic collision
   c) Super elastic collision
   d) Perfectly inelastic collision

10. Collision between two carom coins is an example for
    a) Oblique collision
    b) Perfectly inelastic collision
    c) Inelastic collision
    d) Elastic collision

11. The maximum fluctuation of speed is the
    a) difference of minimum fluctuation of speed and the mean speed
    b) difference of the maximum and minimum speeds
    c) sum of the maximum and minimum speeds
    d) variations of speed above and below the mean resisting torque line

12. The coefficient of fluctuation of speed is the __________ of maximum fluctuation of speed and the mean speed.
    a) product
    b) ratio
    c) sum
    d) difference

13. In a turning moment diagram, the variations of energy above and below the mean resisting torque line is called
    a) fluctuation of energy
    b) maximum fluctuation of energy
    c) coefficient of fluctuation of energy
    d) none of the mentioned

14. If E = Mean kinetic energy of the flywheel, CS = Coefficient of fluctuation of speed and Δ E = Maximum fluctuation of energy, then
    a) $\Delta E = E / CS$
    b) $\Delta E = E2 \times CS$
    c) $\Delta E = E \times CS$
    d) $\Delta E = 2 E \times CS$

15. List four forms in which energy can exist, illustrating your answer by reference to the energy forms at work in the welding workshop.
16. Calculate the work done when a casting is moved 15 m along a workshop floor by a force of 3.5 kN.

17. In a drop-forging operation, the top die and its holder, which have a combined mass of 50 kg, fall freely on to the bottom die. Calculate:
    i. the kinetic energy of the top die just before striking the bottom die if its velocity at that instant is 7.8 m/s
    ii. the height through which the top die has fallen

Tools, Equipment, Supplies and Materials for the specific learning outcome

Scientific Calculators

Mechanical workshop

Relevant reference materials

Relevant practical materials

Stationeries

References (APA)

Hurlow J W & Lake J (1969), Examples in engineering science for mechanical engineering technicians, Bell and Bain Ltd, Glasgow

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Bigelow, J. 1829. *Elements of Technology*. Boston: Boston Press,

Calvert, M. A. 1967. *The Mechanical Engineer in America, 1830-1910.* Baltimore, MD: John Hopkins Press.

6.3.1.6 Learning Outcome No 6: Perform machine calculations

Learning Activities

Learning Outcome No 6; Perform machine calculations	
Learning Activities	**Special Instructions**
Trainee to carry out an experiment in the workshop on a simple lifting machine to find the effort *P* required to overcome a load *W* and plot a graph of *P* against *W* for the various load values obtained to determine the relationship between the effort and the load.	Safety precautions need to be adhered to where lifting in the workshop

Information Sheet: 6.3.1.6

Introduction

A simple machine is a device which enables a small force (the *effort)* acting at a point to overcome a large force (the *load)* acting at some other point. Examples of simple machines are pulley systems, screw jacks, gear systems and levers. By the end of this learning outcome, the trainee should be able to perform simple machine calculations.

Terms used in simple machine theory

Force ratio or mechanical advantage

A machine is usually designed so that the load is overcome by means of a considerably smaller effort.

The ratio of the load to the effort is called the *force ratio* or the *mechanical advantage* of the machine. Hence:

$$\text{Mechanical advantage (MA)} = \frac{\text{Load}}{\text{Effort}}$$

Since mechanical advantage is a ratio of two forces, it has no units and is only a number which varies with the load.

Movement ratio or velocity ratio

The ratio of the distance moved by the effort to that moved by the load (in the same time) is called the *movement ratio* or the *velocity ratio* of the machine. Hence:

$$\text{Velocity ratio (VR)} = \frac{\text{Distance moved by effort}}{\text{Distance moved by load}}$$

Velocity ratio is a dimensionless quantity.
The velocity ratio depends solely upon the construction of the machine, and is constant for any particular machine.

It can be found experimentally simply by moving the machine and measuring the distances moved by the points of application of the effort and the load and dividing the former by the latter, or it can be determined by
calculation from the relevant details or dimensions of the machine.

Efficiency of a machine

The *efficiency* of a machine is defined as the ratio of the useful work done by the machine to the actual work put into the machine. Thus:

$$\text{Efficiency} = \frac{\text{Work output}}{\text{Work input}}$$

$$\text{or Efficiency} = \frac{\text{Work done on load}}{\text{Work done by effort}}$$

A useful relationship exists between mechanical advantage, velocity ratio and efficiency.

Since work done = force x distance, then;

$$\text{Efficiency} = \frac{\text{Load x Distance moved by load}}{\text{Effort x Distance moved by effort}}$$

$$= \frac{\text{Load x Distance moved by load}}{\text{Effort x Distance moved by effort}}$$

$$= \frac{\text{Mechanical advantage}}{\text{Velocity ratio}}$$

The efficiency is usually stated as a percentage, and the above expression should therefore be multiplied by 100 to give a percentage value.
It should be noted that since the velocity ratio of a given machine is constant, the efficiency is directly proportional to the mechanical advantage.

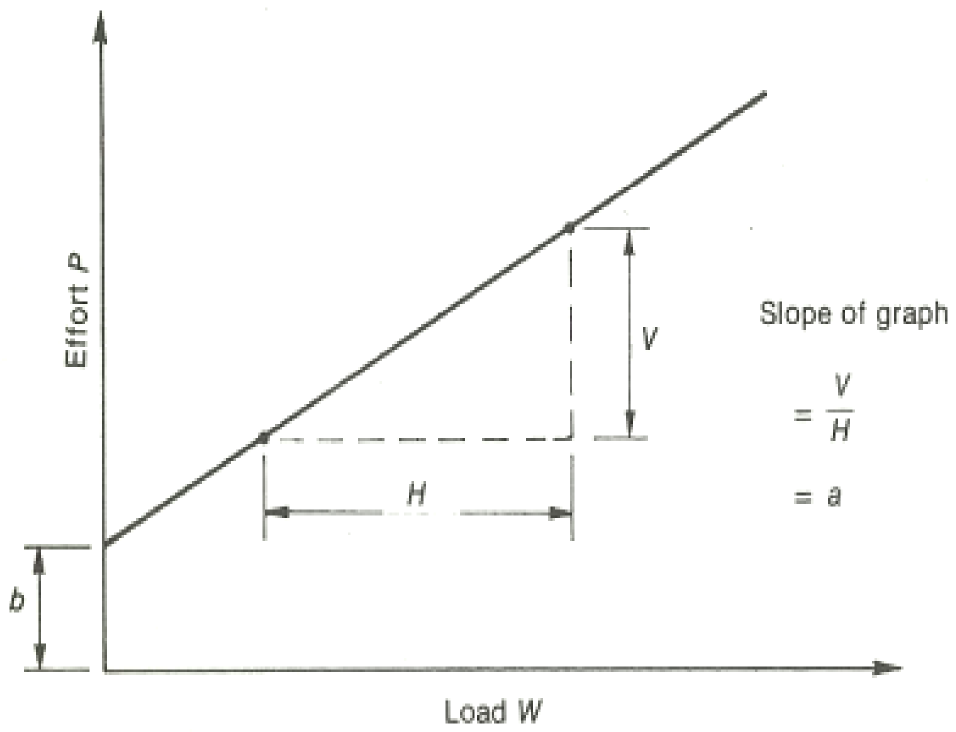
The law of a machine
If an experiment is carried out on a simple machine to find the effort *CP*) required to overcome a load *(W)* and a graph of *P* against *W* is plotted for various load values, then a straight line graph, similar to that shown in figure below, would be obtained. The relationship between the effort P and the load W is therefore of the form:

$P = a W + b$

where a and b are constants whose value depends on the particular machine concerned. This equation is called the law of the machine.

After it has been determined by experiment, it can then be used to estimate the effort which would be required to raise any load on the machine.

The value of the constant b represents the effort required to overcome the frictional resistances when there is no load on the machine, and is the intercept on the effort-load graph. The value of the constant a is the slope of the effort-load graph (V/H), and depends on the mechanical advantage of the machine.



Limiting efficiency of a machine

The mechanical advantage of a machine varies with the load, but the velocity ratio is constant and cannot be altered without making a change to the arrangement of the machine. Since efficiency is obtained by dividing the mechanical advantage by the velocity ratio, it follows that efficiency will depend upon the load; in fact, it will be found to increase with increase of load. However, this increase in efficiency with load does not continue indefinitely, and a limiting efficiency is eventually reached.

Levers

A lever is a simple machine which operates on the principle of moments. It is simply a rigid bar, straight or cranked, which can be turned about a pivot or fulcrum. The lever may be either one of three types or 'orders', depending on the relative positions of the fulcrum, the load and the effort.

A lever of the first order has the fulcrum situated between the effort and the load, as shown in Fig. (a).

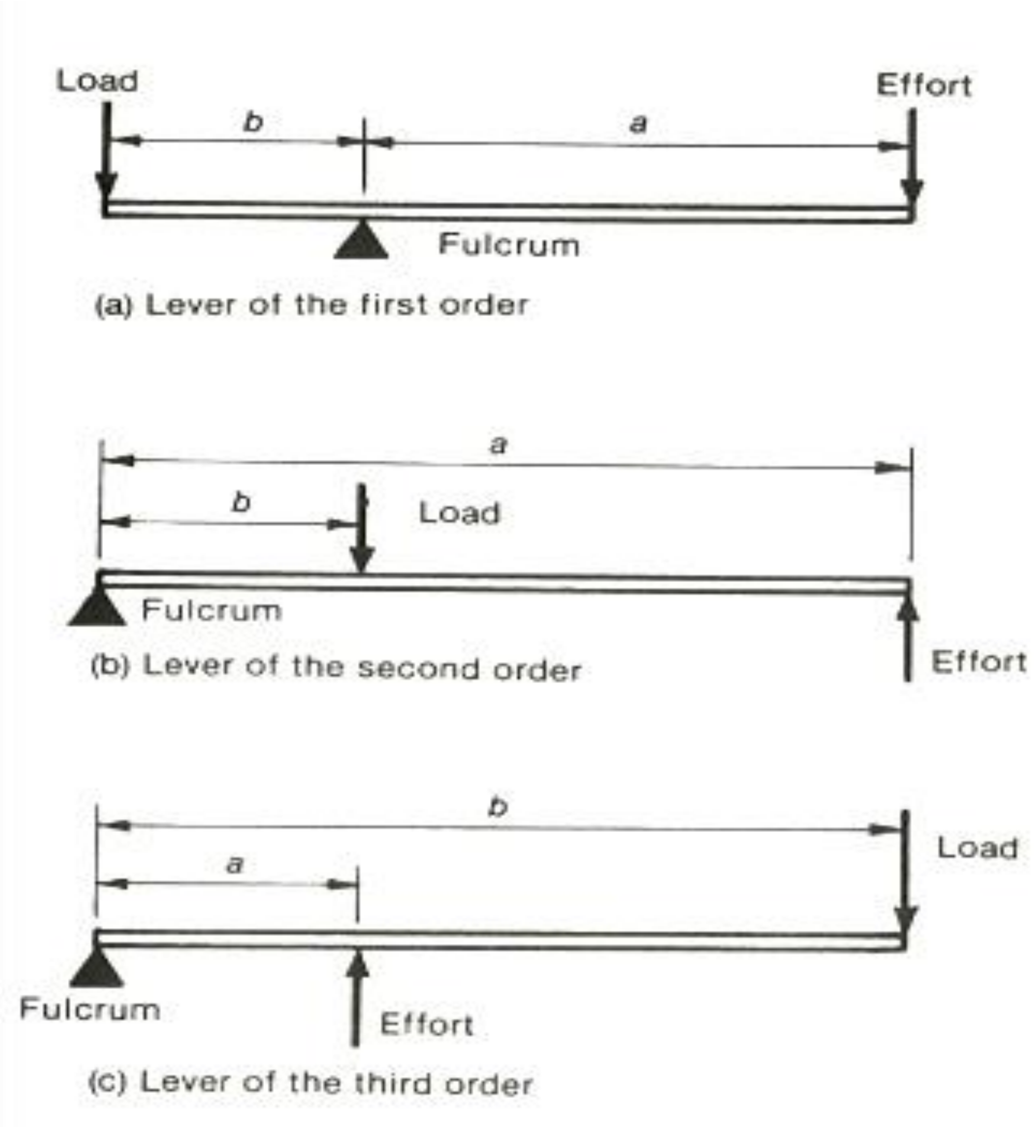
A lever of the second order has the load placed between the fulcrum and the effort, as shown in Fig. (b).

A lever of the third order has the effort applied between the fulcrum and the load, as shown in Fig. (c)

In all cases, if the lever is in equilibrium, the clockwise moment about the fulcrum is equal to the anticlockwise moment about the same point.

Effort x a = Load x b

$$\therefore \frac{\text{Load}}{\text{Effort}} = \frac{a}{b} = \text{Mechanical advantage}$$



Source: Zammit (1987)

Self-Assessment

1. Mechanical advantage is the ratio of effort to load.
   a) True
   b) False

2. Leverage is the ratio of load arm to effort arm.
   a) True
   b) False
   Answer: b
   Explanation: Leverage is the ratio of effort arm to load arm.

3. The distance between fulcrum and dead weights is 100mm. Dead weights are of 2945.2N. An effort of 294.52N acts on the other hand. Find the distance between the fulcrum and other end of the lever.
   a) 1000mm
   b) 100mm
   c) 10mm
   d) 10000mm

4. A right angled bell-crank is designed to raise a load of 5kN at short arm whose length is 100mm. Longer arm is of length 500mm. Calculate the reaction or force acting on the fulcrum.
   a) 5.1
   b) 5.8
   c) 6.1
   d) 6.8

5. A right angled bell-crank is designed to raise a load of 5kN at short arm whose length is 100mm. Also longer arm is of length 500mm. If permissible bearing pressure on pin is $10N/mm^2$ and diameter of the 20mm, find the length of the pin.
   a) 35.5mm
   b) 25.5mm
   c) 20mm
   d) 30mm

6. A right angled bell-crank is designed to raise a load of 5kN at short arm whose length is 100mm. Also longer arm is of length 500mm. If permissible bearing pressure on pin is $10N/mm^2$ and diameter of the 20mm, find the shear stress in the pin.
   a) 8.12
   b) 8.51
   c) 9.12
   d) 9.51

7. How many classes of levers are there?
   a) 2
   b) 3
   c) 4
   d) 5

8. A bottle opener belongs to which class of the levers.
   a) Effort in the middle
   b) Fulcrum in the middle
   c) Resistance in the middle
   d) None of the mentioned

9. Fulcrum can be located at one end of the lever.
   a) True
   b) False

10. Give reasons why the efficiency of a machine can never be 100 per cent.
11. During an experiment on a lifting machine, the following values of the effort P to lift a load W were recorded:

Load, W (N)	500	1000	1500	2000	2500	3000	3500
Effort, P (N)	100	150	200	250	300	350	400

i. Plot these values to show that the law of the machine is of the form P = aW + b, and determine suitable values for the constants a, and b.
ii. For each load, calculate the mechanical advantage and the efficiency of the machine. Plot the graphs of mechanical advantage and efficiency on a base of load. The velocity ratio of the machine is 32.

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Mechanical workshop
- Relevant practical materials

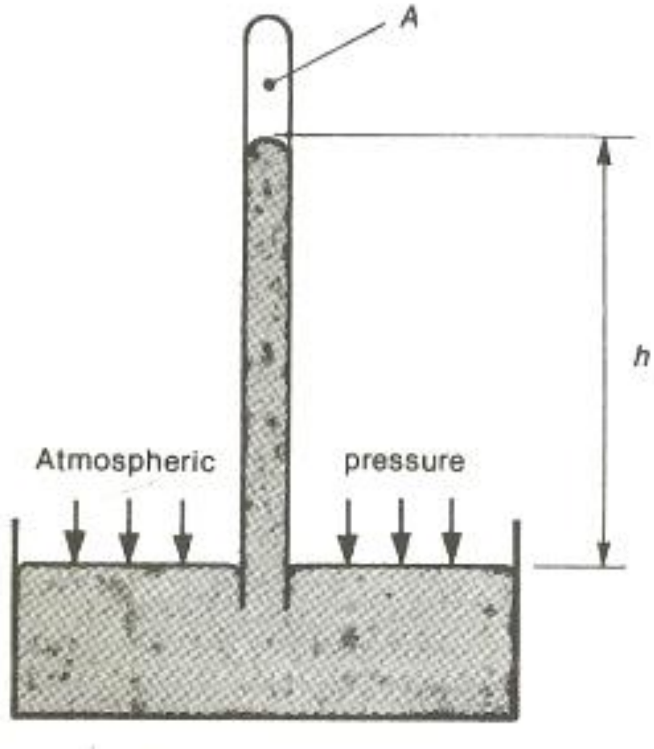
References (APA)

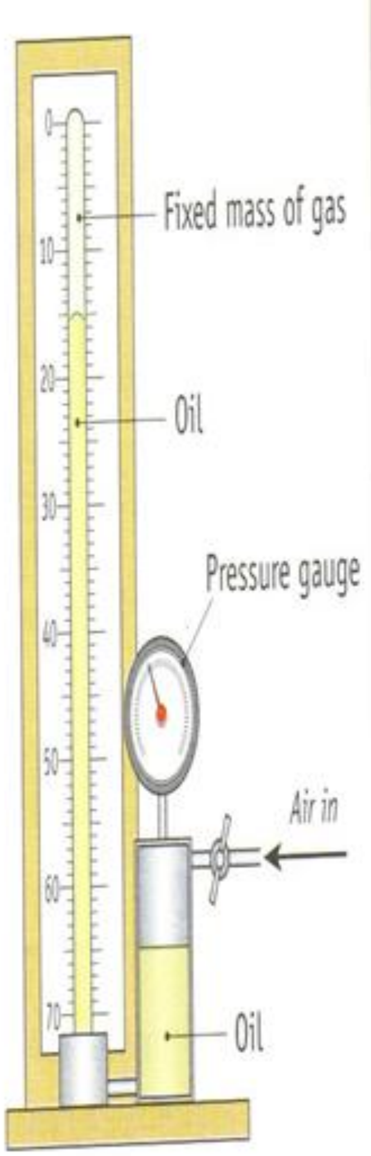
Hurlow J W & Lake J (1969), Examples in engineering science for mechanical engineering technicians, Bell and Bain Ltd, Glasgow

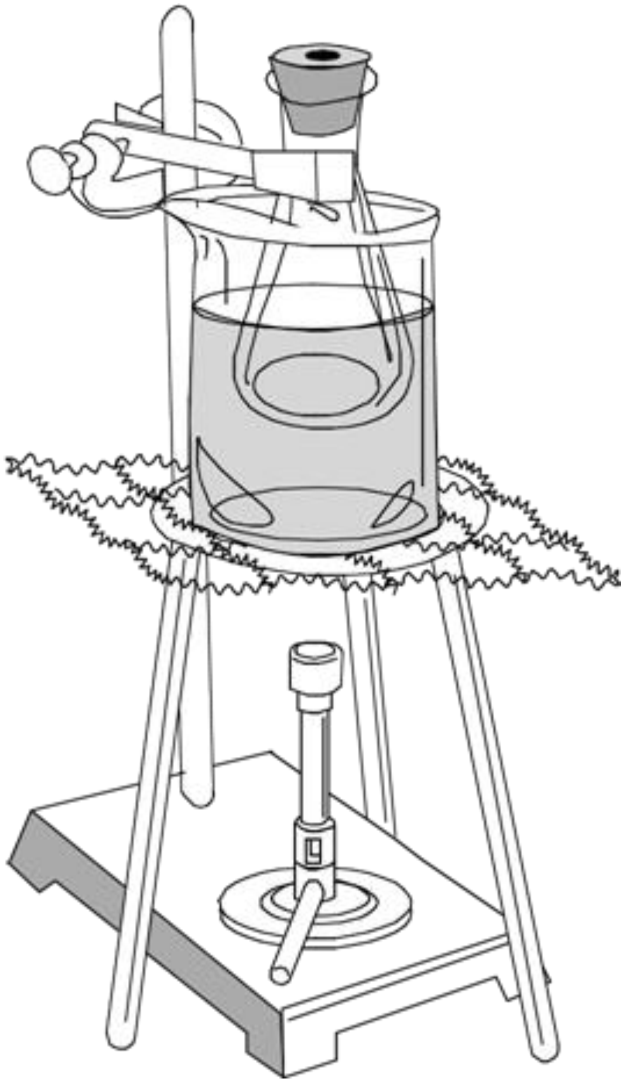
Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

6.3.1.7 Learning Outcome No 7: Demonstrate gas principles

Learning Activities

Learning Outcome No 7; Demonstrate gas principles	
Learning Activities	**Special Instructions**
The trainee to construct a simple mercury barometer in the laboratory.  Source: Rajput (2000) The trainee to carry out an experiment to verify Boyle's law **Apparatus;** A Boyle's Law Apparatus, Air Pump, Hand Vacuum Pump.	**Precautions on Boyle's Law:** After changing the pressure of the trapped air wait a minute or two before reading the pressure or volume, to allow the air to reach room temperature. When reading volume make sure your eye is level with the Mercury Meniscus. Make sure air is connected tightly to oil reservoir inlet. If a hand suction pump is available you will be able to reduce the pressure of the gas below atmospheric pressure. You can then take a future series of values of *p* and *V* include them in the table and graph. **Precautions on Charles's Law;** Be sure that the Erlenmeyer flask together with the clamp around its neck can be easily removed from the rest of the assembly.

 **Source: Hurlow and lake (1969)** The trainee to carry out an experiment to verify Charles's law	



Apparatus; Clean paper towel Erlenmeyer flask. Marking pen beaker wire gauze tripod and clamp Bunsen burner	

Information Sheet: 6.3.1.7
Introduction

By the end of this learning outcome, the trainee should be able to apply gas principles in engineering systems.

Certain important laws governing the behaviour of perfect gases under varying conditions of temperature and pressure have been established from experimental results.

Pressure of a gas

Any quantity of a gas, if placed into a vessel of larger volume than itself, will at once fill every part of the vessel. The rapidly moving molecules of the gas continually collide with the walls of its container and produce forces distributed all over the inside of the vessel.

The amount of the force exerted on unit area of the surface of the container is defined as the *pressure* of the gas.

The unit of pressure is the *newton per square metre* (N/m^2).

This unit has a special name, the *pascal* (symbol Pa).

An alternative unit of pressure in the bar, where:

1 bar = 10^5 Pa = 100 kPa

Atmospheric pressure

The earth's atmosphere above its surface exerts a pressure due to the mass of air. At sea level atmospheric pressure is about 101.3 kPa (101.3 kN/m^2 or 1.013 bar). Atmospheric pressure decreases with altitude Atmospheric pressure varies slightly from day to day and is recorded by means of a *barometer* in which the height of a column of mercury is used as a measure of the pressure.

Gas laws

Boyle's law

Boyle's law gives the relationship between pressure and volume of a quantity of gas under **constant temperature** conditions. It states that:
'*The absolute pressure of a given mass of gas varies inversely as its volume when the temperature of the gas remains constant*.'

Thus, if the absolute pressure of a given mass of gas is doubled, its volume is halved, or if the absolute pressure is halved, the volume will be doubled.
Hence, if p = absolute pressure of gas
and V = **volume of gas**
then, Boyle's law may be expressed as follows:

$$p \propto \frac{1}{V}$$

$$\therefore \quad p = \frac{1 \times C}{V}$$

Or $pV = C$, a constant.

Charles' law

Charles' law gives the relationship between volume and temperature of a quantity of gas when the pressure is kept constant. It states that:
'*The volume of a given mass of gas varies directly as it thermodynamic or absolute temperature when the pressure is kept constant'*.
Thus, at double the absolute temperature, the volume of a given mass of gas is doubled; at three times the absolute temperature, the volume is trebled, and so on.
Hence, if V = volume of gas

and T = absolute temperature of gas

then, Charles' law may be expressed as follows:

$$V \propto T$$
$$V = T \times C$$

or $$\frac{V}{T} = C, \text{ a constant}$$

$$\frac{V_1}{} = \frac{V_2}{}$$

T_1 T_2

It should here be emphasized that in problems dealing with the gas laws, all temperatures must be converted to absolute temperatures.

Thus, if Ѳ is the temperature of the gas in degrees Celsius and *T* the absolute temperature in kelvins, then;

T K = Ѳ °C + 273

The general gas equation

A given mass of gas may undergo simultaneous changes in pressure, volume and temperature. When this change occurs in the state of the gas, neither Boyle's law, which assumes constant temperature, nor Charles' law, which assumes alteration of temperature with constant pressure, can be applied. However, this change of state may be regarded as taking place in two stages:
(1) a change according to Boyle's law; and
(2) a change according to Charles' law.
The resulting change will then be according to the laws of Boyle and Charles combined.

The combination of Boyle's and Charles' laws, is known as the *general gas equation.* It may be expressed in the form:

$$\frac{pV}{T} = C, \text{ a constant}$$

Pressure law

The pressure of a given mass of gas varies directly as its thermodynamic or absolute temperature when the volume is kept constant.
This is exactly analogous with the volume change with temperature at constant pressure, and can therefore be applied to pressure changes at constant volume in a similar manner to the volume changes at constant pressure.

Self-Assessment

1. A mole of a substance has a mass equal to the molecular weight of the substance.
   a) true
   b) false

1. According to Avogadro's law, volume of a g mol of all gases at the pressure of ____ and temperature of ____ is same.
   a) 760 mm Hg, 100 degree Celsius
   b) 760 mm Hg, 0 degree Celsius
   c) 750 mm Hg, 100 degree Celsius
   d) 750 mm Hg, 0 degree Celsius

2. At NTP, the volume of a g mol of all gases is(in litres)
   a) 22.1
   b) 22.2
   c) 22.3
   d) 22.4

3. Which of the following statement is true?
   a) number of kg moles of a gas = mass / molecular weight
   b) molar volume = total volume of the gas / number of kg moles
   c) both of the mentioned
   d) none of the mention

4. The equation of state is a functional relationship between
   a) pressure
   b) molar or specific volume
   c) temperature
   d) all of the mentioned

5. If two properties (out of p,v,T) of a gas are known, the third can be evaluated.
   a) true
   b) false

6. Which of the following statement is true about a gas?
   a) lim(pv) with p tending to 0 is independent of the nature of gas
   b) lim(pv) with p tending to 0 depends only on the temperature
   c) this holds true for all the gases
   d) all of the mentioned

7. Universal gas constant is given by
   a) lim(pv) / 273.16
   b) R

c) 0.083 litre-atm/gmol K
d) all of the mentioned

8. The equation of state of a gas is lim(pv)=RT .
   a) true
   b) false

9. For which of the following gases, does the product (pv) when plotted against p gives depends only on temperature?
   a) nitrogen
   b) hydrogen
   c) air and oxygen
   d) all of the mentioned

10. For the ideal gas equation, what assumptions are made?
    a) there is little or no attraction between the molecules of the gas
    b) the volume occupied by the molecules is negligibly small compared to the volume of the gas
    c) both of the mentioned
    d) none of the mentioned

11. When does a real gas obey the ideal gas equation closely?
    a) at high pressure and low temperature
    b) at low pressure and high temperature
    c) at low pressure and temperature
    d) at high pressure and temperature

12. The real gases deviate from the ideal gas equation when the pressure increases.
    a) true
    b) false

13. The corrected gas equation is given by
    a) (p+a/(v2))(v+b)=RT
    b) (p-a/(v2))(v-b)=RT
    c) (p-a/(v2))(v+b)=RT
    d) (p+a/(v2))(v-b)=RT

14. A given mass of gas is enclosed in a vessel. Explain briefly how the pressure measured at the wall of the vessel is produced by the gas molecules.
15. Describe a laboratory experiment to verify Boyle's law. Include a sketch of the apparatus used.
16. Describe a laboratory experiment to verity Charles' law. Include a sketch of the apparatus used.

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Mechanical workshop
- Relevant practical materials

References (APA)

Hurlow J W & Lake J (1969), Examples in engineering science for mechanical engineering technicians, Bell and Bain Ltd, Glasgow

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Bigelow, J. 1829. *Elements of Technology*. Boston: Boston Press,

Calvert, M. A. 1967. *The Mechanical Engineer in America, 1830-1910.* Baltimore, MD: John Hopkins Press.

6.3.1.8 Learning Outcome No 8: Apply heat knowledge

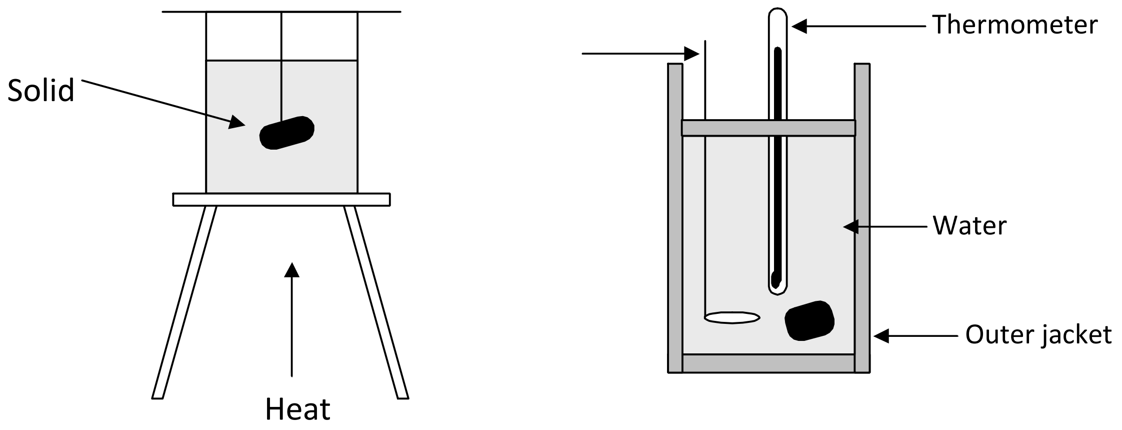
Learning Activities

Learning Outcome No 8; Apply heat knowledge	
Learning Activities	**Special Instructions**
Trainee to carry out an experiment to determine the specific heat capacity of a solid by the method of mixtures. Equipment/ Materials/ Apparatus Solid (e.g. metal ball) of reasonable size Calorimeter with an insulation, outer jacket and stirrer Thermometer (reading up to 0.1oC) Heater Thread Sensitive balance Beaker	Measured quantities should be repeated and averaged The calorimeter should be kept in its insulating jacket. Thermal equilibrium should be achieved before the final temperature is taken. Water should be collected and placed near calorimeter 1hour before the experiment in order to

Experimental Setup for determining the specific heat capacity of a metal ball.	ensure the same temperature.

Information Sheet: 6.3.1.8
Introduction

By the end of this learning outcome, the trainee should have the ability to solve simple problems on heat energy.



Heat energy

When a body is capable of doing work, it is said to possess energy. Heat is one form of energy and, therefore, it provides this capacity for doing work.

Heat can be defined as that kind of energy which is transferred from one body to another when there is a temperature difference between them.

Unit of heat energy

Since heat is a form of energy then, in common with all other types of energy, it is measured in joules (J). The joule is a small unit and in practice, kilojoules (kJ), or even megajoules (MJ), are often used as the unit of heat energy.

1 MJ = 10^5 kJ = 10^6 J

Temperature

Temperature is the term used to refer to the degree of hotness or coldness of a body.
The SI unit of temperature is the Kelvin, (K) and the derived unit is the degree Celsius (°C) .
1°C = 1K of temperature difference.
Kelvin temperature = Celsius temperature + 273; i.e. K=°C+273

Specific heat capacity

The quantity of heat required to raise the temperature of 1 kg of a substance by 1 K is called the *specific heat capacity* of the substance.
This is denoted by c.
The basic unit for specific heat capacity is the joule per kilogram kelvin (J/kg K).
The quantity of heat given out or received by a substance is equal to the product of the mass of the substance, the specific heat capacity of the substance and its change in temperature.
Hence, if m = mass of substance, in kilograms
c = specific heat capacity, in J/kg K
σT = change in temperature, in kelvins
Q = quantity of heat given out or received, in joules
then $Q = m \times c \times \sigma T$

Sensible heat

This is the heat energy which when given to a substance causes a temperature rise. When a susbstance cools, sensible heat has been withdrawn from it.

Heat energy transfer
Heat may be transferred from a hot body to a cooler body in one or more of the following ways;

Conduction
Convection
Radiation

Conduction
Conduction of heat takes place between bodies in actual contact, if they are at different temperatures.
Convection
Convection is the conveyance of heat by the actual movement of a hot fluid which may be a liquid or a gas.

Radiation
Radiation is the transmission of heat by wave or vibratory motion in the space between the source and the body on which waves impinge.

Expansion
Most substances expand when they are heated and contract when cooled. With solids, we are usually concerned with their *linear* expansion, whereas with liquids we are concerned with their change in volume.

Trainee to do more reading on linear expansion from Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London, page 215.

Self-Assessment
1. The transfer of heat between a wall and a fluid system in motion is called
   a) radiation
   b) convection
   c) conduction
   d) none of the mentioned

2. For solids and liquids, specific heat
   a) depends on the process
   b) is independent of the process
   c) may or may not depend on the process
   d) none of the mentioned

3. The specific heat of the substance is defined as the amount of heat required to raise a unit mass of the substance through a unit rise in temperature.
   a) true
   b) false

4. Heat and work are
   a) path functions
   b) inexact differentials
   c) depend upon the path followed
   d) all of the mentioned

5. Latent heat is taken at
   a) constant temperature
   b) constant pressure
   c) both of the mentioned
   d) none of the mentioned

6. The sun shines on a 150 m2 road surface so it is at 45°C. Below the 5cm thick asphalt (average conductivity of 0.06 W/m K), is a layer of rubbles at 15°C. Find the rate of heat transfer to the rubbles.
   a) 5300 W
   b) 5400 W
   c) 5500 W
   d) 5600 W

7. A pot of steel (conductivity 50 W/m K), with a 5 mm thick bottom is filled with liquid water at 15°C. The pot has a radius of 10 cm and is now placed on a stove that delivers 250 Was heat transfer. Find the temperature on the outer pot bottom surface assuming the inner surface to be at 15°C.
   a) 15.8°C
   b) 16.8°C
   c) 18.8°C
   d) 19.8°C

8. A water-heater is covered with insulation boards over a total surface area of 3 m2. The inside board surface is at 75°C and the outside being at 20°C and the conductivity of material being 0.08 W/m K. Find the thickness of board to limit the heat transfer loss to 200 W ?
   a) 0.036 m
   b) 0.046 m
   c) 0.056 m
   d) 0.066 m

9. On a winter day with atmospheric air at −15°C, the outside front wind-shield of a car has surface temperature of +2°C, maintained by blowing hot air on the inside surface. If the wind-shield is 0.5 m2 and the outside convection coefficient is 250 W/Km2, find the rate of energy loss through front wind-shield.
   a) 125 W
   b) 1125 W
   c) 2125 W
   d) 3125 W

10. A large heat exchanger transfers a total of 100 MW. Assume the wall separating steam and seawater is 4 mm of steel, conductivity 15 W/m K and that a maximum of 5°C difference between the two fluids is allowed. Find the required minimum area for the heat transfer.
   a) 180 m2
   b) 280 m2
   c) 380 m2
   d) 480 m2

11. The transfer of heat between two bodies in direct contact is called
    a) radiation
    b) convection
    c) conduction
    d) none of the mentioned

12. Heat flow into a system is taken to be ____, and heat flow out of the system is taken as ____
    a) positive, positive
    b) negative, negative
    c) negative, positive
    d) positive, negative

13. In the equation, dQ=TdX
    a) dQ is an inexact differential
    b) dX is an exact differential
    c) X is an extensive property
    d) all of the mentioned

    Answer: d
    Explanation: This is because heat transfer is a path function.

14. Describe briefly an experiment that you have carried out in the laboratory to determine the specific heat capacity of a metal by the method of mixtures.
15. Calculate the amount of heat energy required to raise the temperature of 3 kg of copper from 25 °C to 75 °C if the specific heat capacity is 390 J/kg K.
16. Conduct an experiment to determine specific heat capacity of a solid metal block using various methods

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Mechanical workshop
- Relevant practical materials

References (APA)

Hurlow J W & Lake J (1969), Examples in engineering science for mechanical engineering technicians, Bell and Bain Ltd, Glasgow

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Hurlow J W & Lake J (1969), Examples in engineering science for mechanical engineering technicians, Bell and Bain Ltd, Glasgow

Bigelow, J. 1829. *Elements of Technology*. Boston: Boston Press,

Calvert, M. A. 1967. *The Mechanical Engineer in America, 1830-1910.* Baltimore, MD: John Hopkins Press.

6.3.1.9 Learning Outcome No 9: Apply density knowledge

Learning Activities

Learning Outcome No 9; Apply density knowledge	
Learning Activities	**Special Instructions**
Activity: *Determine the Density of a Gas* A gas can be compressed so the density of a gas changes. Place a beaker inside a bath filled with water so that the beaker is about ½ filled with water and the other ½ air. (you might have to let some air out by tilting the beaker.) Add water to the bath. What happens to the water level inside the beaker? Has any air escaped the beaker? Has the amount of air inside the beaker changed? What happens to the density of the air inside the beaker when you add the water?	Definition of density for various materials

Information Sheet: 6.3.1.9

Introduction

By the end of this learning outcome, the trainee should have the ability to solve simple problems on density.

Density is the mass per unit volume of material,

i.e. density = $\frac{\text{mass}}{\text{volume}}$

SI unit: kg/m^3

The density of water is 1000 kg/m^3 or 1 g/cm^3 and 1 kg of water has a volume of 10^{-3} m 3 (1 dm^3 or 1 litre).

Relative density or specific gravity of a substance is the ratio:

$\frac{\text{density of substance}}{\text{density of water}}$

Since it is a ratio, relative density has no units.

***Example 1**; A small component has a mass of 22 kg, and its volume is found to be 2000 cm^3. Determine the density of the material.*

Solution

Volume = 2000 x 10^{-6} m^3

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{22\ \text{kg}}{2000 \times 10^{-6}\ \text{m}^3}$$

$$= 11 \times 10^3 = 11\,000\ \text{kg/m}^3 = 11\ \text{g/cm}^3$$

***Example 2**; An oil has a density of 850 kg/m^3. What will be the mass of 50 litres?*

Solution

Volume of oil = 50 litre = 50 x 10^{-3} m^3

Mass = volume x density

= 50 xl0^{-3} m^3 x 850 kg/m^3

= 42,500 x10^{-3} kg

= 42.5 kg

Self-Assessment

1.A cube of ice is floating on water surface and when it completely melts, the level of water would _______

a) Increase
b) Decrease
c) Remains unchanged
d) None of the mentioned

Answer: c

Explanation: There is no change in the volume of the water as the space occupied by the ice inside the water body is filled with it.

2.An object is once immersed in oil and once in water. The loss in weight would be

a) More in water
b) More in oil
c) Equal in both oil and water

d) None of the mentioned

Answer: b
Explanation: Density of oil is more than water so there will be more buoyancy force.

3.Volume of the petroleum products changes with temperature so __________ is used to measure specific gravity.
a) Density
b) Specific volume
c) API gravity
d) None of the mentioned

Answer: c
Explanation: Volume of the petroleum products changes with temperature so API gravity is used to measure specific gravity.

4. ___________ is measured in Hydrometer scale.
a) API gravity
b) Specific gravity
c) Density
d) None of the mentioned

5. If a block has dimensions 6 x 8 x 9 cm and the specific gravity is 2.3. What is the density?
a) 2.3 gm/cm3
b) 0.256 gm/cm3
c) 2.659 gm/cm3
d) .00568 gm/cm3

6. What is the mass of the block?
a) 99.36 Kg
b) 9.996 Kg
c) 0.9936 Kg
d) None of the mentioned

7. A substance has a mass of 20 kg and volume of 40 m3. The specific gravity of the substance is 0.80 kg/cm3. What is the reference density (Kg/m3)?
a) 0.25
b) 0.50
c) 0.75
d) 1.00

8. Answer: a
Explanation: Specific gravity = density of the substance / Reference density.

9. A material have a mass of 2 gms and volume of 4 cm3. The material would _____ on water surface.
   a) Completely Float
   b) Completely Sink
   c) Partially Sink
   d) None of the mentioned
   Answer: b
   Explanation: Specific gravity of the material is less than one.

10. A liquid is filled in a cylinder of height 5 cm. mass of the filled liquid is 40 gms. Specific gravity of the liquid is
    a) 10 gm/cm3
    b) 20 gm/cm3
    c) 30 gm/cm3
    d) 40 gm/cm3

11. A block of wood has a mass of 8 g and occupies a volume of 10 cm3. What is its density?
12. A certain oil has a density of 860 kg/m3. Find the mass of 2.5 litres of the oil.
13. Determine the mass of a lead plate having a volume of 2500 cm3, if the density of lead is 11.4 g/cm3.
14. Design an experiment for determining density the goal of this experiment is to determine the density of a small white ball of unknown composition. Available equipment: Small white ball, graduated cylinder, beaker, water, meter stick, string, digital balance.

Tools, Equipment, Supplies and Materials for the specific learning outcome

Scientific Calculators

Mechanical workshop

Relevant reference material

Relevant practical material

Stationeries

References (APA)

Hurlow J W & Lake J (1969), Examples in engineering science for mechanical engineering technicians, Bell and Bain Ltd, Glasgow

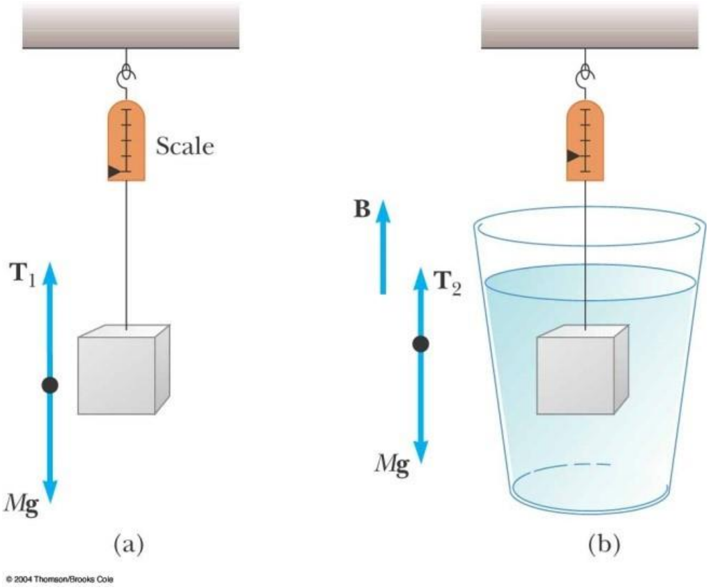
Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Bigelow, J. 1829. *Elements of Technology*. Boston: Boston Press,

Calvert, M. A. 1967. *The Mechanical Engineer in America, 1830-1910.* Baltimore, MD: John Hopkins Press.

6.3.1.10 Learning Outcome No 10: Apply pressure principles

Learning Activities

Learning Outcome No 10; Apply pressure principles	
Learning Activities	**Special Instructions**
Activities; In the workshop, the trainee is to do two experiments involving Archimedes' principle involving metal block submerged in water and **Equipment:** Vertical long rod, clamp, force sensor, metal block + string, plastic beaker, balance plastic cup, small weight, He tank (machine shop), water. 	Definition of pressure to different materials

Information Sheet: 6.3.1.10

Introduction

By the end of this learning outcome, the trainee should be able to solve simple problems on pressure.

Liquids and gases exist in abundance on earth. The existence of life is intimately related to the characteristics of matter in these phases. So consequently, the physics of liquids and gases is not just another topic but is basic to life itself.

A fluid is either *a gas* or *a liquid*
Liquids are nearly incompressible whereas gas is easily compressed

Pressure is the amount of force per unit area upon which the force acts,

i.e. pressure = <u>force</u>

area

SI units; N/m^2, sometimes called pascal (Pa); another useful unit is the bar (bar or b).

$1N/m^2=1Pa$

1 bar = 10^5 N/m^2

= 10 N/cm^2

1 atm = 1.01325 x 10^5 Pa

1 psi = 6.89 x 10^3 Pa

- Measuring device: fluid pushes against "spring", deduce force from displacement
- Pressure exists at all points, not just walls (like tension in string)
- Pressure is *same* in all directions at a point
- Pressure increases with depth in liquid (*not* in gas)

Causes of Pressure
- Difference in pressure between liquids and gases due to (in) compressibility
- compare 2 jars containing mercury liquid and gas: without gravity (outer space) and with gravity
- 2 contributions to pressure:
    (i) Gravitational: fluid pulled down, exerts forces on bottom and side
    (ii) Thermal: collisions of gas molecules with walls

Pressure in Gases
- For lab. -size container, gravitational contribution negligible → pressure is same at all points
- increases with density (more collisions with wall)

Atmospheric pressure

• Density decreases as we go away from earth's surface → atmospheric pressure decreases• At sea-level: 101, 300 Pa = 1 atm. (not SI unit)

• Fluid exerts pressure in all directions net force = 0 ("sucking" force due to no air on one side)

Pressure in liquids

• Gas fills entire container (compressible) vs. liquid fills bottom, exerting force: gravitational contribution dominant

• Pressure at depth d (assuming density constant: <u>not</u> for gas):

$mg + p_0A = pA$

$m = \rho A$

$p = p_0 + \rho gd$

Connected liquid rises to same height in all open regions of container

Pressure same at all points on horizontal line

Pascal's principle: change in pressure same at all points;

$p = p_0 + \rho gd \rightarrow p^1 = p_1 + \rho gd$

(change in pressure at surface)

$\Rightarrow \Delta p = p_1 - p_0$ for all d

Measuring Pressure

• Manometer (for gas pressure):

• Barometer (for atmospheric pressure)

1 atm. = 101.3 k Pa h = 760 mm of mercury

Hydraulic Lift

• Use pressurized liquids for work (based on Pascal's principle): increase pressure at one point by pushing piston...at another point, piston can push upward

Buoyancy: Archimedes' principle

• Buoyant force: upward force of a fluid

• Buoyant force, F_B = weight of displaced fluid, $\rho_f V_f g$

Trainees are encouraged to do further reading on fluids and pressure.

Self-Assessment

1. If the atmospheric pressure at sea level is 7.5 N/cm2, determine the pressure at a height of 3000m assuming the pressure variation follows isothermal law. The density of air is given as 1.2 km/m3.
   a) 4.68 N/cm2
   b) 9.37 N/cm2
   c) 2.34 N/cm2
   d) None of the mentioned

2. The barometric pressure at sea level is 760 mm of Mercury while that on a mountain top is 715 mm. If the density of air is assumed constant at 1.2 kg/m3 , what is the elevation of the mountain top?
   a) 510 m
   b) 1020 m
   c) 255 m
   d) 128 m

3. Calculate the pressure at a height of 6500m above the sea level if the atmospheric pressure is 10.145 N/cm2 and temperature is 25℃ assuming air is incompressible. Take density of air as 1.2 kg/m3. Neglect variation of g.
   a) 4.98 N/cm2
   b) 2.49 N/cm2
   c) 1.24 N/cm2
   d) None of the mentioned

4. Calculate the pressure of air at a height of 3500m from sea level where pressure and temperature of air are 10 N/cm2 and 25℃ respectively. The temperature lapse rate is given as 0.0065 ℃ /m. Take density of air at sea level equal to 1.2 kg/m3.
   a) 19.7 N/cm2
   b) 9.85 N/cm2
   c) 4.93 N/cm2
   d) 6.24 N/cm2

5. Pressure variation for compressible fluid is maximum for which kind of process?
   a) Isothermal
   b) Adiabatic
   c) Quasi Static
   d) None of the mentioned

6. Why can't the density be assumed as constant for compressible fluids?
   a) It shows variation with temperature and pressure
   b) It remains constant with temperature and pressure
   c) It becomes almost constant at very high temperature
   d) None of the mentioned

7. If your mass is 70 kg and the total area of the soles of your feet is 0.2 m2, what pressure would you exert on the ground?
8. If the density of sea water is ρ = 1, 030 kg m−3, what is the pressure at 10 m below sea level?
9. Perform and experiment to show that pressure in liquids increases with depth

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Scientific Calculators
- Relevant reference materials
- Stationeries
- Mechanical workshop
- Relevant practical materials

References (APA)

Hurlow J W & Lake J (1969), Examples in engineering science for mechanical engineering technicians, Bell and Bain Ltd, Glasgow

Zammit S.J (1987), Motor vehicle engineering science for technicians, Longman Group UK Ltd, London

Bigelow, J. 1829. *Elements of Technology*. Boston: Boston Press,

Calvert, M. A. 1967. *The Mechanical Engineer in America, 1830-1910.* Baltimore, MD: John Hopkins Press.

CHAPTER 7: MATERIAL SCIENCE AND METALLURGICAL PROCESSES

7.1 Introduction of the Unit of Learning /Unit of Competency

Material science is the investigation of the relationship among processing, structure, properties, and performance of materials. This unit prepares the trainee to be able to select a material for a given use based on considerations of cost and performance, understand the limits of materials and the change of their properties with use, and create a new material that will have some desirable properties. This branch of science encompasses; determining the structure, measuring the properties of materials, devising suitable ways of processing them i.e. creating materials, transforming existing materials and making useful things out of them, thus materials scientists think about how a material is suited to the purpose it serves already and how it may be enhanced to give better performance for particular applications.

All engineers are involved with materials on a daily basis: They manufacture, process materials, design and construct component or structures using materials, analyze failures in materials. This unit is meant to create awareness to trainees on the types of materials available, to understand their general behavior and capability and to recognize the effects of the environment and service condition and the material performance

7.2 Performance Standard

Test and analyze properties of engineering materials as per material testing method and operation standards procedures, Tabulate, calculate and interpret material testing results, maintain testing machines while observe safety procedures according to OSHA.

7.3 Learning Outcome

7.3.1 List of Learning Outcomes

a. Analyze properties of engineering materials
b. Perform ore extraction processes
c. Produce iron materials
d. Produce alloy materials
e. Produce non-ferrous material
f. Produce ceramic material
g. Produce composite material
h. Utilize other engineering materials
i. Perform heat treatment
j. Perform materials testing
k. Prevent material corrosion

6.3.1.1 Learning Outcome No.1 Analyze Properties of Engineering Materials

Learning Activities

<table>
<tr><td colspan="2">Learning Outcome No1 Analyze Properties Of Engineering Materials</td></tr>
<tr><td>Learning Activities</td><td>Special Instructions</td></tr>
<tr><td rowspan="2">Activity 1
Identify materials as per procedures and determine their physical properties
Materials
emery paper
bulb
electrical cable
magnet
ferrous and nonferrous materials ,
polymers,
Metals and alloys
ceramics
composites
Activity 2
Test engineering material properties
Determine the Yield Strength, Proportional Limit, Modulus of Elasticity, and Ultimate Strength for each metal.</td><td>Use the machine manual on its operation.
Observe Occupational Health and safety as per Act of Kenya laws 2007 with focus on personal safety ,machine safety and workplace

Outline the safety of the engineering materials</td></tr>
<tr><td>EQUIPMENT:
Universal Testing Machine
Extensometer (with dial indicator)
Blade micrometer,
Scale (mm)
Dividers
Gauge mark punch
Hammer
MATERIALS:
Two standard tensile specimens: choose steel, aluminum, brass, or cast iron</td></tr>
</table>

Information sheet: 7.3.1.1

Broad classification of engineering materials

Materials are classified into groups, and according to structure, or properties, or use. Based on the mechanical, physical, chemical and manufacturing properties materials are selected according to the application. These types of materials include;

Metals

Ceramics

Polymers

Semiconductors

Composite materials

Advanced materials

Metals – steel, Al, Mg, Zn

Have good electrical and thermal properties

High strength

High stiffness

Are ductile and thus formable

Are shock resistance

Desirable properties in metals can be improved by a combination of metals – alloys.

Ceramics – Bricks, glass, table ware, ceramics, abrasives.

Have low electrical and thermal conductive thus used as insulators.

Strong and hard but brittle.

Have high excellent resistance to high temperature.

Have unusual optical and electrical properties thus used in constructing ICs.

Polymers: Rubber, plastics and adhesives.

Produced by polymerization process that involves creating large molecular structures for organic molecules.

Have low electrical and thermal conductors.

Have low strength.

Thermoplastic are ductile and formable (softer/fuse when heated and harden or becomes rigid again when cooled.)

Thermosetting (becomes permanently hard and rigid when heated or cooled) are strong and brittle.

Semiconductors: Silicon, germanium.

Are brittle but good for electronics, computer and communication application.

Have a controlled electrical conductivity suitable for devices such as transistors, diodes and integrated circuits.

Composite materials: Concrete, plywood, fiber glass, carbon fiber – reinforced polymers

Formed from 2 or more materials aimed at producing properties that cannot be obtained by any single material.
They have light weight, strong and ductile.
High temperature resistance material

Advanced Materials:

Materials used in "High-Tec" applications, usually designed for maximum performance, and normally expensive. Examples are titanium alloys for supersonic airplanes, magnetic alloys for computer disks, special ceramics for the heat shield of the space shuttle, etc.

Properties of engineering materials

Engineering materials are the backbone of an industry, for an engineer it's not possible to keep detailed knowledge of thousands of materials, as well as keep the detailed knowledge of thousands of materials already available as well as keep in touch with new developments discoveries and inventions .therefore to select the most promising materials the evaluation of service condition followed by evaluation of material characteristics and properties

Categorized as either:
Mechanical properties
Physical properties

Mechanical properties:
Describe how a material responds to an applied force. They include strength, ductility, stiffness, impact,fatigue,endurance,creep,malleability,elasticity,toughness,Brittleness,plasticityhardness ,stiffness,resilience
Other mechanical properties include;
Impact – Sudden intense blow,
Fatigue – Cycling continually through an alternating form,
Creep – Exposed to high temperature,
Wear – Subjected to abrasive conditions.

Physical properties:

This depends on structure and processing. They Are inherent in a material and are determined by the electron structure and bond. They include color, luster, density, electric and thermo conductivity, texture, melting point, electrical resistivity.

Tasks

(i) Read more on various mechanical and physical characteristics of materials,

(ii) Experiments carry out various mechanical properties tests using the necessary apparatus/machines

Structure of materials
Atomic structure – Arrangements of electrons surrounding the nuclear affect most of the physical properties. Types of bonding-primary and secondary bonds

Primary bonds –*discuss the various types of bonds-ionic, covalent, metallic*
Secondary bond *Discuss types of secondary bonds*

Crystalline state of metals or metallic space lattices

Crystal structure-regular and repetitious pattern in which groups of atoms of crystalline materials arrange themselves

Space lattice- a distribution of points/atoms in three dimensions if every point has identical surrounding

Unit cell- the fundamental grouping of atoms which is repeated indefinitely in all three dimensions in a crystal's space lattice
The common metal crystallize in one of the three main types of metallic space lattices these are:
Body centred cubic(B.C.C.)
Face centred cubic (F.C.C.)
Hexagonal close packed (H.C.P)

Draw the space lattices and give examples of metals in each category

Dendritic solidification of pure metal
Nuclei formation
Dendrite formation
Dentrite growth
Liquid between the arms of the dendrite solidifies giving homogeneous grains with no evidence of dendrite growth, except where shrinkage occurs ,with the formation of dentritic porosity

Further reading on the following Content;

classification of engineering materials, types of materials, properties of engineering materials, structure of materials, analysis of crystal structure, application of materials, safety

Further reading on defects or imperfections in crystals. R.S. Khurmi and J.K. Gupta (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

Self-Assessment

1.The tendency of a deformed solid to regain its actual proportions instantly upon unloading known as ______________

a) Perfectly elastic
b) Delayed elasticity
c) Inelastic effect
d) Plasticity

2. The permanent mode of deformation of a material known as _____________
   a) Elasticity
   b) Plasticity
   c) Slip deformation
   d) Twinning deformation

3. The ability of materials to develop a characteristic behavior under repeated loading known as ___________
   a) Toughness
   b) Resilience
   c) Hardness
   d) Fatigue

4. What effect does the addition of thermal energy have on a material?
   a) Thermal contraction
   b) Thermal expansion
   c) No change
   d) Reproduction

5. Which term is used to define the temperature at which a substance changes its status from solid to liquid?
   a) Boiling point
   b) Melting point
   c) Condensation point
   d) Freezing point

6. Define the following terms

i. Ductility
ii. Malleability
iii. Brittleness

7. Identify the types of engineering materials as per the procedures

8. Determine the physical properties of engineering materials

9. Explain how mechanical properties of engineering are tested

10. Observe the crystal structure of materials and analyze it

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Testing instrument
- Extraction materials
- Measuring instrument
- Inspection tools

References (APA)

R.S. Khurmi and J.K. Gupta (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.2 Learning Outcome No 2 Perform Ore Extraction Processes

Learning Activities

Learning Outcome No 2 Perform Ore Extraction Processes	
Learning Activities	**Special Instructions**
Activity Perform ore extraction **Material** Integrated Extraction Simulator (IES) - CRC ORE soft ware *Safety procedures are observed according OSHA* *2Method of extraction is determined as per material properties and its composition* *Procedure in extraction process is determined as per extraction method* *Extraction by- products are stored as per SOPs*	Integrated Extraction Simulator (IES) - CRC ORE software guide Use the machine manual on its operation. Observe Occupational Health and safety as per Act of Kenya laws 2007 with focus on personal safety ,machine safety and workplace

Extraction by- products are disposed as per SOPs	

Information sheet: 7.3.1.2
Introduction

Extraction is the process that involves the removal of minerals from the ore. Ore are rocks that contains minerals in them.

Safety Tips to Reduce Mining Accidents

- Don't Ignore the Danger
- Dangerous Tasks Require Planning and Communication
- Get Professional Training
- Always Wear Safety Equipment
- Document Your Safety Procedures
- Follow the Latest Safety Standards
- Ensure all safety equipment is serviced regularly and satisfies all the latest safety standards. Never try to save

Reduction of Metals (Extraction from Ore)

There are 3 main methods of extracting metals from their ore.

They are reduction of the ore with carbon, reduction of the molten ore by electrolysis, and reduction of the ore with a more reactive metal.

Extraction using carbon

Metals such as zinc, iron and copper are present in ores as their **oxides.** Each of these oxides is heated with carbon to obtain the metal.

The metal oxide **loses** oxygen, and is therefore **reduced**. The carbon **gains** oxygen, and is therefore **oxidized.**

Electrolysis

Ionic substances can be **broken down** into the elements they are made from by electricity, in a process called **electrolysis.**

For electrolysis to work, the ions must be **free to move**. When an ionic compound is **dissolved** in water, or melts the ions break free from the ionic lattice. These ions are then free to move. The solution or molten ionic compound is called an **electrolyte.**

During electrolysis:

Positively charged ions move to the negative electrode. Metal ions are positively charged, so metals are produced at the negative electrode (cathode).

Negatively charged ions move to the positive electrode. Non-metal ions, such as oxide ions and chloride ions, are negatively charged, so gases such as oxygen or chlorine are produced at the positive electrode (anode).

Reduction of metal halides with metals

In many cases, carbon cannot be used to reduce the metal oxide to the metal as the metal reacts with carbon to form the carbide instead.

It is possible to avoid this problem by first converting the ore to the chloride, and then reducing the chloride with a more reactive metal such as magnesium or sodium. This is the method used to extract titanium.

MINERAL: It is a naturally occurring inorganic compound of one or more metals in association with nonmetals such as oxygen, Sulphur and the halogens. A mineral has fixed composition and well defined physical and chemical properties.

ORE: It is the naturally occurring aggregate or combination of minerals from which one or more metals or minerals may be extracted economically (profitably).

UNIT OPERATIONS: The physical processes like crushing, grinding, classification, concentration etc. are called unit operations.

UNIT PROCESSES: The chemical processes like calcination, smelting, roasting, leaching etc. are called unit processes.

Pyrometallurgy:

Pyro metallurgy deals with the methods of extraction of metals from their ores and their refining and is based on physical and chemical changes occurring at high temperatures.

What are the advantages of high temperature?

As at high temperature, the reaction rate is accelerated which leads to more metal production.

Also at high temperature the inexpensive reducing agent can be used and cheaper raw material can be used

As we know that the reaction rate doubles in each 10ºC rise of temperature which requires small activation energy. It helps in fast reaction.

Shift of reaction is possible.

Brings about a reduction which cannot takes place in presence of water.

Only pyrometallurgy and fused salt electrolysis can extract reactive metals namely the alkaline earth metals zirconium and titanium.

Ability to treat a large tonnage of ore in a compact space, which leads to a saving in capital cost.

There are 4 processes that are included in pyro metallurgical treatment. i.e.

i. Calcination
ii. Roasting
iii. Smelting
iv. Refining

Calcination:

Calcination is the thermal treatment of an ore that brings about its decomposition and elimination of volatile products i.e. carbon dioxide and water.

Temperature required for this process can be calculated from free energy temperature relationship for the reaction under consideration.

As the most decomposition reaction is endothermic, so the temperature of calcination is generally depends on the transfer of heat into the particle. This result in even high temperature of the furnace (kiln) at the expanse of some fuel.

For example, $CaCO_3$ (c) = CaO (c) + CO_2. This reaction is endothermic and requires high temperature to decompose it in the kiln

Roasting

Roasting of an ore or a concentrate is a chemical process in which chemical conversion of ore is taken place by employing oxygen or other element.

This process was used to remove Sulphur or other elements such as arsenic and tellurium in the form of a volatile oxide from an ore.

Factors Affecting Roasting

Time (duration)

Availability of oxygen or air

Temperature

Physical condition of the ore

Nature of the mechanical device used

Duration of Roasting Process Varies Greatly

Blast roasting is done in a mere flash of time

Hearth roasting takes hour.

Heap roasting months

Weather roasting year.

Sinter Roasting (Sintering):

Heavy dust loss if agglomeration is not done.

Permeability reduced it jam the furnace

Steps in sinter roasting

The fine concentrate is charged as a layer 15-50 cm thick on to the endless revolving belt or grate or pallets which moves over wind boxes at regular speed.

Burners under the ignition hood is used to start the combustion of the bed surface. This combustion is propagated through the mass or charge by a current of air drawn through the charge into the wind box below which is connected a suction fan sufficient high temperature are develop in the material to cause partial or incipient fusion which produces a pores cinder like material called sinter

When the sinter reaches the end of the machine it is discharged and cooled

The cooled sinter is sized to give a uniform product.

Smelting

Process by which a metal is obtained, either as the element or as a simple compound, from its ore by heating beyond the melting point, ordinarily in the presence of oxidizing agents, such as air, or reducing agents, such as coke.

Heating process of production of metal or matte.

• Reducing agent- C/S/sulphide

• Furnace used- reverberatory furnace, blast furnace, electric arc furnace

• As gangue is less fusible than metal so flux must be added to form slag which is easily fusible.

Mineral + gangue+ reducing agent+ flux = metal/matte + slag + gas

Blast furnace- reduction smelting

Reverberatory furnace- matte smelting

Electric arc furnace- reduction smelting and matte smelting

Further reading on;

ore extraction processes, methods of extraction, procedures, factors affecting extraction methods, storage of by-products, disposal of extracted by-products, safety, application

Watch videos on the operation of furnaces

Self-Assessment

1. Which is the most reactive metal?
   a. Iron
   b. Mercury
   c. Sodium
   d. Potassium

2. What is the maximum permissible amount of ash on carbonization after coal is washed?
   a) 2%
   b) 6%
   c) 14%
   d) 21%

3. What is the solid residue that remains after heating of coal in the absence of air?
   a) Resin

b) Coke
c) Powder
d) Whisker

4. What is the level of fineness to be achieved in crushed coal?
   a) 10-20%
   b) 25-40%
   c) 50-60%
   d) 70-80%

5. For how long must coke be burnt?
   a) 2-3 hours
   b) 6-8 hours
   c) 18-24 hours
   d) 30-36 hours

6. What is the appearance of oven coke?
   a) Bluish-green
   b) Reddish-brown
   c) Dark grey to light silver
   d) Matte black

7. Which of the following factors are not used to evaluate the quality of coke?
   a) Size and shape
   b) Moisture
   c) Ignitability
   d) Electrical resistivity

8. Which of the following is not an advantage of coke over coal?
   a) Purity
   b) Porosity
   c) Low smoke
   d) Water

9. Discuss the working principle of smelting furnaces

10. Determine the method of extraction as per material properties and its composition

11. Determine the process of extraction as per extraction method procedure

12. Carry out extraction by-production storage and disposal as per SOPs

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Testing instrument
- Extraction materials
- Measuring instrument
- Inspection tools

References (APA)

Khurmi, R. S. & Gupta, J. K. (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.3 Learning Outcome No 3 Produce Iron Material

Learning activities

Learning Activities	**Special Instructions**
Activity 1 Watch you tube video on extraction of iron- Number 7 Blast Furnace - YouTube https://www.youtube.com/watch?v=og-Pzzf2zdM Blast Furnace (1940-1949) - YouTube https://www.youtube.com/watch?v=rvlOmkaxre8 Describe the process **Activity 2** Produce pig iron, cast iron and steel **Material** steeluniversity.org simulator	Simulator manual Use the machine manual on its operation. Observe Occupational Health and safety as per Act of Kenya laws 2007 with focus on personal safety ,machine safety and workplace

Information sheet: 7.3.1.3

Ferrous Alloys

Metal alloys, by virtue of composition, are often grouped into two classes ferrous, and nonferrous. Ferrous alloys, those in which iron is the principal constituent, include steels and cast irons.

Pig Iron

It's the crude form of iron and is used as the raw material for the production of various other ferrous metals such as cast iron, wrought iron and steel. The pig iron is obtained by smelting iron ores in a blast furnace. The principals raw materials required in the production of pig iron are; iron ore, fuel and flux.

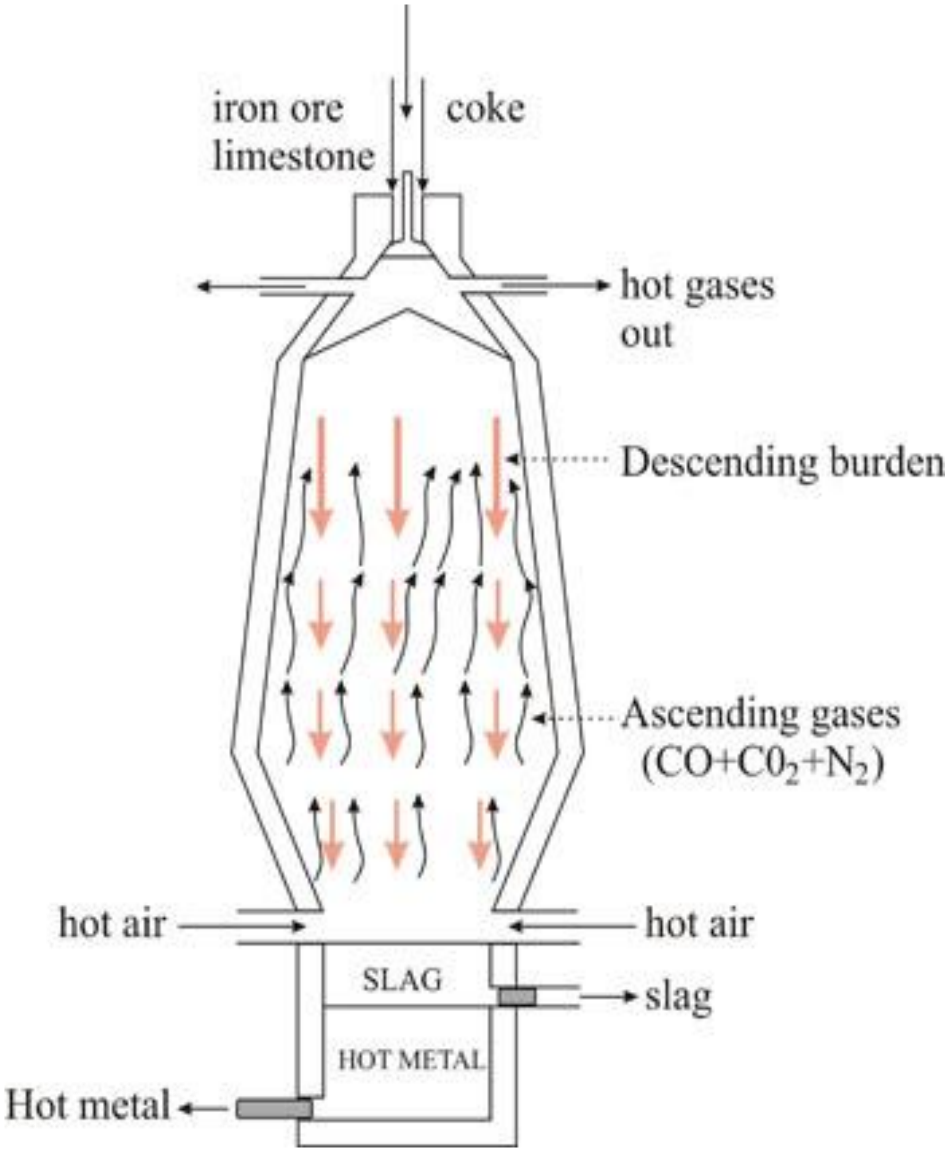
The iron ore itself is usually found in the form

i. Magnetite (Fe_3O_4),
ii. Hematite (Fe_2O_3)
iii. Goethite ($FeO(OH)$)
iv. Limonite ($FeO(OH).n(H_2O)$)
v. Pyrite (FeS_2)
vi. or siderite ($FeCO_3$).

Pig iron is obtained from the iron ore in the following Steps:

Concentration
Calcinations/roasting
Smelting

Blast furnace



Task: Describe the blast furnace, the melting of iron ore in the blast furnace (the reactions)

Watch you tube video on the manufacture of pig iron

Manufacture of cast iron (cupola)

The cupola furnace works on a simple principal that combustion of coke generates carbon dioxide and heat and this causes the iron to melt. The iron drains downward when get melted

Task draw and describe the working principles of a cupola furnace

Broadly, iron's compounds can be divided into two groups known as ferrous and ferric (the old names) or **iron (II)** and **iron (III)**; you can always substitute "iron (II)" for "ferrous" and "iron (III)" for "ferric" in compound names.

In iron (II) compounds, iron has a valency (chemical combining ability) of +2. Examples include iron (II) oxide (FeO), a pigment (coloring chemical); iron (II) chloride ($FeCl_2$), used in medicine as "tincture of iron"; and an important dyeing chemical called iron (II) sulfate ($FeSO_4$).

In iron (III) compounds, iron's valency is +3. Examples include iron (III) oxide (Fe_2O_3), used as the magnetic material in things like cassette tapes and computer hard drives and also as a paint pigment; and iron (III) chloride ($FeCl_3$), used to manufacture many industrial chemicals.

Wrought iron

Puddling process, Aston or Byres process

Manufacture of steel

In all the processes of manufacturing steel, either carbon is added to wrought iron or first decarburizing pig iron and the added the proper amount of carbon

The Bessemer process
Open hearth process
Crucible process
Basic oxygen steelmaking (B.O.S)
Electric furnaces: Direct arc type, induction furnace
Task describe the working principles of the above furnaces

Ferrous Alloys:
Ferrous alloys are those of which iron is the prime constituent—are produced in larger quantities than any other metal type. They are especially important as engineering construction materials. Their widespread use is accounted for by three factors:
iron-containing compounds exist in abundant quantities within the earth's crust;
metallic iron and steel alloys may be produced using relatively economical extraction, refining, alloying, and fabrication techniques; and
Ferrous alloys are extremely versatile, in that they may be tailored to have a wide range of mechanical and physical properties.
The principal disadvantage of many ferrous alloys is their susceptibility to corrosion.
Plain carbon steels

Contain only residual concentrations of impurities other than carbon and a little manganese.

Types of plain carbon steels
Carbon, plain carbon steels are classified into three groups depending on the percentage composition;
Low carbon
Medium carbon
High carbon steels.

Limitations of plain carbon steels
Poor resistance to corrosion and oxidation or scaling at high temperatures.
They suffer rapid softening at elevated temperatures (i.e., above 300^0 C)thus limiting their use in high speed metal cutting operations and other high temperature operations.
They have low hardenability i.e., large sections cannot be effectively hardened hence their use is restricted only to thin sections that can be full-hardened effectively.
Decrease in ductility as the carbon content decreases.
Maximum tensile strength obtainable in plain carbon steels and steels having reasonable toughness and ductility is about 700 MPa.

Steels
Steels are iron–carbon alloys that may contain appreciable concentrations of other alloying elements; there are thousands of alloys that have different compositions and/or heat treatments. The mechanical properties are sensitive to the content of carbon, which is normally less than 1.0 wt%. Some of the more common steels are classified according to carbon concentration, namely, into low-, medium-, and high carbon types. Subclasses also exist within each group according to the concentration of other alloying elements.

Alloy steels
These are steels with other alloying elements in addition to carbon required to introduce new properties that are not available in plain carbon steels. They also improve and extend the existing properties of plain carbon steel.
Alloy steels are classified into:
High–alloy steels - possess microstructures different from plain carbon steels
Low–alloy steels - contains up to 3 or 4 % of one or more alloying elements for the purpose of increasing strength and toughness.

High–Speed Tool Steels

High carbon steels alloyed with tungsten and chromium are used as hard wearing metal–cutting tools, which retain their high hardness at temperatures up to 600^0C. e.g. Composition of commonly used high-speed tool is 18% tungsten, 4% chromium, 1% vanadium and 0.8% carbon.

Stainless Steels

The stainless steels are highly resistant to corrosion (rusting) in a variety of environments, especially the ambient atmosphere. Their predominant alloying element is chromium; a concentration of at least 11 wt% Cr is required.

Stainless steels are divided into three classes on the basis of the predominant phase constituent of the microstructure:

Martensitic Stainless Steels: Are capable of being heat treated in such a way that martensite is the prime micro-constituent. Are iron-chromium alloy steels containing between 12-18%Cr and high carbon content in the range of 0.15-1.2%C.

Properties
Are magnetic under all conditions
Has BCC crystal structure
Have good resistance to corrosion and oxidation at high temperatures.
Applications; pump shafts, turbine blades, springs, ball bearing, surgical instruments, vessels, and regulator valves.
They are magnetic.

Ferritic Stainless Steels: Are composed of the ferrite (BCC) phase. Are the most corrosion resistant because of the high chromium contents and nickel additions; they are produced in the largest quantities. Are hardened and strengthened by cold work because they are not heat treatable.

Properties:
Are magnetic
Relatively soft and ductile
When annealed they are superior than martensite stainless steels in machinability and corrosion resistance
Used extensively in deep drawn parts.
Applications; table ware, beer barrels, cutlery etc.

Austenitic stainless steels:
Have a composition of 18% Cr, 8%Ni and are relatively low carbon content of approximately 0.1%. are generally the most widely used of the stainless steels.
From the composition, the main alloying elements are nickel which is an austenite stabilizer and chromium which is a ferrite stabilizer.

Properties
Non-magnetic in the stabilized austenite structure.
However when cold worked, the austenite stainless steel tends to form ferrite and the material becomes slightly magnetic.
This effect of producing ferrite upon cold working makes the steel difficult to machine
Has FCC crystal structure.
Most ductile compared to the other types of stainless steels.
They do not harden if heat treated, however they can be readily hot worked

Further reading on Content; ferrous materials, composition of iron extraction of pig iron from iron ore, steps to obtain pig iron, blast furnace, manufacture of cast iron, properties, methods of producing iron materials, refinement processes, procedures, safety, application

Further reading; Formation of alloys R. A. Higgins Engineering Metallurgy Part I Applied Physical Met Allurgy By R.A.Higgins (Higgins, Raymond A.)

Self-Assessment
1. What kind of steel requires definite amounts of other alloying elements?
   a) Carbon steel
   b) Alloying steel
   c) Stainless steel
   d) Tool steel

2. Which of these is not a function of alloy steels?
   a) Increases strength
   b) Improves ductility
   c) Reduces cost
   d) Improves machinability

3. Steels containing up to 3% to 4% of one or more alloying elements are known as ________
   a) Low alloy steels
   b) HSLA steels
   c) High alloy steels
   d) Stainless steels

4. What does AISI steel stand for?
a) American-Indian Steel Institute
b) American-Indian Society of Iron
c) American Iron and Steel Institute
d) Alloys, Iron and Steel Institute

5. Which of these is not an application of HSLA steels?
a) Bridges
b) Automobiles and trains
c) Building columns
d) Leaf and coil springs

6. Steels containing more than 5% of one or more alloying elements are known as ________
a) HSLA steels
b) High alloy steels
c) Tool and die steels
d) Stainless steels

7. Which of the following groups of alloying elements stabilize austenite?
a) Ni, Mn, Cu, and Co
b) Cr, W, Mo, V, and Si
c) Cr, W, Ti, Mo, Nb, V, and Mn
d) Co, Al, and Ni

8. Which family of steels are referred to as chromoly?
a) 40xx
b) 41xx
c) 43xx
d) 44xx

9. What is the common name of COR-TEN steel?
a) Weathering steel
b) Control-rolled steel
c) Pearlite-reduced steel
d) Microalloyed steel

10. Alloy steels containing 0.05% to 0.15% of alloying elements are called _______
a) Weathering steel
b) Stainless steel
c) Tool and die steel
d) Microalloyed steel

11. Perform ore smelting according to standard operating procedures
12. Determine composition of iron

13. Establish the methods of producing iron material
14. Identify refinement processes based on iron material required
15. Perform refinement process on iron material

Tools, Equipment, Supplies and Materials for the specific learning outcome
Testing instrument
Extraction materials
Measuring instrument
Inspection tools

References (APA)
R.S. Khurmi & J.K. Gupta (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.4 Learning Outcome No 4 Produce Alloy Material

Learning Activities

Learning Activities	Special Instructions
Activity 1 **Making an alloy (solder)** **Eye protection** **Thermal protection gloves** **Each working group requires:** **Crucible** **Pipe clay triangle** **Bunsen burner** **Tripod** **Heat resistant mat** **Spatula** **Tongs (Note 1)** **Casting sand (Note 2)** **Metal sand trays or sturdy metal lids, 2 (Note 2)** **Balance (no decimal places needed)** Lead (Toxic, Dangerous For The Environment), about 2 g Tin, about 2 g Carbon powder, about 2 g **Procedure** **Making the alloy** Weigh out 1 g each of lead and tin. Put the lead into the crucible, but keep the tin to one side. If using casting sand, fill one of the sand trays with casting and push your finger into it to make an indent. This is your cast. Put the crucible onto a pipe clay triangle. Make sure that it is stable on a tripod and mat. Heat the crucible strongly with a Bunsen burner until the lead is molten. Add a spatula of carbon powder to the top of it to prevent a skin forming. Add the tin and stir with a spatula until the metals are both molten and thoroughly mixed. Move the Bunsen away from the tripod and put it onto a yellow flame. Wearing thermal protection gloves, pick up the crucible using the tongs, and pour the molten metal into the cast or onto a ceramic	Use the machine manual on its operation. Observe Occupational Health and safety as per Act of Kenya laws 2007 with focus on personal safety ,machine safety and workplace

tile. Take great care as you do this to avoid splashing or dripping. Let it cool down completely before you touch it.	

Information sheet: 7.3.1.4

Alloy is a metal that is made by mixing together two or more metals, or a metal and another

Basic properties

Melting point. Mixing two or more metals in the liquid state produces a new material, typically with a lower melting point and often with temperature range for complete melting to occur. This property is the basis for many brazing and soldering alloys , where two or more metal are mixed to reduce the melting point and provide a material that flows into different types of joint gaps.

Process ability

Alloys can be forged into complex shapes or extruded into small wires.
Strength as in Ultimate Tensile strength and Yield strength.
Mixing two or more metals increases the strength and hardness of the material. Which translates to an increase in strength and hardness
Electrical and thermal conductivity.

These are grouped together because they are intrinsically linked by their dependence on their metallic electron cloud. Adding two pure metals to make an alloy nearly always produces a material with higher resistivity (lower conductivity) than either of the pure metals

Further Reading:

Content; alloys, basic properties of alloy, alloys formation, identification of materials in alloy formation, alloy formation processes, procedures, uses of equilibrium diagrams, test of alloys, safety, application

Formation of alloys R. A. Higgins Engineering Metallurgy Part I Applied Physical Met Allurgy By R.A.Higgins (Higgins, Raymond A.) pg 165-183

Self-Assessment

1. How much carbon is present in cast irons?
   a) Less than 0.05%
   b) Up to 1.5%
   c) 1.5% to 2%
   d) More than 2%

2. Cast iron is a _____ alloy.
   a) Eutectic
   b) Eutectoid

c) Peritectic
d) Peritectoid

3. Iron obtained from broken ______ is known as white iron.
a) Cementite
b) Graphite
c) Pearlite
d) Bainite

4. If the iron surface contains graphite, it is known as ________
a) Alloy cast iron
b) White iron
c) Grey iron
d) Spheroidal graphite

5. Which element causes cementite to behave in a stable manner?
a) Silicon
b) Sulphur
c) Manganese
d) Carbon

6. An iron with high-silicon content is a _______
a) White iron
b) Grey iron
c) Malleable iron
d) Pig iron

7. What is the effect of phosphorus and sulphur in cast irons?
a) Induces brittleness
b) Increases strength
c) Destabilizes cementite
d) No effect

8. Decomposition of cementite to form ferrite and graphite is known as _______
a) Decomposition of cast irons
b) Production of cast irons
c) Growth of cast irons
d) Prevention of growth of cast irons

9. Which of these are applications of grey cast iron?
a) Camshafts, engine blocks
b) Wear plates, pump linings
c) Brake shoes, pedals
d) Gears, rocker arms

10. Which of the following cast irons cannot be machined?
a) White cast iron
b) Grey cast iron

c) Malleable cast iron
d) Spheroidal graphite cast iron

11. Draw the various thermal equilibrium diagrams for alloys

12. Perform ore smelting according to standard operating procedures

13. Determine the composition of iron

14. Establish the methods of producing iron materials

15. Identify refinement processes based on iron material required

16. Carry out alloy test based on alloy production requirement

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Testing instrument
- Extraction materials
- Measuring instrument
- Inspection tools

References (APA)

R.S. Khurmi & J.K. Gupta (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.5 Learning Outcome No 5 Produce Non Ferrous Metals

Learning Activities

Learning Outcome No 5 Produce Non Ferrous Metals	
Learning Activities	Special Instructions
Activity 1 To recycle aluminum cans and make a useful product, Alum (potassium aluminum sulfate $KAl(SO_4)_2 \cdot 12H_2O$. To understand the processes involved in recycling, their importance, and the difficulties in doing so. MATERIAL 2 large ice baths 1 full aluminum beverage can Sand paper Scissors 4.00 g KOH 50 mL volumetric flask Distilled water 250 mL beaker 100 mL beaker 2-25 mL graduated cylinders 12.0 mL concentrated sulfuric acid Filter paper (2 pieces; 1) Funnel Universal ring stand assembly Stirring rod Hot plate Electronic balance 12 mL Ethanol	Use the machine manual on its operation. Observe Occupational Health and safety as per Act of Kenya laws 2007 with focus on personal safety ,machine safety and workplace

7.3.1.5 Information sheet

Introduction

Non-ferrous metals are those which do not contain significant quantity of iron or iron as base metal. These metals possess low strength at high temperatures, generally suffer from hot shortness [FAD] and have more shrinkage than ferrous metals.

They are utilized in industry due to following advantages:

High corrosion resistance

Easy to fabricate, i.e., machining, casting, welding, forging and rolling

Possess very good thermal and electrical conductivity

Attractive colour and low density

But these metal are expensive than ferrous metals as they are not abundantly available
However different materials have distinct characteristics, and are used for specific purposes.
The various non-metals used in industry are: copper, aluminium, tin, lead, zinc, and nickel, etc., and their alloys.

Aluminium

Aluminium is white metal which is produced by electrical processes from clayey mineral known as bauxite. However, this aluminium ore bauxite is available in India in plenty and we have a thriving aluminium industry.

Properties:

These are characterized by low density, high thermal & electrical conductivities,
Good corrosion resistant characteristics because of formation of Al2O3 protective layer.
As Al has FCC crystal structure, these alloys are ductile even at low temperatures and can be formed easily.
However, the great limitation of these alloys is their low melting point (660 ◌̊C), which restricts their use at elevated temperatures.

Procedure: (This is a two day lab)

Remove the paint from the outside of the aluminium can using sand paper (this is easier to do if the can is full). Why is it important to remove the paint?

Once the paint has been removed, drain the contents of the can and rinse it. Then cut a piece of aluminum approximately 5 cm x 7.5 cm from the can. Using sand paper, remove the polymer coating on the inside of the can. Why do you think there is a coating on the inside of the can? Why is it important to remove it?
Weigh the cleaned piece of aluminium. You need approximately 1.0 g of aluminium (a mass between 0.90 g and 1.20 g is acceptable). If your mass of aluminium is between these values, proceed to step 4. If not, then cut to the appropriate mass range before proceeding to step 4.

Obtain the mass of a labelled 250 mL beaker. Record in the data table provided. Cut your aluminium sample into small pieces. (How will this affect the rate of the reaction compared with leaving the aluminium in one large piece?) Place the small pieces of aluminium into the 250 mL beaker.

Obtain the mass of the beaker containing the aluminium (to the nearest 0.01 g). Record in the data table provided.

Determine the mass of the aluminium by subtracting the mass of the beaker from the mass of the beaker containing the aluminium pieces. Record in the data table provided.

Mass (to the nearest 0.01 g) approximately 4.0 g of KOH and add it to 50 mL volumetric flask. Record the exact mass of the KOH in the data table provided. Add about 25 mL of distilled water and swirl to dissolve the KOH. Once the KOH has been dissolved, fill the volumetric flask with distilled water to the 50 mL mark.

Which ions/molecules are present in the volumetric flask?

Add this KOH solution the 250 mL beaker containing the aluminium pieces.

Place the 250 mL beaker in the fume hood for about 15 minutes or until all of the aluminium pieces have finished reacting. The reaction is complete when no more aluminium pieces are visible and no more H_2 gas is evolving.

The reaction is: $2KOH(aq) + 2Al(s) + 6H_2O(l) \rightarrow 2KAl(OH)_4(aq) + 3H_2(g)$

Record qualitative observations while the aluminum is reacting with the KOH. Is this an endothermic or exothermic reaction?

Note the periodic rise and fall of aluminum pieces during the reaction. Suggest an explanation.

During the 15 minute waiting period, place 13 mL of distilled water into a labelled 100 mL beaker and very slowly add 12 mL of concentrated H_2SO_4 (pre-measured for you in a 25 mL graduated cylinder). Always add acid to water. This step should be performed in a fume hood. Use gloves if available.

Carefully place the beaker of hot H_2SO_4 solution in an ice bath for approximately 10 minutes.

After the aluminium has finished reacting with the KOH solution, place the 250 mL beaker into an ice bath. Allow the black residue to settle to the bottom of the beaker. This black residue may be a result of the decomposition of residual paint or plastic lining.

While both solutions are cooling, set up the filtration apparatus using the universal stand and ring assembly.

Filter the $KAl(OH)_4$ through a funnel into the cold sulphuric acid solution. Slowly stir the white precipitate (which is $Al(OH)_3$).

The reaction is: $2KAl(OH)_4(aq) + H_2SO_4(aq) \rightarrow 2Al(OH)_3(s) + K_2SO_4(aq) + 2H_2O(l)$

Some of the solid aluminium hydroxide reacts with the sulphuric acid, forming aluminium sulphate which reacts with potassium sulfate in the solution to form the final product alum. The overall reaction is shown in step 18 below.

Once filtering is complete, warm the white precipitate gently on a hot plate until it has all dissolved.

Leave the beaker to sit undisturbed overnight. As the solution cools, solid alum will precipitate forming crystals.

The overall balanced reaction is:

$2Al(s) + 2KOH(aq) + 4H_2SO_4(aq) + 22H_2O(l) \rightarrow 2KAl(SO_4)_2 \cdot 12H_2O(s) + 3H_2(g)$

Applications:
Aerospace: The absolute requirement for light structures, make aluminium and its alloys now more than ever the number one material in the sky.
Automotive: Chassis, bodies, engine blocks, radiators, hubcaps etc. because of its lightweight and corrosion resistance
Marine: Marine transport is increasing its use of aluminium by capitalizing on its two leading qualities: lightness and corrosion resistance. Advanced alloys have enabled the design of high-speed ships, by lightening hulls by 40% to 50% over steel.

Alloys of Aluminium
Aluminium may be alloyed with one or more alloying elements such as copper, manganese, magnesium, silicon and nickel.
Advantage of alloy addition
The addition of small quantities of alloying elements converts the soft and weak aluminium into hard and strong metal, while it retains its light weight.
The main **alloys of aluminium** are: Duralumin, Y-alloy, Magnalium and Hindalium which are discussed as follows

a) Duralumin
Composition:
This is a famous alloy of aluminium containing 4% copper, 0.5% manganese, 0.5% magnesium and a trace of iron with remainder as aluminium is known as duralumin.
Properties:
It possesses high strength comparable with mild steel and low specific gravity
However, its corrosion resistance is much lower as compared with pure aluminium
The strength of this alloy increases significantly when heat treated and allowed to age for 3 to 4 weeks, it will be hardened.
To improve upon the corrosion resistance of it, a thin film of aluminium is rolled on the duralumin sheets.
Applications:
These aluminium rolled sheets are known as Alclad by trade name and are widely used in aircraft industry.
Due to lightweight and high strength this alloy may be used in automobile industry.

b) Y-Alloy
It is also known as copper-aluminium alloy.
Composition:
The addition of copper to pure aluminium improves its strength and machinability.
Y-alloy contains 93% aluminium, 2% copper, 1% nickel and magnesium.

Properties:
This alloy is heat treated as well as age hardened just like duralumin.
A heat treatment of Y-alloy castings, consisting of quenching in boiling water from 510°C and then aging for 5 days develops very good mechanical characteristics in them.
Applications:
Since Y-alloy has better strength at elevated temperature than duralumin therefore it is much used in aircraft cylinder heads and piston.
It is also used in strip and sheet form.

c) Magnalium
It is produced by melting the aluminium and 2 to 10% magnesium in a vacuum and then cooling it in vacuum or under a pressure of 100 to 200 atmospheres.
About 1.75% copper is also added to it.
Applications:
Due to its light weight and good mechanical characteristics, it is mainly used for aircraft and automobile components.

d) Hindalium
It is an alloy of aluminium and magnesium with small quantity of chromium.
It is manufactured as rolled product in 16 gauge mainly used in manufacture of anodized utensils.

Further reading materials and Metallurgy by V.K.Machada and G.B.S . Narang p.g 132-141

Copper
The crude form of copper extracted from its ores through series of processes contains 68% purity known as Blister copper. By electrolytic refining process, highly pure (99.9%) copper which is remelted and casted into suitable shapes.
Copper is a corrosion resistant metal of an attractive reddish brown colour.
Properties and Uses:
High Thermal Conductivity: Used in heat exchangers, heating vessels and appliances, etc.
High Electrical Conductivity: Used as electrical conductor in various shapes and forms for various applications.
Good Corrosion Resistance: Used for providing coating on steel prior to nickel and chromium plating
High Ductility: Can be easily cold worked, folded and spun. Requires annealing after cold working as it loses its ductility.
Further reading on manufacture of copper: Reverberatory furnace process (welsh process) and Blast furnace process (Manhe's Process)
Commercial grades of copper

Alloys of Copper

Most copper alloys cannot be hardened or strengthened by heat-treating procedures. Consequently, cold working and/or solid-solution alloying must be utilized to improve these mechanical properties.
Copper alloys are among the best conductors of heat and electricity and they have good corrosion resistance.
The common types of copper alloys are brasses and bronzes.

a) Brass
All brasses are basically alloys of copper and zinc.
Commercially there are two main varieties of brasses:
Alpha brass: Contains up to 36% Zn and rest copper for cold working.
Alpha-Beta brass: Contains 36 to 45% Zn and remainder is copper for hot working.

Effect of Zinc on Copper:
The tensile strength and ductility of brass both increase with increase in content of Zn up to 30% zinc.
With further increase in zinc content beyond 30%, the tensile strength continues to increase up to 45% of Zn, but ductility of brasses drops significantly.
β- phase is less ductile than α-phase but it is harder and stronger.
There are various types of brasses depending upon proportion of copper and zinc.
Fundamentally brass is a binary alloy of copper with as much as 50% zinc.
Various classes of brasses such as cartridge brass, Muntz Metal leaded brass, Admiralty brass, naval brass and nickel brass depending upon the proportion of copper and zinc plus third alloying metal are available for various uses.
Applications:
Brasses possess very good corrosion resistance and can be easily soldered.
Costume jewelry, cartridge casings, automotive radiators, musical instruments, electronic packaging, and coins.

b) Bronze
The alloy of copper and tin are usually termed bronzes.
The useful range of composition is 75 to 95% copper and remainder tin.
In general, it possesses superior mechanical properties and corrosion resistance to brass.
Properties:
The alloy can be easily cold rolled into wire, rods and sheets.
With increase in tin content, the strength of this alloy and its corrosion resistance increases. It is then known as hot working bronze.
Applications:
Bronze is generally utilized in hydraulic fittings, bearings, bushes, utensils, sheets, rods and many other stamped and drawn products.

The properties of bronzes are modified with different alloying elements as below

Phosphor bronze
When bronze contains phosphorus, it is known as phosphor bronze.
Properties:
The composition of the alloy varies according to whether it is to be forged, wrought or cast.
A common type of phosphor bronze has the following composition as per Indian standards.
Copper is 93.6%, tin is 9%, and phosphorus is 0.1 to 0.3%.
The alloy possesses good wearing qualities and high elasticity.
The alloy is resistant to saltwater corrosion.
Applications:
Cast phosphor bronze is utilized for production of bearings and gears.
Bearings of bronze contain 10% tin and small addition of lead.
This is also used in making gears, nuts, for machine lead screws, springs, pump parts, linings and many other such applications.

Gun metal
Composition:
Gun metal contains 2% zinc, 10% tin and 88% copper.
Properties:
Sometimes very small amount of lead is also added to improve castability and machinability.
The presence of zinc improve its fluidity.
Applications:
This bronze is used for bearing bushes, glands, pump valves and boiler fittings, etc.

Silicon bronze
Composition: Silicon bronze has an average composition of 3% silicon, 1% manganese and rest copper.
Properties:
It possesses good general corrosion resistance of copper with higher strength and toughness.
It can be cast rolled, stamped, forged and pressed either hot or cold and can be welded by all the usual methods.
Applications:
Silicon bronze is widely utilized for parts of boilers, tanks, stoves or where high strength as well as corrosion resistance is required.

Bell metal
Composition: This alloy contains 20 to 21% tin and rest copper.
Properties:
It is hard and resistant to surface wear.
It can be readily cast

Applications: Generally utilized for casting bells, gongs and utensils, etc.

Manganese Bronze

Composition: It contains 55 to 60% copper, 40% zinc, with 3.5% manganese.

Properties:

This alloy is highly resistant to corrosion.

It is stronger and harder than phosphor bronze. It has poor response to cold working but can be easily hot worked.

Applications:

It is generally utilized for producing bushes, plungers, feed pumps and rods, etc.

Worm gears are frequently made of manganese bronze.

Muntz Metal

Composition: 60% copper and 40% zinc. Sometimes a small quantity of lead is also added.

Properties:

This alloy is stronger, harder and more ductile than normal brass.

While hot working between 700°C to 750, it responds excellently for process but does not respond to cold working.

Applications:

This alloy is utilized for a wide variety of small components of machines, bolts, rods, tubes, electrical equipment as well as ordnance works.

It is widely employed in producing such articles which are required to resist wear.

Lead

Lead is the heaviest of the common metal. Lead is extracted from its ore known as galena. It is bluish grey in colour and dull lusture which goes very dull on exposure to air.

Properties and Uses:

Its specific gravity is 7.1(w.r.to water) and melting point is 360°C.

It is resistant to corrosion and many chemicals do not react with it (even acids).

It is soft, heavy and malleable, can be easily worked and shaped.

Lead is utilized as alloying element in producing solders and plumber's solders.

It is alloyed with brass as well as steel to improve their machinability.

It is utilized in manufacturing of water pipes, coating for electrical cables, acid tanks and roof covering etc.

Tin

It is a brilliant white metal with yellowish tinge. Melting point of tin is 240°C

Properties and Uses:

Tin is malleable and ductile, it can be rolled into very thin sheets.

It is used for tinning of copper and brass utensils and copper wire before its conversion into cables.

It is useful as a protective coating for iron and steel since it does corrode in dry or wet atmosphere.
It is utilized for making important alloys such as fine solder and moisture proof packing with thin tin sheets.

Zinc
The chief ores of zinc are blende (ZnS) and calamine (ZnCO3).
Zinc is a fairly heavy, bluish-white metal principally utilized in view of its low cost, corrosion resistance and alloying characteristics. Melting point of zinc is 420°C and it boils at 940°C.
Properties and Uses:
High corrosion resistance: Widely used as protective coating on iron and steel. Coating may be provided by dip galvanizing or electroplating.
High fluidity and low melting point: Most suitable metal for pressure die casting generally in the form of alloy.
When rolled into sheets, zinc is utilized for roof covering and for providing a damp proof non-corrosive lining to containers.
The galvanized wires, nails, etc. are produced by galvanizing technique and zinc is also used in manufacture of brasses.

Nickel
About 85% of all nickel production is obtained from sulphide ores.

Properties and Uses:
Pure nickel is tough, silver coloured metal, harder than copper having some but less ductility but of about same strength.
It is plated on steel to provide a corrosion resistance surface or layer.
Widely used as an alloying element with steel. Higher proportions are advantageously added in the production of steel such as monel or inconel.
It possesses good resistance to both acids and alkalis regarding corrosion so widely utilized in food processing equipment.

Alloys of Nickel

a) German silver
Composition:
The composition of this alloy is 60% Cu, 30% Ni and 10% zinc.
Properties:
It displays silvery appearance and is very ductile and malleable.

Applications:
It is utilized for electrical contacts, casting of high quality valves, taps and costume jewellery.
It is also used in producing electrical wires.

b) Monel metal

Composition:

It contains 68% Ni, 30% Cu, 1% iron and remainder small additions of Mn and other elements.

Properties:

It is corrosion resistant and possesses good mechanical properties and maintains them at elevated temperatures.

c) Nichrome

It is an alloy of nickel and chromium which is utilized as heat resistant electrical wire in electrical appliances such as furnaces, geysers and electric iron, etc.

d) Inconel and incoloy

These alloys principally contain, Ni, Cr, Fe, Mo, Ti and very small proportions of carbon. These are used as high temperature alloys. Inconel does not respond to heat treatment.

Magnesium

Principal Ores of magnesium are magnesite, carnallite and dolomite. Magnesium is extracted by electrolytic process.

Properties and Uses:

It is the lightest of all metals weighing around two-thirds of aluminium.

The tensile strength of cast metal is the same as that of ordinary cast aluminium, i.e., 90 MPa.

The tensile strength of rolled annealed magnesium is same as that of good quality cast iron.

Magnesium can be easily formed, drawn forged and machined with high accuracy. (5) In powdered form it is likely to burn, in that situation adequate fire protection measures should be strictly observed.

It's castings are pressure tight and achieve good surface finish. Magnesium castings include motor car gearbox, differential housing and portable tools.

Vanadium

It occurs in conjunction with iron pyrite, free sulphur and carbonaceous matter.

Properties and Uses:

It is silvery white in colour.

Its specific gravity is 5.67.

Its melting point is 1710°C.

When heated to a suitable temperature it can be hammered into any shape or drawn into wires.

It is used in manufacture of alloy steels.

Vanadium forms non-ferrous alloys of copper and aluminium from which excellent castings can be produced.

Antimony

Chief ore of antimony is **stibnite**. To a small extent, antimony is obtained as a by-product in refining of other metals such as lead, copper silver and zinc.

Properties and Uses:

It is silvery white, hard, highly crystalline and so brittle that it may be readily powdered.

Its specific gravity is 6.63 and melting point is 630°C.

It is generally used as an alloying element with most of heavy metals.

Lead, tin and copper are the metals which are most commonly alloyed with antimony.

Cadmium

It is obtained commercially as a by-product in the metallurgy of zinc and to some extent of lead.

Properties and Uses:

White metal with bluish tinge, capable of taking a high polish.

Its specific gravity is 8.67 and melts at 321°C.

It is slightly harder than tin but softer than zinc.

It is malleable and ductile and can be readily rolled and drawn into wires.

It is chiefly utilized in antifriction alloys for bearings. It is also used as rust proof coating for iron and steel. Components of automobiles and refrigerator such as nuts, bolts and trimmings, locks and wire products are plated with it.

Bearing Materials

A bearing material should possess the following characteristics:

It should possess enough compressive strength to provide adequate load carrying capacity.

It should possess good plasticity to negate small variations in alignment and fitting.

Its wear resistance should be adequate to maintain a specified fit.

The coefficient of friction of the bearing material should be low to avoid excessive heating.

Some significant bearing metals are as follows:

Babbitt's metal: It is utilized for production of heavy duty bearings. It is white in colour containing 88% tin, 8% antimony and 4% copper. It is a soft material with a low coefficient of thermal expansion.

Titanium alloys

Ti and its alloys are of relatively low density, high strength and have very high melting point. At the same time they are easy to machine and forge.

However the major limitation is Ti's chemical reactivity at high temperatures, which necessitated special techniques to extract. Thus these alloys are expensive.

They also possess excellent corrosion resistance in diverse atmospheres, and wear properties.

Applications:

Common applications include: space vehicles, airplane structures, surgical implants, and petroleum & chemical industries.

Refractory metals
These are metals of very high melting points. For example: Nb, Mo, W and Ta.
They also possess high strength and high elastic modulus.

Applications:
Space vehicles, x-ray tubes, welding electrodes, and where there is a need for corrosion resistance.

Noble metals
These are eight altogether: Ag, Au, Pt, Pa, Rh, Ru, Ir and Os.
All these possess some common properties such as: expensive, soft and ductile, oxidation resistant.
Ag, Au and Pt are used extensively in jewelry, alloys are Ag and Au are employed as dental restoration materials; Pt is used in chemical reactions as a catalyst and in thermocouples.

Content; non-ferrous materials extraction, non-ferrous material smelting and purification, test of non-ferrous material, identification of alloying elements in non-ferrous material, alloy formation process, test for non-ferrous alloys, procedures, application, safety

Self-Assessment
1.Which of the metal if present will make the alloy ferrous?
   a) Aluminium
   b) Lead
   c) Zinc
   d) Iron

2. Which of the following is costliest among the non-ferrous materials?
   a) Magnesium
   b) Aluminum
   c) Titanium
   d) Copper

3. Which of the following is the lightest among the following?
   a) Magnesium
   b) Aluminum
   c) Titanium
   d) Copper

4. Which of the following element when alloyed with magnesium does not reduce the tendency to crack under stress?
   a) Aluminum
   b) Silicon
   c) Zinc
   d) Copper

5. Which of the following is an alloy of tin?
   a) Brass
   b) Bronze
   c) Pewter
   d) Steel

6. Which of the metal is alloyed with silver to make sterling silver?
   a) Zinc
   b) Copper
   c) Magnesium
   d) Aluminum

7. Tin has low viscosity.
   a) True
   b) False

8. Which of the following is highly resistant to corrosion?
   a) Aluminum
   b) Copper
   c) Iron
   d) Zinc

9. Monel is an alloy of nickel.
   a) True
   b) False

10. Extract non-ferrous materials according to SOP
11. Smelt and purify the extracted non-ferrous as per the SOP
12. Perform the test for non-ferrous material according to SOP
13. Identify alloying elements for non-ferrous materials
14. Identify alloy formation process based on alloy to be produced
15. Perform the test for alloys for non-ferrous material based on production requirement

Tools, Equipment, Supplies and Materials for the specific learning outcome

Testing instrument
Extraction materials
Measuring instrument
Inspection tools

References (APA)

Khurmi R.S. & Gupta J.K. (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.6 Learning Outcome 6 Produce Ceramics

Learning Activities

Learning Outcome No 6 PRODUCE CERAMICS	
Learning Activities	**Special Instructions**
Activity1 **POTTERY MAKING** MATERIAL Kiln clay model drawings Activity 2 **Production of ceramic material** Materials Ceramic material as per the required product Production machine as per the product Finishing machine-lapping, grinding, polishing.as per the quality of the final product .	Observe safety Manufacturing process guidance Use the machine manual on its operation. Observe Occupational Health and safety as per Act of Kenya laws 2007 with focus on personal safety ,machine safety and workplace

Information sheet: 7.3.1.6
Ceramic

A ceramic is a material that is neither metallic nor organic. It may be crystalline, glassy or both crystalline and glassy. Ceramics are typically hard and chemically non-reactive and can be formed or densified with heat. Ceramics are more than pottery and dishes: clay, bricks, tiles, glass, and cement are probably the best-known examples. Ceramic materials are used in electronics because, depending on their composition, they may be semiconducting, superconducting, ferroelectric, or an insulator. Ceramics are also used to make objects as diverse as spark plugs, fiber optics, artificial joints, space shuttle tiles, cooktops, race car brakes, micro positioners, chemical sensors, self-lubricating bearings, body armor, and skis

The dominant characteristics of ceramics are summarized by the following:
They are stable and resistant to chemical attack.
They are brittle, hard, and wear resistant.
They have high temperature strength.
They are good electrical insulators at room temperature.
Their thermal conductivities lie between those of polymers and of metals

CARBON: Carbon occurs in two alternative forms of engineering and commercial importance: graphite and diamond. They compete with ceramics in various applications:

Graphite in situations where its refractory properties are important, and

Diamond in industrial applications where hardness is the critical factor (such as cutting and grinding tools

METALCARBIDE TOOL MATERIALS

Silicon carbide (SiC), tungsten carbide (WC), titanium carbide (TiC), tantalum carbide (TaC) and chromium carbide (Cr_3C_2) are examples of materials for making cutting tools.

They are valued for their hardness and wear resistance in cutting tools and other applications requiring these properties.

WC, TiC, and TaC must be combined with a metallic binder such as cobalt or nickel in order to make/ fabricate useful products. In effect, the carbide powders bonded in a metal framework creates what is known as a cemented carbide

Task Further reading on ceramics V.K. MANCHANDA AND G.B.S.NARANG (1996) Materials and Metallurgy

Content; ceramic materials, composition of ceramic materials, identification of manufacturing processes, ceramic materials production, finishing processes identification, procedures, safety, applications

Self-Assessment

1.Graphite is a good conductor of electricity.
   a) True
   b) False

2. Which of the following is false about ceramic structures?
   a) They are made up of two or more different elements
   b) More complex than metal structures
   c) They are electrically neutral
   d) Less complex than metal structures

3. Which of the following bonds are present in ceramic structures?
   a) Ionics bonds only
   b) Covalent bonds only
   c) Ionic, covalent and a mix of ionic and covalent bond
   d) Mix of ionic and covalent bond only

4. Which of the following is an aluminosilicate?
   a) Steatite
   b) Cordierite
   c) Forsterite
   d) Porcelain

5. Which of the following is magnesium silicates?
   a) Porcelain
   b) Earthenware
   c) Stoneware
   d) Steatite

6. According to the percentage of water absorption in dense silicate ceramic which of the following is has fine microstructure?
   a) 1%
   b) 3%
   c) 4%
   d) 5%

7. There are ceramics which are electric resistant.
   a) True
   b) False

8. According to the percentage of water absorption in porous silicate ceramic which of the following has fine microstructure?
   a) 1%
   b) 1.9%

c) 0.4%
d) 2.1%

9. Which of the following is the firing temperature of earthenware?
   a) 1400 °C
   b) 1300 °C
   c) 1500 °C
   d) 1200 °C

10. Carbon is a ceramic.
    a) True
    b) False

11. What kind of bonds are present in diamond?
    a) Covalent bond only
    b) Ionic bond only
    c) Mix of covalent and ionic bond
    d) Metallic bonds

12. Which of the following materials can be used as a substitute ceramic?
    a) Diamond
    b) Brass
    c) Bismuth
    d) Lead

13. What is a difference between carbon and ceramic?
    a) Both are hard
    b) Both are non metallic
    c) Both have covalent bonds
    d) Both have very high thermal conductivity

14. Identify the composition of ceramic materials
15. Identify the manufacturing process Produce ceramic materials according to manufacturing processes
16. identify the finishing processes

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Testing instrument
- Extraction materials
- Measuring instrument
- Inspection tools

References (APA)

Khurmi, R. S. & Gupta, J.K. (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.7 Learning Outcome No 7 Produce Composites

Learning activities

Learning Outcome No 7 PRODUCE COMPOSITES	
Learning Activities	**Special Instructions**
Activity 1 make composite materials Select composite materials as per instruction manual Composite formation instruction manual testing machine Activity 2 **Carryout finishing processes** Requirements Emery cloth, lapping machine Grinding machine Polishing machine Testing machine	Test the test piece as per composite production requirements Use the machine manual on its operation. Observe Occupational Health and safety as per Act of Kenya laws 2007 with focus on personal safety ,machine safety and workplace

Information sheet: 7.3.1.7
Composite

A composite, in the present context, is a multiphase material that is artificially made, as opposed to one that occurs or forms naturally. In addition, the constituent phases must be chemically dissimilar and separated by a distinct interface. Thus, most metallic alloys and many ceramics do not fit this definition because their multiple phases are formed as a consequence of natural phenomena many composite materials are composed of just two phases; one is termed the matrix, which is continuous and surrounds the other phase, often called the dispersed phase. The properties of composites are a function of the properties of the constituent phases, their relative amounts, and the geometry of the dispersed phase. "Dispersed phase geometry" in this context means the shape of the particles and the particle size, distribution, and orientation a

Definition of a Composite Material

A composite material is defined as a material which is composed of two or more materials at a microscopic scale and has chemically distinct phases.

The following conditions must be satisfied to be called a composite material:

The combination of materials should result in significant property changes. One can see significant changes when one of the constituent material is in platelet or fibrous from.

The content of the constituents is generally more than 10% (by volume).

In general, property of one constituent is much greater than the corresponding property of the other constituent.

In a composite, typically, there are two constituents. One of the constituent acts as a reinforcement and other acts as a matrix. Sometimes, the constituents are also referred as phases.

The reinforcements in a composite material come in various forms:

1. **Fibre:**

Fibre is an individual filament of the material. A filament with length to diameter ratio above 1000 is called a fibre. The fibrous form of the reinforcement is widely used. The fibres can be in the following two forms:

Continuous fibres: If the fibres used in a composite are very long and unbroken or cut then it forms a continuous fibre composite. A composite, thus formed using continuous fibres is called as fibrous composite. The fibrous composite is the most widely used form of composite.

Short/chopped fibres: The fibres are chopped into small pieces when used in fabricating a composite. A composite with short fibres as reinforcements is called as short fibre composite.

In the fibre reinforced composites, the fibre is the major load carrying constituent

2. Particulate:

The reinforcement is in the form of particles which are of the order of a few microns in diameter

Flake: Flake is a small, flat, thin piece or layer (or a chip) that is broken from a larger piece

Whiskers: These are nearly perfect single crystal fibres. These are short, discontinuous and polygonal in cross-section.

Types of fibre

A. Natural fibres- Mineral fibres, Plant/vegetable fibre, Animal fibre.

B. Advanced fibres- Carbon and/or Graphite, Glass fibres, Alumina, Aramid, Silicon carbide, Sapphire

Particle-Reinforced Composites,

Large-particle and dispersion-strengthened composites are the two sub classifications of particle-reinforced composites

Large–Particle Composites

Concrete is a common large-particle composite in which both matrix and dispersed phases are ceramic materials. Since the terms "concrete" and "cement" are sometimes incorrectly interchanged, perhaps it is appropriate to make a distinction between them

Portland cement Concrete The ingredients for this concrete are portland cement, a fine aggregate (sand), a coarse aggregate (gravel), and water

Reinforced Concrete The strength of Portland cement concrete may be increased by additional reinforcement. This is usually accomplished by means of steel rods, wires, bars (rebar), or mesh, which are embedded into the fresh and uncured concrete

Dispersion-strengthened composites

Metals and metal alloys may be strengthened and hardened by the uniform dispersion of several volume percent of fine particles of a very hard and inert material

Task: Explain properties of composite

Reinforced concrete, fibre, reinforced plastics, resin metal, bonded sintered powders, ceramics

Further reading Ning Hu (2012), composite and their properties, Chiba University, Japan

Content; composite materials, types of composite, production of composite materials, formation of composite, elements involved in composite formation, test of composite, safety

Self-Assessment

1. The continuous phase of a composite material is known as its _______
   a) dispersed phase
   b) surrounding phase

c) matrix phase
d) fiber phase

2. Which of the following is a glass forming technique?
a) Powder pressing
b) Hydro-plastic forming
c) Slip casting
d) Fiber forming

3. Drawing and firing operations are done on which of these processes?
a) Pressing
b) Fiber forming
c) Blowing
d) Slip casting

4. Which of the following is not a form of powder pressing?
a) Hot pressing
b) Cold pressing
c) Uniaxial
d) Isostatic

5. What is the firing temperature for particulate forming processes?
a) 50-100oC
b) 150-250oC
c) 300-700oC
d) 900-1400oC

6. What does the term 'green' refer to for drying and firing operations?
a) Fired but not dried
b) Dried but not fired
c) Dried then fired
d) Fired then dried

7. Which pressing technique employs a rubber envelope and application of pressure by fluid?
a) Hot pressing
b) Uniaxial pressing
c) Isostatic pressing
d) Powder pressing

8. Which of these holds true for cementitious bonds?
a) High cost

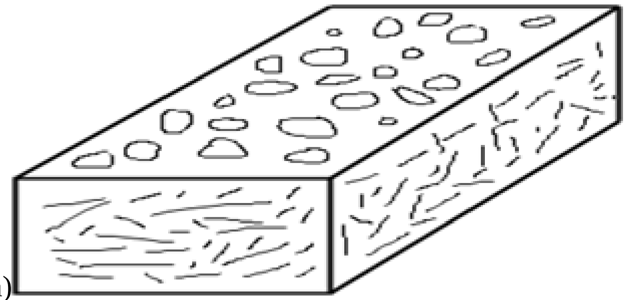
b) Easy to repair
c) Short curing time
d) Hard to repair

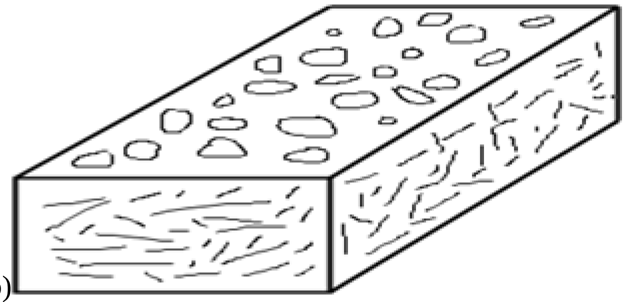
9. Injection molding can be used for parts of thickness up to __________
a) 4 mm
b) 6 mm
c) 8 mm
d) 12 mm

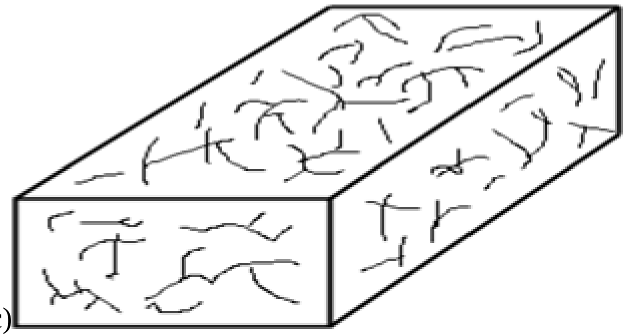
10. What is the common name for fired clay wares?
a) Porcelain
b) Ceramic
c) Pottery
d) China

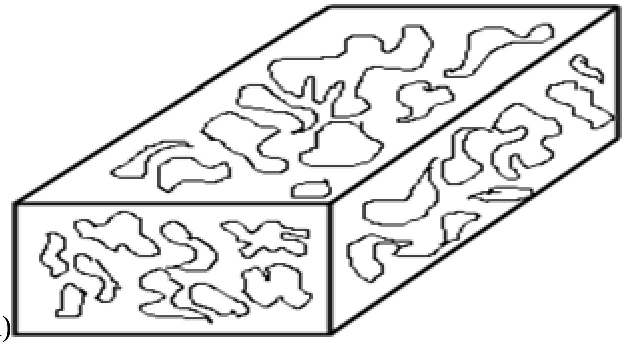
11. The shape forming process PIM known as __________
a) Porcelain Injection Molding
b) Plastic Injection Molding
c) Particulate Injection Molding
d) Pottery Injection Molding

12. Which of the following structures represents that of a fiber composite?


a)


b)

c) 

d) 

13. The classification of fibers having thin crystals is known as _______
    a) Whisker
    b) Fiber
    c) Wires
    d) Matrix

14. Which of the following materials are common for whiskers?
    a) Graphite, silicon carbide
    b) Glass, boron
    c) Steel, tungsten
    d) Polymers, ceramics

15. Kevlar is a ______ type of material.
    a) Glass
    b) Thermoplastic
    c) Whisker
    d) Polymer

16. Which of the following is not a characteristic trait of composite materials?
    a) High strength, toughness, modulus
    b) Lightweight
    c) Easy to assemble
    d) Sensitive to temperature change

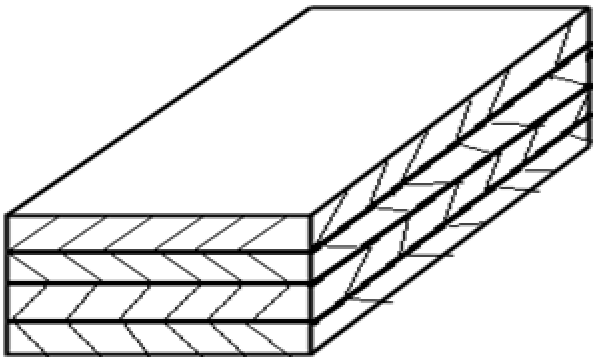
17. How much SiO2 is present in the glass which is drawn into fibers?
    a) 55%
    b) 15%

c) 10%
d) 4%

18. Fiberglass materials have a usable temperature up to ______
a) 50oC
b) 100oC
c) 200oC
d) 500oC

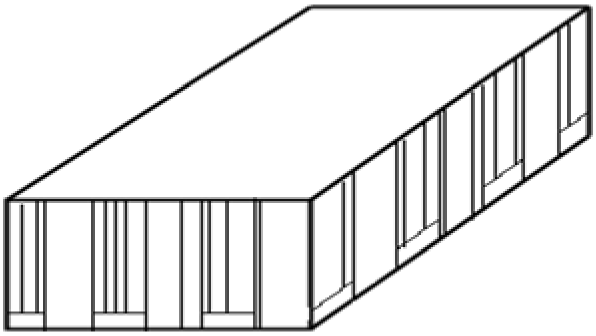
19. What is the purpose of fiberglass that is made as a thread?
a) Insulating material
b) Conductive material
c) Heat resistant
d) Cloth

20. The below figure depicts the structure of ________ composite materials.



a) Discontinuous
b) Aligned
c) Laminate
d) Dispersion-strengthened

21. The below figure is an example of ______ type of structural composites.



a) Laminar
b) Sandwich panel
c) Discontinuous
d) Randomly oriented

22. Manufacturing of components having continuous lengths and the constant cross-sectional shape is done by _____ process.
    a) Roving
    b) Pultrusion
    c) Curing
    d) Pulling

23. What amount of principle reinforcement materials is used in pultrusion process?
    a) 10-20%
    b) 25-35%
    c) 40-70%
    d) 75-90%

24. Identify the type of composite
25. Identify the elements involved in composite formation
26. Identify the formation process of composite production
27. Test the composite as per composite production requirement

Tools, Equipment, Supplies and Materials for the specific learning outcome

Testing instrument

Extraction materials

Measuring instrument

Inspection tools

References (APA)

Khurmi R.S. & Gupta J.K. (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.8 Learning Outcome No 8 Utilize Other Engineering Materials

Learning Activities

Learning Outcome No 8 Utilize Other Engineering Materials	
Learning activities	**Special Instructions**
POLYMER EXTRUSION LAB Activity 1 **Objective** To demonstrate about polymer direct extrusion process using portable PITSCO polymer extruder. **Introduction** Figure 1: Screw extruder **Materials and equipment** **Requirements** polymer extruder Polymer pellets Graduated measuring cylinder and water Measuring weight. **ACTIVITY 2** Natural seasoning of timber Wood seasoning Materials Freshly felled timber Make wood joints Materials Bevel and miter square Cutting tools :saw, chisels Planning tools Boring Sticking tools ;hammers ,mallet Holding Tools; bench vice-cramp-clamp, Bench stop etc Miscellaneous tools; screw driver, pincer ,raphs and file, oil stone etc	Knowledge of various materials

Information sheet: 7.3.1.8

Plastics

Plastics are organic substances formed by microcells called polymers. These polymers are large groups of monomers linked by a chemical process called polymerization. Plastics provide the necessary balance of properties that cannot be achieved with other materials such as: color, lightweight, soft touch and resistance to environmental and biological degradation.

Discuss the general properties of plastics

Polymers

Classification of Polymers

Polymers can be classified in several different ways-according to their;

- structures,
- the types of reactions by which they are prepared,
- their physical properties, or
- Their technological uses.

From the physical point of view polymers are categorized into

- thermoplastics
- thermosetting
- elastomers

Thermoplastics

Thermoplastic polymers are hard at room temperature, but on heating become soft and more or less fluid and can be molded.

Read and make short notes on different types of thermosetting plastics and their applications.

Identify the different thermosetting plastics in the locality

Thermosetting

Thermosetting polymers normally are made from relatively low molecular weight, usually semi-fluid substances, which when heated in a mold become highly cross-linked, thereby forming hard, infusible, and insoluble products having a three-dimensional network of bonds interconnecting the polymer chains. Thermosetting polymers can be molded at room temperature or above, but when heated more strongly become hard and infusible

Read and make short notes on different types of thermosetting plastics and their applications.

Identify the different thermosetting plastics in the locality

Elastomers

Elastomers are rubbers or rubberlike elastic materials.

Read and make notes on the different types of rubbers (elastomers)

NB: These categories overlap considerably but are nonetheless helpful in defining general areas of utility and types of structures.

Polymerization

Polymerization: It is the process of forming a polymer

Degree of polymerization: It is the number of repetitive units (or mers) present in one molecule of a polymer.

Mathematically, $\text{Degree of polymerization} = \frac{\text{Molecular weight of a polymer}}{\text{Molecular weight of a single monomer}}$

The molecular weight (MW) of a polymer is the sum of the molecular weights of the mers in the molecule; it is n times the molecular weight of each repeating unit.

Types of polymerization

Addition polymerization

This is the process in which two or more chemically similar monomers are polymerized to form long chain molecules. It takes place in unsaturated organic compounds. E.g. Ethene forms polyethene and vinyl chloride forms PVC.

Condensation polymerization

This is the process through which two or more chemically different monomers are polymerized to form a cross linked polymer along with a by-product such as water or ammonia. It takes place in unsaturated organic compounds and requires suitable conditions such as high pressure, temperature and presence of a catalyst.
Example is, methyl alcohol (CH_3OH) and acetic acid (CH_3COOH) condenses to form an ester with water as a by product

Polymer structure

Physical properties of polymers depend not only on their molecular weight/shape, but also on the difference in the chain structure

Four main structures

Linear polymers
Branched polymers
Cross-linked polymers
Network polymers

Linear polymers

Polymers in which the mer units are connected end-to-end along the whole length of the chain
These types of polymers are often quite flexible
Van der waal's forces and H-bonding are the two main types of interactions between chains
Some examples – polyethylene, teflon, PVC, polypropylene

Branched polymers

Polymer chains can branch:
The fibers may aligned parallel, as in fibers and some plastic sheets.
chains off the main chain (backbone)
This leads to inability of chains to pack very closely together
These polymers often have lower densities
These branches are usually a result of side-reactions during the polymerization of the main chain
Most linear polymers can also be made in branched forms
The presence of branching and cross-linking in polymers has a significant effect on properties.
It is the basis of the difference between the three categories of polymers: Thermoplastic polymers
Always possess linear or branched structures, or a mixture of the two.

Branching increases entanglement among the molecules, usually making the polymer stronger in the solid state and more viscous at a given temperature in the plastic or liquid state.

Thermosetting plastics
Are cross-linked polymers.
Are chemically set; the reaction cannot be reversed. The effect is to permanently change the structure of the polymer; upon heating, it degrades or burns rather than melts.

- possess a high degree of cross-linking
- are hard and brittle

Example.
Amino resins
Epoxies
Phenolic
Polyesters

Elastomers
Are cross-linked polymers.
Possess a low degree of cross-linking.
Are elastic and resilient.

Polymer Additives
In most cases, it becomes very essential to add some extra materials into the monomers before or during the process of polymerization in order to impart certain desired properties to the polymers. The various substances which are usually added into the monomers are:

Plasticizers: They act as internal lubricants and prevent crystallization by keeping the chains separated from one another

Fillers: They are added to improve strength, dimensional stability and heat resistance. Examples include wood, asbestos, glass, fibres, mica and slate powder

Catalyst: Are added to expedite as well as complete the polymerization reaction. Are also called accelerators or hardeners

Initiators: Are added to initiate the reaction among monomers and to stabilize the end reaction of the molecular chains. Example is hydrogen peroxide (H_2O_2)

Dyes and pigments: These are added to impart the desired colour to the finished polymers

Mechanical Properties of Polymers
Specified with many of the same parameters that are used for metals, that is,

modulus of elasticity, and
Yield and tensile strengths.
For many polymeric materials, the simple stress–strain test is employed for the characterization of some of these mechanical parameters.
The mechanical characteristics of polymers, for the most part, are highly sensitive to the rate of deformation (strain rate), the temperature, and the chemical nature of the environment (the presence of water, oxygen, organic solvents, etc.).
Some modifications of the testing techniques and specimen configurations used for metals are necessary with polymers, especially for the highly elastic materials, such as rubbers.

Modulus of elasticity and **ductility** in percent elongation are determined for polymers in the same manner as for metals
For plastic polymers, the yield point is taken as a maximum on the curve, which occurs just beyond the termination of the linear-elastic region the stress at this maximum is the yield strength (σ_y).
Tensile strength (TS) corresponds to the stress at which fracture occurs. It may be greater than or less than (σ_y) Strength, for these plastic polymers, is normally taken as tensile strength

Mechanical properties of polymers are highly influenced by temperature. See graph below;
Increasing the temperature produces;
decrease in elastic modulus,
reduction in tensile strength, and
an enhancement of ductility
at 4 ^{0}C the material is totally brittle, whereas considerable plastic deformation is realized at both 50 and 60 ^{0}C

Polymer Recycling
Recycling means recovering the discarded plastic items and reprocessing them into new products, in some cases products that are quite different from the original discarded items.
Trainees to
Carryout recycling of thermoplastics
Apply heat test to plastics
Test plastics for various properties
Identify applications for plastics
Identify polymeric adhesive
Distinguish different types of rubbers
carry out plastic molding

WOOD

Structure of a timber tree

- The cross-section of an exogenous trees shows the following structure

- Pith or Medulla
- Annual Rings
- Heart wood
- Sap wood
- Cambium layer
- Metullary rays
- Bark
- Task
- Identify and discuss the uses of the above listed sections of a exogenous tree
- Differentiate between exogenous tree and endogenous tree in the locality-give examples Characteristics of hard and soft wood

Glass

Definition of glass:

The glass is an amorphous solid completely lacking in long range, periodic atomic structure, and exhibiting a region of glass transformation (transition) behavior. Any material, inorganic, organic, or metallic, formed by any technique, which exhibits glass transformation (transition) behavior, is a glass.

Common types of glass

The following is a list of the more common types of silicate glasses, and their ingredients, properties, and applications:

Fused quartz, also called fused silica glass, vitreous silica glass, is silica (SiO_2) in vitreous or glass form (i.e., its molecules are disordered and random, without crystalline structure). It has very low thermal expansion, is very hard, and resists high temperatures (1000–1500°C). It is also the most resistant against weathering (caused in other glasses by alkali ions leaching out of the glass, while staining it). Fused quartz is used for high temperature applications such as furnace tubes, lighting tubes, melting crucibles, etc.

Soda-lime-silica glass, window glass: silica (SiO_2) 72% + sodium oxide (Na_2O) 14.2% + lime (CaO) 10.0% + magnesia (MgO) 2.5% + alumina (Al_2O_3) 0.6%. It is transparent, easily formed, and most suitable for window glass (flat glass). It has a high thermal expansion and poor resistance to heat (500–600°C). It is used for windows, some low temperature incandescent light bulbs, and tableware. Container glass is a soda-lime glass that is a slight variation on flat glass, which uses more alumina and calcium, and less sodium and magnesium which are more water-soluble. This makes it less susceptible to water erosion.

Sodium borosilicate glass, Pyrex: silica (SiO_2) 81% + boric oxide (B_2O_3) 12% + soda (Na_2O) 4.5% + alumina (Al_2O_3) 2.0%. Stands heat expansion much better than window glass. Used for chemical glassware, cooking glass, car headlamps, etc. Borosilicate glasses (e.g. Pyrex) have as main constituents: silica and boron oxide. They have fairly low coefficients of thermal expansion (7740 Pyrex CTE is 3.25×10^{-6}/°C as compared to about 9×10^{-6}/°C for a typical soda-lime glass, making them more dimensionally stable. The lower CTE also makes them less subject to stress caused by thermal expansion, thus less vulnerable to cracking from thermal shock. They are commonly used for reagent bottles, optical components, and household cookware.

Lead-oxide glass, crystal glass: silica 59% + lead oxide (PbO) 25% + potassium oxide (K_2O) 12% + soda (Na_2O) 2.0% + zinc oxide (ZnO) 1.5% + alumina 0.4%. Because of its high density (resulting in a high electron density) it has a high refractive index, making the look of glassware more brilliant (called "crystal", though of course it is a glass and not a crystal). It also has a high elasticity, making glassware 'ring'. It is also more workable in the factory, but cannot stand heating very well.

Aluminosilicate glass: silica 57% + alumina 16% + lime 10% + magnesia 7.0% + barium oxide (BaO) 6.0% + boric oxide (B_2O_3) 4.0%. Extensively used for fiberglass, used for making glass-reinforced plastics (boats, fishing rods, etc.) and for halogen bulb glass.

Oxide glass: alumina 90% + germanium oxide (GeO_2) 10%. Extremely clear glass, used for fiber-optic waveguides in communication networks. Light loses only 5% of its intensity through 1 km of glass fiber. However, most optical fiber is based on silica, as are all the glasses above.

Content; identification of engineering materials, selection of engineering materials, properties of materials, operation plan development, machine set up, production parameters, production performance, safety in production, application

Self-Assessment

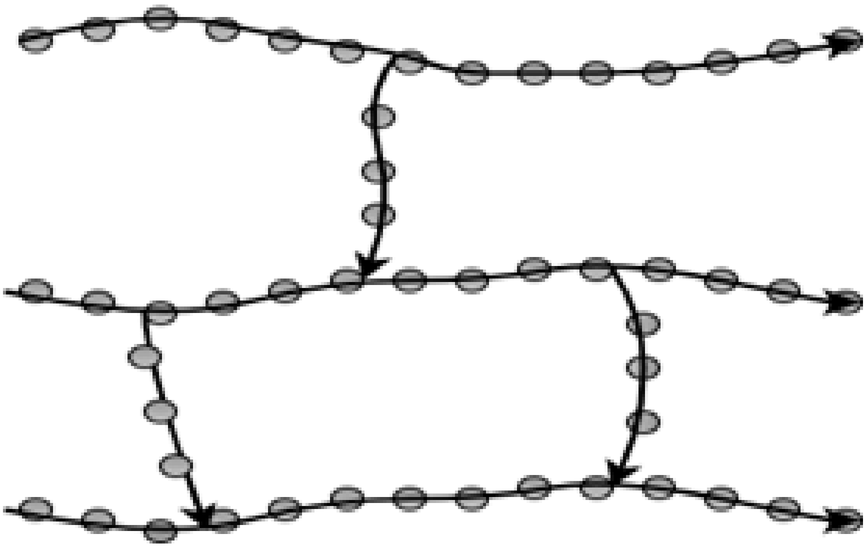
1. Which of the following is not a characteristic trait of polymer materials?
   a) Low density
   b) Resistant to chemical attack
   c) Low cost
   d) High strength

2. The number of repeating units in a polymer is known as __________
   a) monomer
   b) degree of polymerization
   c) molecule
   d) chain

3. A polymer made of identical monomer units is called ______
   a) Homopolymer

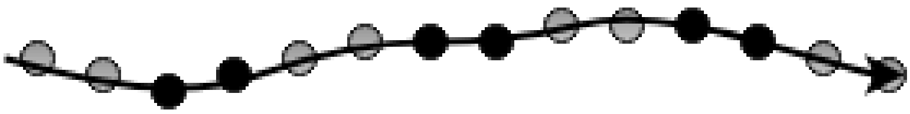
b) Linear polymer
c) Copolymer
d) Branched polymer

4. Liquid or gas polymers having short chains and low molecular weights are known as ______
   a) High-polymers
   b) Homopolymers
   c) Copolymers
   d) Oligo-polymers
5. Which molecular structure does the below figure represent?



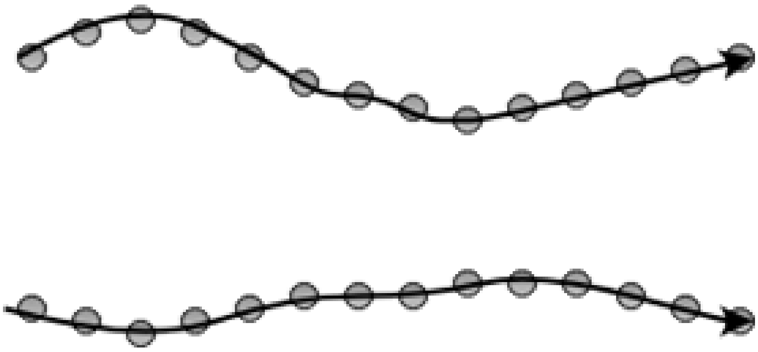
   a) Linear
   b) Branched
   c) Cross-linked
   d) Network

6. Which molecular structure does the figure represent?

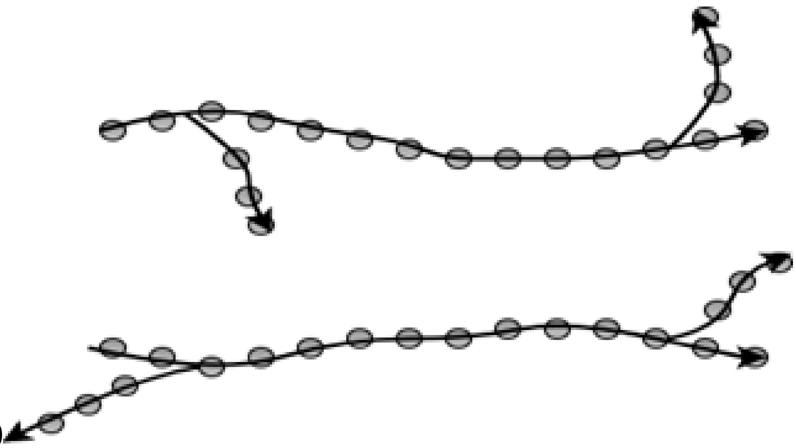


   a) Random
   b) Alternating
   c) Block
   d) Graft

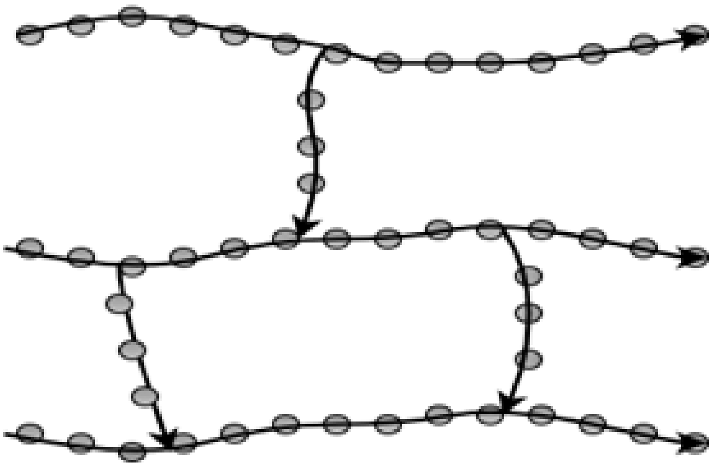
7. Which figure represents the branched molecular structure?



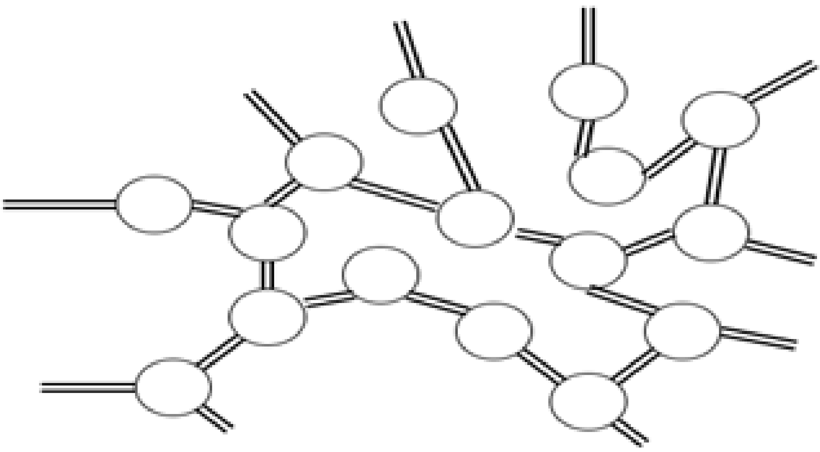
a)



b)



c)



d)

8. Which of the following types of polymers is a copolymer?
   a) Graft
   b) Network
   c) Linear
   d) Branched

9. Which of the following is not a stage of addition polymerization?
   a) Initiation
   b) Propagation
   c) Termination
   d) Recrystallisation

10. Thermosetting plastics are formed by ________
   a) addition polymerization
   b) copolymerization
   c) condensation polymerization
   d) isomerism

11. Which of the following is a property of thermosetting plastics?
   a) Can be molded
   b) Soft
   c) Recyclable
   d) Can be used at high temperatures

12. Which among these is an example of a commodity thermosetting plastic polymer material?
   a) Polyethylene
   b) Polypropylene
   c) Polystyrene
   d) Phenolic

13. Which of the following is not an example of a thermoplastic polymer?
   a) Urethane
   b) Melamine
   c) Epoxide
   d) Acetal

14. Phenolics are otherwise commonly known as _____
   a) Bakelite
   b) Polyformaldehyde
   c) Urea formaldehyde
   d) Melamine formaldehyde

15. Chilled castings are made by using __________
    a) Natural sand
    b) Synthetic sand
    c) Zircon sand
    d) Chromite sand

16. Why are Kaolinite and Bentonite used as clay in molding sand?
    a) High expansion ratio
    b) High thermo-chemical stability
    c) High coefficient of expansion
    d) Non-reactive with molding sand

17. ___________ additives improve the permeability of the molds.
    a) Sawdust
    b) Seacoal
    c) Cereals
    d) Silica flour

18. Identify and select engineering material according to production requirements
19. Develop operation plan according to engineering drawing
20. Set up appropriate machine according to manufacturer's manual
21. Set production parameters according to production requirement
22. Carryout glass blow molding

Tools, Equipment, Supplies and Materials for the specific learning outcome

Testing instrument
Extraction materials
Measuring instrument
Inspection tools

References (APA)

R.S. Khurmi and J.K. Gupta (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.9 Learning Outcome No 9 Perform Heat Treatment

Learning Activities

Learning Outcome N0. 9 Perform Heat Treatment	
Learning Activities	**Special Instructions**
Activity 1 **Heat treatment** MATERIALS Muffle furnace with temperature control and thermocouple pyrometer, quenching medium , hardness testing machine, tongs, emery cloth, smooth file, bench vice number of punches and a hand hammer, plain carbon steel test piece. Cary out Hardening, annealing, normalizing, tempering follow the heat treatment required procedure/manual	Avoid overheating of the specimen Observe safety according to OSHA 2007

Information sheet: 7.3.1.9

Heat treatment can be defined as the combination of processes or in which the heating and cooling of a metal or alloy is done in order to obtain desirable characteristics or properties.

Stages of Heat Treatment

Heat treating is accomplished in three major stages

Stage 1: **Heating the metal slowly** to ensure a uniform temperature

Stage 2: Soaking (holding) the metal at a given temperature for a given time and cooling the metal to room temperature

Stage 3: Cooling the metal to room temperature

Heat treatment processes

The processes include

Annealing

Normalising

Hardening

Tempering

Case hardening/case hardening: carburizing, cyaniding, nitriding, induction hardening, flame hardening

Surface hardening

Annealing
Annealing involves heating the material to a predetermined temperature and hold the material at the temperature and cool the material to the room temperature slowly.

Normalising
The processes consist of heating the) steel 30^0c- 50 ^{0}c above its upper critical temperature(for hypo-eutectoid steel) or Acm line for (hyper-eutectoid steels) .it's held at this temperature for about fifteen minutes and then allowed to cool down in still air.

Hardening
The process consists of heating the metal to a temperature of 30-50 0c above the upper critical point for hypo-eutectoid steels and by the same temperature above the lower critical temperature for hyper-eutectoid steels
Keeping the metal at this temperature for a considerable time depending upon its thickness.
Quenching in a suitable medium

Surface Hardening
Toughness of a materials decreases as hardness and strength increases. Shafts and gears, for example, require a tough material of high surface hardness. The solution for this problem would be to create a very hard surface layer on a comparatively soft and tough material. Surface hardening of steels is accomplished by a variety of methods.

Case Carburising Is a method used for producing hard surface on ductile steel. It involves introduction of additional carbon into the surface of mild steel, producing a composite material consisting of low carbon steel within a thin case of 0.5-0.7 mm thickness of high carbon steel. The principal methods of carburising are:

Pack carburising: parts are heated above the upper critical temperature in contact with wood or barium carbonate, within a cast iron container.

Gas carburising: parts are heated above the upper critical temperature in a furnace with an atmosphere of methane or mixed hydrocarbon gases. Three stage heat treatment is given to carburised parts to achieve desired properties:

Cyaniding
Steel components are heated in a bath of molten sodium cyanide and sodium carbonate at temperature of 950^0C. During the treatment, both carbon and nitrogen diffuse into the surface

of the steel. Formation of hard iron nitride contributes to the surface hardening of the steel. After cyaniding, parts undergo the three stage heat treatment mentioned above.

Nitriding

Not suitable for plain carbon steels. Suitable for low-alloy steels containing chromium and molybdenum. Parts for nitriding are first heat treated to produce the best core properties. Machining to final dimensions is then carried out, while the material is still in soft condition, allowing for the small growth of 0.02 mm that occurs during nitriding. Nitriding is, then, carried out by heating the steel parts at about 500^0C in a gas–tight chamber, in atmosphere of ammonia. The ammonia dissociates at the steel surface into nitrogen and hydrogen and nitrogen is absorbed by the steel. Advantages of nitriding include:

An extremely hard surface is formed

Treatment is conducted at comparatively low temperatures, minimizing cracking and distortion

No subsequent heat treatment is necessary

Content; heat treatment processes, procedure in heat treatment processes, performance of heat treatment in metals, safety practices in heat treatment

Self-Assessment

1. Heat treatment is a process which alters the mechanical properties of metal by changing the pro duct shape.
   a) True
   b) False

2. Proper equipment with close control must be implemented in the heat treatment of metals.
   a) True
   b) False

3. In heat treatment of metals, quenching is a method which induces ductility in the metal.
   a) True
   b) False

4. The heating rate of metals mainly depends on the thermal conductivity of metal which being treated.
   a) True
   b) False

5. In heat treatment, soaking is a stage in which metal product is cleaned by finishing operation.

a) True
b) False

6. In heat treatment of materials, the purpose of annealing is totally opposite to that of hardening.
   a) True
   b) False

7. Annealing of ferrous materials, the material is heated with a faster rate to get the desired properties.
   a) True
   b) False

8. In the heat treatment, normalizing method cannot be applicable for non-ferrous materials.
   a) True
   b) False

9. Carburizing is a case hardening process in which carbon is added to the surface of a metal.
   a) True
   b) False
10. Discuss main objective of various heat treatment processes
11. Factors which determine hardenability of steel
12. Carryout hardenability test-jominy end quench test
13. Identify heat treatment processes
14. Carryout heat treatment processes
15. Observe safety practices according to OSHA 2007

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Testing instrument
- Extraction materials
- Measuring instrument
- Inspection tools

References (APA)

Khurmi R.S. & Gupta J.K. (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.1.10Learning Outcome No 10 Perform Material Testing

Learning Activities

Learning Activities	**Special Instructions**
Activity 1 Dye penetrant test Material - Dye - Developer - Test piece Activity 2 Magnetic particle test Material Magnetic particle/dust Magnet Test piece Activity 3 Ultrasonic testing Material Ultrasonic machine/ Test piece Activity iv Radiography - X And Gamma Radiography - X And Gamma testing Material Radiographic machine/simulators, test piece Activity v Hardness test Material Hardness testing machine Indentors Activity (vi) Impact test: **Material** Impact testing machine Activity (vii) Macro and micro examination **Material** Metallurgical microscope, hack saw, emery cloth ,polishing machine, buffing machine, etchant (dil sulphuric acid/ Hydro choric acid	Follow material testing procedure Observe safety in material testing procedures Identify material testing method depending on material to be tested. Follow procedure of material testing as per material testing method

Information sheet: 7.3.1.10

Non- destructive tests

That testing of a component or material which does not impair the function of the component or material is known as non-detractive test and all such tests are termed as non-destructive tests

Commonly used non-destructive tests are

Liquid penetrant tests

Magnetic particle tests

Acid pickling tests

The above for detection of surface defects

Ultrasonic tests

Radiographic tests

Liquid penetrant tests

This type of test help to examine non –porous materials for defects that are open to the surface. There are two types of liquid penetrant tests.

Dye penetrant test

Fluorescent penetrant test

Dye penetrant test

In this test the dye penetrant is applied to clean dry surface and allowed to soak for a while. The dye penetrates the surface defects .Extra dye is wiped off, and a thin coating of developer chemical is applied. The developer draws the dye to the surface. Contrast between the colour of the developer (usually white) and the dye penetrant (usually red) helps to locate the defects.

Fluorescent penetrant test

In this test the fluorescent penetrant is applied to clean and degreased ,dry surface and allowed to soak for a while the fluorescent liquid penetrant enters the into the defects Excess liquid is wiped off. The surface is the inspected under black light. Cracks or flaws glow brightly under this light

Magnetic particle test

These tests can be applied only to magnetic materials .in this type of test, magnetic lines of force are generated in the component

Radiography - X and Gamma

Radiography This technique is suitable for the detection of internal defects in ferrous and nonferrous metals and other materials.

X-rays, generated electrically, and Gamma rays emitted from radio-active isotopes, are penetrating radiation which is differentially absorbed by the material through which it passes; the greater the thickness, the greater the absorption. Furthermore, the denser the material the greater the absorption.

X and Gamma rays also have the property, like light, of partially converting silver halide crystals in a photographic film to metallic silver, in proportion to the intensity of the radiation reaching the film, and therefore forming a latent image. This can be developed and fixed in a similar way to normal photographic film

Ultrasonic

This test method uses high frequency sound waves to conduct examinations and take measurements. Ultrasonic inspection can be used for flaw detection/evaluation, dimensional measurements, material characterization, flaw sizing and more. Produces a 100% volumetric inspection of the mater

Eddy current

Eddy current testing is used to detect surface and near-surface irregularities in ferrous and non-ferrous materials by inducing an eddy current field in the part under test.

Destructive testing

Destructive physical analysis, (DPA) tests are carried out to the specimen's failure, in order to understand a specimen's performance or material behaviour under different loads they include:

Hardness test : used to determine the hardness value it includes
Brinell hardness test
Rockwell hardness test
Vickers hardness test
Knoops /microhardness hardness test
Impact test:
Charpy test
Izod test
Fatigue test
Creep test

Content; materials testing procedures, material testing methods, tabulation and calculation of material testing results, material testing equipment care and maintenance, safety in material testing procedures

Self-Assessment

1. What is the disadvantage of LPI?
   a) Expensive
   b) Slow
   c) Not reliable
   d) Depth restriction

2. LPI can't be used on __________ specimen.
   a) Large
   b) Simple
   c) Complex
   d) Internally defected

3. Which order is right for LPI?
   a) Penetrant apply, development, inspection, surface preparation
   b) Surface preparation, penetrant apply, development, inspection
   c) Penetrant apply, development, surface preparation, inspection
   d) Development, surface preparation, penetrant apply, inspection

4. What is general dwell time?
   a) 20 seconds
   b) 2 minutes
   c) 20 minutes
   d) 2 hours

5. __________ increases the visibility of the flaw in LPI.
   a) Developer
   b) Penetrant
   c) Benzene
   d) Spirit

6. Developer is chosen such as benzene.
   a) True
   b) False

7. Small components are dipped in penetrant.
   a) True
   b) False

8. Which materials can be tested by MPI?
   a) Magnetic
   b) Non-magnetic

c) Paramagnetic
d) Ferromagnetic

9. Which material can't be tested by MPI?
a) Co
b) Fe
c) Ni
d) Mg

10. What is Curie point for most of the ferrous magnetic materials?
a) 550˚C
b) 760˚C
c) 910˚C
d) 1133˚C

11. The minimum width of crack, which can be inspected by MPI, is _________
a) 1nm
b) 1μm
c) 10μm
d) 1mm

12. What is the advantage of using DC in MPI?
a) Battery maintenance
b) Demagnetize easy
c) Variable voltage supply
d) Subsurface detection

13. Benzene and alcohol are used to decrease component.
a) True
b) False

14. Plain carbon steels are applied with magnetic particles by a residual method?
a) True
b) False

15. In what terms, fatigue life is measured?
a) Time of failures
b) Number of cycles of failure
c) Stress of failure
d) Appearance of fracture

16. Fatigue curves are popularly known as __________ curves.
a) S
b) R

c) N
d) S-N

17. What term is used for the maximum stress at which material fail on a specified number of cycle?
    a) Fatigue strength
    b) Fatigue life
    c) Ultimate tensile strength
    d) Endurance limit

18. Word “endurance limit” is used for _____________
    a) Plastics
    b) Ferrous materials
    c) Nonferrous materials
    d) Alloys

19. Which ferrous material doesn’t show fatigue limit?
    a) Cast iron
    b) Wrought iron
    c) Austenitic stainless steel
    d) Low carbon steel

20. Which of the following show a fatigue limit?
    a) Titanium
    b) Cast iron
    c) Magnesium
    d) Al-Mg alloys

21. What is the reason for fatigue failure?
    a) Movement of Dislocations
    b) Submicroscopic cracks
    c) Dynamic recovery
    d) Vacancy coalescence

22. Trainers to perform the above destructive tests and nondestructive tests
23. Observe safety in material testing procedures
24. Identify material testing methods depending on material to be tested
25. Follow procedure of material testing as per material testing method
26. Tabulate, calculate and interpret material testing results
27. Trainee to take care of and maintain material testing equipment

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Testing instrument
- Extraction materials
- Measuring instrument
- Inspection tools

References (APA)

Khurmi R.S. & Gupta J.K. (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

7.3.4 Learning Outcome No 11 Prevent Material Corrosion

Learning Activities

Learning Outcome No 11 Prevent Material Corrosion	
Learning Activities	**Special Instructions**
ACTIVITY 1 **Understanding the mechanism of corrosion** Carry out electrolytic action /wet corrosion involving dissimilar elements MATERIALS Copper strip, zinc strip, electrolyte (Dil.sulphuric acid), Ammeter Carry out electrolytic action /wet corrosion involving Electrolytes of non-uniform composition MATERIALS Porous plate, dil. Iron Chloride sol, Conc. Iron (Chloride sol., pure iron strip 2 pieces **ACTIVITY 2** Identify different form of corrosion in the locality and their possible causes MATERIALS corroded materials **ACTIVITY 4** *Carryout different forms of corrosion protection method:* ***Cathodic Protection*** *Sacrificial Coatings, Protective Coatings painting* MATERIALS Paint ,paint brush, turpentine,	Sources of corrosion

Information sheet: 7.3.4

Corrosion is the deterioration of materials due to chemical reaction with the environment. It is reverse extractive metallurgy, which is dependent on temperature and concentration of environment. Other factors such as stress and erosion also affect the corrosion rate corrosion is termed as the chemical or electrochemical reaction between a material and its environment that leads to deterioration of the material and/or its properties.

The most important types are:

Uniform corrosion.

Galvanic corrosion, concentration cells, water line attack

Pitting

Dezincification, Dealloying (selective leaching)
Atmospheric corrosion.
Erosion corrosion Fretting Crevice corrosion; cavitation
Stress corrosion, intergranular and transgranular corrosion, hydrogen cracking and embitterment
Corrosion fatigue

Crevice corrosion is a localized attack on a metal adjacent to the crevice between two joining surfaces (two metals or metal-nonmetal crevices). The corrosion is generally confined to one localized area to one metal

Pitting corrosion is a localized phenomenon confined to smaller areas. Formation of micro-pits can be very damaging. Pitting factor (ratio of deepest pit to average penetration) can be used to evaluate severity of pitting corrosion which is usually observed in passive metals and alloys. Concentration cells involving oxygen gradients or ion gradients can initiate pitting through generation of anodic and cathodic areas. Chloride ions are damaging to the passive films and can make pit formation auto-catalytic. Pitting tendency can be predicted through measurement of pitting potentials. Similarly critical pitting temperature is also a useful parameter

Uniform corrosion is a very common form found in ferrous metals and alloys that are not protected by surface coating or inhibitors. A uniform layer of „rust‟ on the surface is formed when exposed to corrosive environments Atmospheric corrosion is a typical example of this type.

Galvanic corrosion often referred to as dissimilar metal corrosion occurs in galvanic couples where the active one corrodes. EMF series (thermodynamic) and galvanic series (kinetic) could be used for prediction of this type of corrosion. Galvanic corrosion can occur in multiphase alloys Eg: - Copper containing precipitates in aluminium alloys. Impurities such as iron and copper in metallic zinc

Erosion corrosion The term “erosion” applies to deterioration due to mechanical force. When the factors contributing to erosion accelerate the rate of corrosion of a metal, the attack is called “erosion corrosion”. It is the result of a combination of an aggressive chemical environment and high fluid surface velocities

You can prevent corrosion by selecting the right:
Metal Type
Protective Coating
Environmental Measures
Sacrificial Coatings
Corrosion Inhibitors
Design Modification

There are two main techniques for achieving sacrificial coating: cathodic protection and anodic protection.

Cathodic Protection

The most common example of cathodic protection is the coating of iron alloy steel with zinc, a process known as galvanizing. Zinc is a more active metal than steel, and when it starts to corrode it oxides which inhibits the corrosion of the steel. This method is known as cathodic protection because it works by making the steel the cathode of an electrochemical cell. Cathodic protection is used for steel pipelines carrying water or fuel, water heater tanks, ship hulls, and offshore oil platforms.

Anodic

Anodic protection involves coating the iron alloy steel with a less active metal, such as tin. Tin will not corrode, so the steel will be protected as long as the tin coating is in place. This method is known as anodic protection because it makes the steel the anode of an electrochemical cell.

Anodic protection is often applied to carbon steel storage tanks used to store sulfuric acid and 50% caustic soda. In these environments cathodic protection is not suitable due to extremely high current requirements.

Corrosion Inhibitors

Corrosion inhibitors are chemicals that react with the surface of the metal or the surrounding gases to suppress the electrochemical reactions leading to corrosion. They work by being applied to the surface of a metal where they form a protective film. Inhibitors can be applied as a solution or as a protective coating using dispersion techniques. Corrosion inhibitors are commonly applied via a process known as passivation.

Passivation

In passivation, a light coat of a protective material, such as metal oxide, creates a protective layer over the metal which acts as a barrier against corrosion. The formation of this layer is affected by environmental pH, temperature, and surrounding chemical composition. A notable example of passivation is the Statue of Liberty, where a blue-green patina has formed which actually protects the copper underneath. Corrosion inhibitors are used in petroleum refining, chemical production, and water treatment works.

Design Modification

Design modifications can help reduce corrosion and improve the durability of any existing protective anti-corrosive coatings. Ideally, designs should avoid trapping dust and water, encourage movement of air, and avoid open crevices. Ensuring the metal is accessible for regular maintenance will also increase longevity

Self-Assessment

1. The compressive test is done on which of the following materials?
   a) Cast iron
   b) Aluminum
   c) Gold
   d) Thermocouple

2. Which of the following is not a method of shear test?
   a) Double sheer system for round bar
   b) Double knife shear system for rectangular section
   c) Double shear system for conical surfaces
   d) Shearing of disc using punch and die

3. ________ plating is used for protection against wear in lead bearings.
   a) Gallium
   b) Arsenic
   c) Indium
   d) Helium

4. What are the applications of chromium plating?
   a) Plastics
   b) Wheel and rims
   c) IC engine parts
   d) Castings

5. What is the hardness of a rhodium plate?
   a) 140-425 Vickers
   b) 540-640 Vickers
   c) 720-880 Vickers
   d) 950-1050 Vickers

6. The alumilite process uses ________ as an electrolyte for anodizing.
   a) Sulfuric acid
   b) Hydrogen peroxide
   c) Nitric acid
   d) Ammonium sulfate

7. Which of the following is a use for flash anodic coatings?
   a) Cartridge cases
   b) Airplane propeller
   c) Paint adherence
   d) Hydraulic pistons

8. Chromizing is carried out at a temperature of __________
   a) 400-600 F
   b) 800-1200 F
   c) 1650-2000 F
   d) 2250-2750 F

9. Siliconizing is otherwise known as _________
   a) Chromizing
   b) Nitriding
   c) Ihrigizing
   d) Oxy-cyaniding

10. __________ is used as a catalyst in siliconizing.
   a) Hydrogen peroxide
   b) Chlorine gas
   c) Sulfuric acid
   d) Magnesium sulfate

11. Observe the safety in material testing procedures
12. Carryout different forms of corrosion protection methods
13. Identify different type of corrosion in the locality and their possible causes
14. Identify methods of corrosion prevention

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Testing instrument
- Extraction materials
- Measuring instrument
- Inspection tools

References (APA)

Khurmi R.S. & Gupta J.K. (2012) A text book of workshop technology (manufacturing process) S.Chand and company, New Delhi pg 21-27

CHAPTER 8: THERMODYNAMICS PRINCIPLES

8.1 Introduction of the Unit of Learning / Unit of Competency

This unit describes the competencies required by a technician in order to apply thermodynamics principles in welding and fabrication and related works. It includes understanding fundamentals of thermodynamics, performing steady flow processes, performing non-steady flow processes, understanding perfect gases, generating steam, performing thermodynamics reversibility and entropy, understanding idea gas cycle, demonstrating fuel and combustion, perform heat transfer, understanding heat exchangers, understanding air compressors, understanding gas turbines and understanding of impulse steam turbines.

Thermodynamics is a physics specialty devoted to the study of energy within large systems directly applicable to welding and fabrication processes. Welding is the process where the interrelation of temperature and deformation appears throughout the influence of thermal field on material properties and modification of the extent of plastic zones. The study of thermodynamics principle involves studying thermal effects with coupled or uncoupled theories of thermo mechanical response. In this unit of learning the basic requirements includes and not limited to Scientific Calculators, thermodynamics tables and relevant reference materials. At the end of the unit self-assessment, further reading and references have been provided.

8.2 Performance Standard

Perform steady and non-steady flow processes in relation to appropriate utilities**,** Perform thermodynamics reversibility and entropy, Perform heat transfer, demonstrate understanding on principles of turbine as per the equation.

8.3 Learning Outcome

8.3.1 List of Learning Outcomes

a. Understand fundamentals of thermodynamics
b. Perform steady flow processes
c. Perform non-steady flow processes
d. Understand perfect gases
e. Generate steam
f. Perform thermodynamics reversibility and entropy
g. Understand idea gas cycle
h. Demonstrate fuel and combustion
i. Perform heat transfer
j. Understand heat exchangers

k. Understand air compressors
l. Understand gas turbines
m. Understand impulse steam turbines

8.3.1.1 Learning Outcome No.1 Thermodynamic principles

Learning Activities

Learning Outcome No1: Thermodynamic principles	
Learning Activities	**Special Instructions**
Identify the fundamental application of thermodynamics in welding process Terms used in thermodynamics are described Thermodynamics processes and cycles are described First law of thermodynamics is applied	Ensure safety requirement in the laboratory

Information Sheet: 8.3.1.1

Introduction

Scientists in the late 18th and early 19th centuries adhered to caloric theory, first proposed by Antoine Lavoisier in 1783, and further bolstered by the work of Sadi Carnot in 1824, according to the American Physical Society. Caloric theory treated heat as a kind of fluid that naturally flowed from hot to cold regions, much as water flows from high to low places. When this caloric fluid flowed from a hot to a cold region, it could be converted to kinetic energy and made to do work much as falling water could drive a water wheel. It wasn't until Rudolph Clausius published "The Mechanical Theory of Heat" in 1879 that caloric theory was finally put to rest.

Thermodynamic systems

Energy can be divided into two parts, according to David McKee, a professor of physics at Missouri Southern State University. One is our human-scale macroscopic contribution, such as a piston moving and pushing on a system of gas. Conversely, things happen at a very tiny scale where we can't keep track of the individual contributions.

McKee explains, "When I put two samples of metal up against each other, and the atoms are rattling around at the boundary, and two atoms bounce into each other, and one of the comes off faster than the other, I can't keep track of it. It happens on a very small time scale and a very small distance, and it happens many, many times per second. So, we just divide all energy transfer into two groups: the stuff we're going to keep track of, and the stuff we're not going to keep track of. The latter of these is what we call heat."

Thermodynamic systems are generally regarded as being open, closed or isolated. According to the University of California, Davis, an open system freely exchanges energy and matter with its surroundings; a closed system exchanges energy but not matter with its surroundings;

and an isolated system does not exchange energy or matter with its surroundings. For example, a pot of boiling soup receives energy from the stove, radiates heat from the pan, and emits matter in the form of steam, which also carries away heat energy. This would be an open system. If we put a tight lid on the pot, it would still radiate heat energy, but it would no longer emit matter in the form of steam. This would be a closed system. However, if we were to pour the soup into a perfectly insulated thermos bottle and seal the lid, there would be no energy or matter going into or out of the system. This would be an isolated system.

In practice, however, perfectly isolated systems cannot exist. All systems transfer energy to their environment through radiation no matter how well insulated they are. The soup in the thermos will only stay hot for a few hours and will reach room temperature by the following day. In another example, white dwarf stars, the hot remnants of burned-out stars that no longer produce energy, can be insulated by light-years of near perfect vacuum in interstellar space, yet they will eventually cool down from several tens of thousands of degrees to near absolute zero due to energy loss through radiation. Although this process takes longer than the present age of the universe, there's no stopping it.

Heat engines

The most common practical application of the First Law is the heat engine. Heat engines convert thermal energy into mechanical energy and vice versa. Most heat engines fall into the category of open systems. The basic principle of a heat engine exploits the relationships among heat, volume and pressure of a working fluid. This fluid is typically a gas, but in some cases it may undergo phase changes from gas to liquid and back to a gas during a cycle.

When gas is heated, it expands; however, when that gas is confined, it increases in pressure. If the bottom wall of the confinement chamber is the top of a movable piston, this pressure exerts a force on the surface of the piston causing it to move downward. This movement can then be harnessed to do work equal to the total force applied to the top of the piston times the distance that the piston moves.

There are numerous variations on the basic heat engine. For instance, steam engines rely on external combustion to heat a boiler tank containing the working fluid, typically water. The water is converted to steam, and the pressure is then used to drive a piston that converts heat energy to mechanical energy. Automobile engines, however, use internal combustion, where liquid fuel is vaporized, mixed with air and ignited inside a cylinder above a movable piston driving it downward.

Refrigerators, air conditioners and heat pumps

Refrigerators and heat pumps are heat engines that convert mechanical energy to heat. Most of these fall into the category of closed systems. When a gas is compressed, its temperature increases. This hot gas can then transfer heat to its surrounding environment. Then, when the compressed gas is allowed to expand, its temperature becomes colder than it was before it was compressed because some of its heat energy was removed during the hot cycle. This cold gas can then absorb heat energy from its environment. This is the working principal behind an air conditioner. Air conditioners don't actually produce cold; they remove heat. The working fluid is transferred outdoors by a mechanical pump where it is heated by compression. Next, it transfers that heat to the outdoor environment, usually through an air-cooled heat exchanger. Then, it is brought back indoors, where it is allowed to expand and cool so it can absorb heat from the indoor air through another heat exchanger.

A heat pump is simply an air conditioner run in reverse. The heat from the compressed working fluid is used to warm the building. It is then transferred outside where it expands and becomes cold, thereby allowing it to absorb heat from the outside air, which even in winter is usually warmer than the cold working fluid.

Geothermal or ground-source air conditioning and heat pump systems use long U-shaped tubes in deep wells or an array of horizontal tubes buried in a large area through which the working fluid is circulated, and heat is transferred to or from the earth. Other systems use rivers or ocean water to heat or cool the working fluid.

The First Law of Thermodynamics

The first law of thermodynamics, also known as Law of Conservation of Energy, states that energy can neither be created nor destroyed; energy can only be transferred or changed from one form to another. For example, turning on a light would seem to produce energy; however, it is electrical energy that is converted.

A way of expressing the first law of thermodynamics is that any change in the internal energy (ΔE) of a system is given by the sum of the heat (q) that flows across its boundaries and the work (w) done on the system by the surroundings:

[latex]\Delta E = q + w[/latex]

This law says that there are two kinds of processes, heat and work, that can lead to a change in the internal energy of a system. Since both heat and work can be measured and quantified, this is the same as saying that any change in the energy of a system must result in a corresponding change in the energy of the surroundings outside the system. In other words, energy cannot be created or destroyed. If heat flows into a system or the surroundings do work on it, the internal energy increases and the sign of q and w are positive. Conversely, heat flow out of the system or work done by the system (on the surroundings) will be at the expense of the internal energy, and q and w will therefore be negative.

The Second Law of Thermodynamics

The second law of thermodynamics says that the entropy of any isolated system always increases. Isolated systems spontaneously evolve towards thermal equilibrium—the state of maximum entropy of the system. More simply put: the entropy of the universe (the ultimate isolated system) only increases and never decreases.

A simple way to think of the second law of thermodynamics is that a room, if not cleaned and tidied, will invariably become more messy and disorderly with time – regardless of how careful one is to keep it clean. When the room is cleaned, its entropy decreases, but the effort to clean it has resulted in an increase in entropy outside the room that exceeds the entropy lost.

The Third Law of Thermodynamics

The third law of thermodynamics states that the entropy of a system approaches a constant value as the temperature approaches absolute zero. The entropy of a system at absolute zero is typically zero, and in all cases is determined only by the number of different ground states it has. Specifically, the entropy of a pure crystalline substance (perfect order) at absolute zero temperature is zero. This statement holds true if the perfect crystal has only one state with minimum energy.

The First Law of Thermodynamics states that heat is a form of energy, and thermodynamic processes are therefore subject to the principle of conservation of energy. This means that heat energy cannot be created or destroyed. It can, however, be transferred from one location to another and converted to and from other forms of energy.

Thermodynamics is the branch of physics that deals with the relationships between heat and other forms of energy. In particular, it describes how thermal energy is converted to and from other forms of energy and how it affects matter. The fundamental principles of thermodynamics are expressed in four laws.

“The First Law says that the internal energy of a system has to be equal to the work that is being done on the system, plus or minus the heat that flows in or out of the system and any other work that is done on the system," said Saibal Mitra, a professor of physics at Missouri State University. "So, it’s a restatement of conservation of energy."

Mitra continued, "The change in internal energy of a system is the sum of all the energy inputs and outputs to and from the system similarly to how all the deposits and withdrawals you make determine the changes in your bank balance.” This is expressed mathematically as: $\Delta U = Q - W$, where ΔU is the change in the internal energy, Q is the heat added to the system, and W is the work done by the system.

Definition of terms

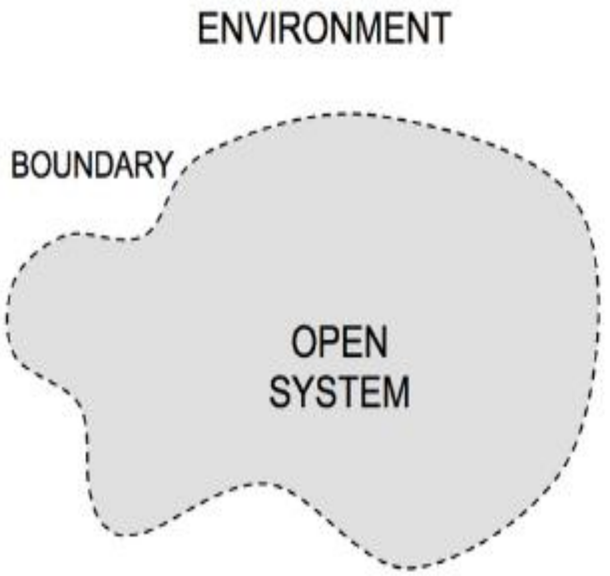
Thermodynamics – the study of heat related to matter in motion.

Thermodynamic system – defined as a quantity of matter or a region in space chosen for study.

Surroundings – Everything external to the system is defined to be the system’s surroundings.

Boundary- The area separating the system from its surrounding is the boundary of the system. The boundary may be at rest or in motion.

A closed system- is a definite quantity of matter contained within some closed surface. A closed system is sometimes referred to as a control mass because the matter composing the system is assumed known for all time.



A system is said to be isolated if no energy is transferred across the boundaries. An open system is a definite fixed location in space. The system is called open because mass may flow in or out of the system.

A phase is a state where all of the matter has the same chemical composition throughout. Matter that is in the same phase is homogeneous.

A property is any quantity which serves to describe a system .e.g. mass, volume, pressure, density, temperature, energy etc.

The state of a system is the condition of the system as determined by its properties.

A process is a transformation from one state to another. Whenever any property of a system undergoes a change (e.g., a change in pressure), then by definition the state changes, and the system is said to have undergone a process.

If none of a system's properties change with time, then the system is said to be in steady state.

A property of a system is called extensive if its value for the overall system is the sum of the values of the parts to which the system has been divided into. Examples include mass, volume and energy.

A property of a system is called intensive if its value is independent of the extent (size) of the system, and may vary from place to place and from moment to moment. Examples include pressure, density, temperature and specific volume.

Process – is said to have taken place when a substance is changed by means of an operation or operations having been carried out on the substance.

Processes
Isobaric process – Constant pressure process
Isothermal process – Constant temperature process
Isochoric/ isometric process- constant volume process
Adiabatic process- No heat transfers across the boundary
Polytrophic process – $PV^n = C$ a, constant.

Cycles
if processes are carried out on a substance such that, at the end the substance is returned to its original states, then the substance is said to have been taken through a cycle.

The First Law of Thermodynamics

The law relates heat and work. It means if some work is converted into heat or vice versa, then the relationship is:

$W = Q$ Where w = work transfer

$Q =$ Heat transfer

Self-Assessment

1. One kg of diatomic Oxygen is present in a 500 L tank. Find the specific volume on both mass and mole basis.
   a) 0.6 m^3/kg , 0.260 m^3/mole
   b) 0.5 m^3/kg , 0.0160 m^3/mole
   c) 0.56 m^3/kg , 0.0215 m^3/mole
   d) 0.7 m^3/kg , 0.0325 m^3/mole

2. A piston/cylinder with a cross-sectional area of 0.01 m^2 is resting on the stops. With an outside pressure of 100 kPa, what should be the water pressure to lift the piston?
   a) 178kPa
   b) 188kPa
   c) 198kPa
   d) 208kPa

3. A large exhaust fan in a lab room keeps the pressure inside at 10 cm water relative vacuum to the hallway? What is the net force acting on the door measuring 1.9 m by 1.1 m?
a) 2020 N
b) 2030 N
c) 2040 N
d) 2050 N

4. A 5 m long vertical tube having cross sectional area 200 cm^2 is placed in a water. It is filled with 15°C water, with the bottom closed and the top open to 100 kPa atmosphere. How much water is present in tube?
a) 99.9 kg
b) 109.9 kg
c) 89.9 kg
d) 79.9 kg

5. A 5 m long vertical tube having cross sectional area 200 cm2 is placed in a water. It is filled with 15°C water, with the bottom closed and the top open to 100 kPa atmosphere. What is the pressure at the bottom of tube?
a) 119 kPa
b) 129 kPa
c) 139 kPa
d) 149 kPa

6. Find the pressure of water at 200°C and having specific volume of 1.5 m3/kg.
a) 0.9578 m3/kg
b) 0.8578 m3/kg
c) 0.7578 m3/kg
d) 0.6578 m3/kg

7. Find the pressure of water at 200°C and having specific volume of 1.5 m^3/kg.
a) 141.6 kPa
b) 111.6 kPa
c) 121.6 kPa
d) 161.6 kPa

8. A 5m^3 container is filled with 840 kg of granite (density is 2400 kg/m^3) and the rest of the volume is air (density is 1.15 kg/m^3). Find the mass of air present in the container.
a) 9.3475 kg
b) 8.3475 kg
c) 6.3475 kg
d) 5.3475 kg

9. A 100 m tall building receives superheated steam at 200 kPa at ground and leaves saturated vapor from the top at 125 kPa by losing 110 kJ/kg of heat. What should be the minimum inlet temperature at the ground of the building so that no steam will condense inside the pipe at steady state?
a) 363.54°C
b) 263.54°C

c) 163.54°C
d) none of the mentioned

10. The pressure gauge on an air tank shows 60 kPa when the diver is 8 m down in the ocean. At what depth will the gauge pressure be zero?
a) 34.118 m
b) 24.118 m
c) 14.118 m
d) none of the mentioned

11. Define the following terms
    i. Process
    ii. Cycle
    iii. Extensive property
12. Differentiate the following process
    i. Isothermal
    ii. Adiabatic
    iii. Isometric
    iv. Isobaric

13. Outline a procedure of carrying out an isobaric process in the laboratory
14. Carry out an experiment on isobaric process in the laboratory

Tools, Equipment, Supplies and Materials for the specific learning outcome

Laboratory equipment

Pressure, temperature and volume measuring instruments

References (APA)

Eastop T. D & Mconkey A. (2009): Applied Thermodynamics' for Engineering Technologist (fifth Edition) .Dorling Kindersley; New Delhi

Rayners Joel (1996) Basic engineering Thermodynamics (5th Edition) Addison Wesley Longman Limited. Edinburg Gate.

8.3.1.2. Learning Outcome No.2 Steady Flow Energy Process

Learning Activities

Learning Outcome No 2: Steady Flow Energy Process	
Learning Activities	**Special Instructions**
Observe the fluid through: Boiler and measure inlet and outlet parameters Air compressor Steady flow energy equation is derived Steady flow energy equation is applied in problem solving Steady flow energy equation is applied in utilities	Take of safety measures necessary in a boiler house

Information Sheet: 8.3.1.2

Perform Steady –Flow Energy Process

The mass flow rate of fluid or substance throughout the system is constant.

Energy of fluid mass entering the system. $= u_1 + P_1V_1 + KE_1 + PE_1$

Energy of fluid mass leaving the system $u_2 + P_2V_2 + KE_2 + PE_2$

By principle of conservation of energy for a system

Initial energy + energy entering = Final energy + energy leaving

$$E_1U_1 + P_1V_1 + KE_1 + PE_1 + Q$$

$$E_2U_2 + P_2V_2 + KE_2 + PE_2 + W$$

But $U + PV = H$

$E_1 + H_I + KE_1 + PE_1 + Q = E_2 + H_2 + KE_2 + PE_2 + W$

It is considered that the total energy of the fluid mess in the system remains constant

$(i.e)E_1 = E_2$

$\therefore Q - w = (H_2 - H_1)(KE_2 - KE_1) + (PE_2 - PE_1)$

This is known as the steady flow energy equation $(SFEE)$

It's illustrated as follows:-

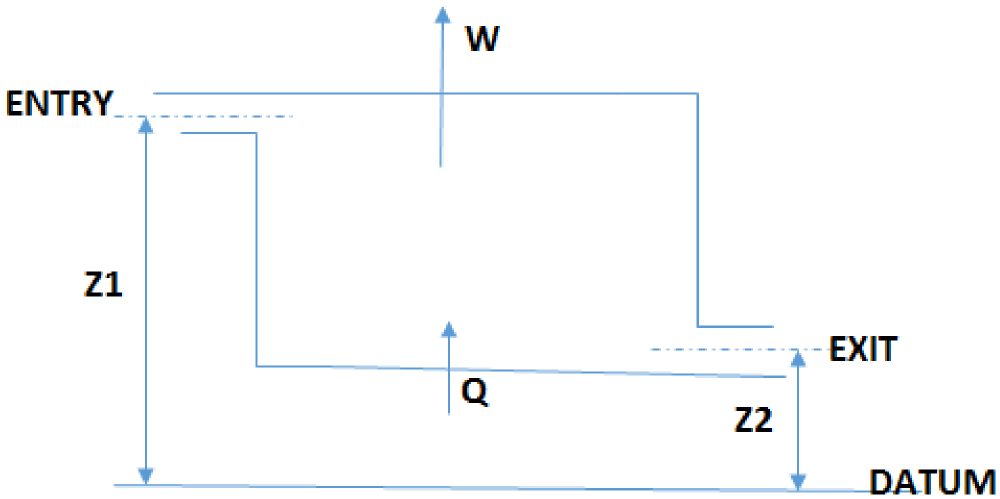


Figure 62: SFEE

The $(SFEE)$ becomes

$h_1 + \frac{{c_1}^2}{2} + gz + Q = h_2 + \frac{{c_2}^2}{2} + gz_2 + W$

Self-Assessment

1. What does a nozzle do?
   a) decreases the velocity of a fluid at the cost of its pressure gain
   b) increases the velocity of a fluid at the cost of its pressure drop
   c) increases the velocity of a fluid and also its pressure
   d) none of the mentioned.

2. What does a diffuser do?
   a) increases the pressure of the fluid at the expense of its KE
   b) decreases the pressure of the fluid and also increases its KE
   c) increases the pressure of the fluid and also its KE
   d) decreases the pressure of the fluid and also its KE

3. For an insulated nozzle, SFEE of the control surface gives (considering change in PE is zero and inlet velocity is small compared to exit velocity)
   a) V2=sqrt(4xΔh)
   b) V2=sqrt(Δh)
   c) V2=sqrt(Δh/2)
   d) V2=sqrt(2xΔh)

4. Fluid flow through which of the following throttles the flow?
   a) Partially opened valve
   b) orifice
   c) porous plug
   d) all of the mentioned

5. In a throttling device, what do we get as SFEE when changes in PE and KE are taken zero?
   a) dQ/dm≠0
   b) dW/dm≠0
   c) h1=h2
   d) none of the mentioned

6. Turbines and engines ____ positive power output, and compressors and pumps ____ power input.
   a) Require, give
   b) give, require
   c) give, give
   d) require, require

7. For a turbine, it is seen that work is done by the fluid at the expense of its enthalpy.
   a) True

b) false

8. For an adiabatic compressor or pump,
   a) the enthalpy of fluid remains constant with the amount of work input
   b) the enthalpy of fluid decreases by the amount of work input
   c) the enthalpy of fluid increases by the amount of work input
   d) none of the mentioned

9. A heat exchanger is a device in which heat is transferred from one fluid to another.
   a) True
   b) false

10. For an inviscid frictionless fluid flowing through a pipe, Euler equation is given by
    a) Vdp+VdV+gdZ=0
    b) Vdp-VdV+gdZ=0
    c) Vdp-VdV-gdZ=0
    d) none of the mentioned

11. Outline the meaning of steady flow energy process
12. Derive steady flow energy equation
13. Air is compressed by a rotary compressor in a steady flow process at a rate of 1.5 kg/s. At entry the air has a specific volume of 0.9m3/kg and has a velocity of 80m/s. At exit, the air has a specific volume of 0.4m3/kg and has a velocity of 45m/s. In its passage through the compressor the sp. Enthalpy of the air is increased by 110kg and it experiences heat transfer loss of 20kg/kg. Determine:

i. Inlet and exit areas of the compressor in m2
ii. Power required to drive the compressor

Tools, Equipment, Supplies and Materials for the specific learning outcome

Boilers
Compressors
Throttling process apparatus

References

Rayner Joel (1996) Basic Engineering Thermodynamics (fifth Edition) Addison Wesley Longman limited Edinburg Gate

Singh, O (2009): Applied Thermodynamic (3rd Edition). New age International Limited, New Delhi

8.3.1.3 Learning Outcome No.3 Non- Steady Flow Energy Process
Learning Activities

Learning Outcome No. 3 Non- Steady Flow Energy Process	
Learning Activities	**Special Instructions**
Carry out experiment on air compression using a player air pump and determine changes in air parameters of pressure and temperature	Carryout inspection of various pumps

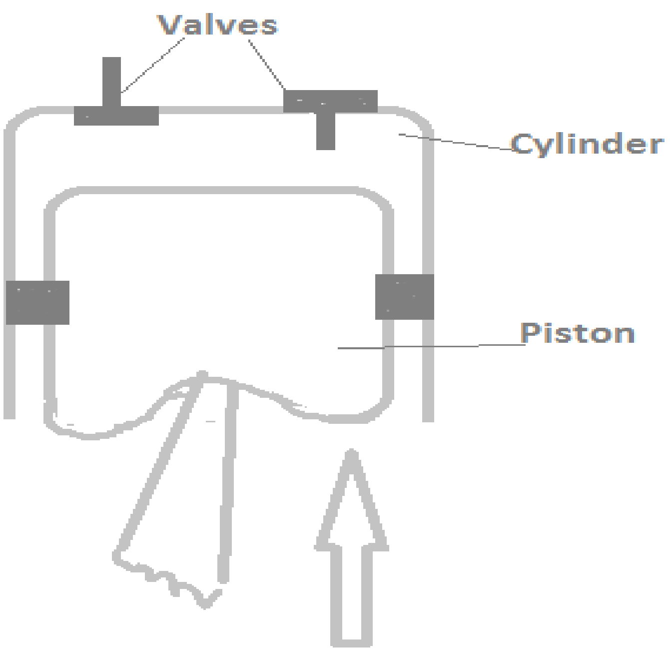
Information Sheet: 8.3.1.3

The Non Flow Energy Process

For a substance enclosed by the system, it possess internal energy u_1 resulting from the motion of its atoms or molecules. In this case

$U_1 + Q = U_2 + W$

$$\therefore Q = \Delta U + w$$



Compression Process

The process in a closed system is referred to as a non-flow process and the equation is referred to as the non-flow energy equation, ($NFEE$)

A typical non- flow process is the expansion or compression of a substance in cylinder

Self-Assessment

1. Thermodynamic process occurring at Constant volume is called …………..
2. In reversible polytropic thermodynamic process True heat transfer occurs.

a. True
b. False

3. Coefficient of performance of refrigerator and heat pump is always…………
4. Non flow energy equation for reversible process is…………..
5. Non flow energy equation for reversible process is…………….
6. Derive the non-flow energy equation
7. In a non –flow process carried output on 5.4 kg of fluid substance, there is a specific internal energy decrease of 50kj/kg and a work transfer from the substance of 85kg/kg. Determine the heat transfer
8. Demonstrate an experiment to illustrate non-flow energy process

Tools, Equipment, Supplies and Materials for the specific learning outcome

Plunger air pump (compressor)

Instrument to measure pressure and temperature.

References (APA)

Rayner Joel (1996) Basic Engineering Thermodynamics (fifth Edition) Addison Wesley Longman limited Edinburg Gate

8.3.1.4 Learning Outcome No.4 Understand Perfect Gas

Learning Activities

Learning Outcome No 4 UNDERSTAND PERFECT GAS	
Learning Activities	**Special Instructions**
Carry out experiment on Gas laws Boyler's law Charles law Joule's law ***Perfect gas laws*** are stated Gas laws experiment are carried out Gas laws are applied	State properties of various gases

Information Sheet:8.3.1.4

UNDERSTAND PERFECT GAS

A perfect gas may be defined as a gas which obeys the gas laws exactly

For any fixed mass of gas, changes of state are connected by the equation.

$$\frac{PV}{T} = a\ constant$$

For v =volume of 1 kg of gas, the specific volume, the equation becomes;

$$\frac{PV}{T} = a\ constant$$

The constant is written R and is called the characteristic gas constant (sometimes specific gas constant)

∴ $\frac{PV}{T}$=R

For m kg of gas, then

$\frac{P(mV)}{T} = mR\ where\ mr = total\ volume\ of\ gas$

$\frac{PV}{T} = mR\ \ or\ mv = mRT.$

This is known as the characteristic equation of a perfect gas.

Self-Assessment

1. A mole of a substance has a mass equal to the molecular weight of the substance.
   a) true
   b) false

2. According to Avogadro's law, volume of a g mol of all gases at the pressure of ____ and temperature of ____ is same.
   a) 760 mm Hg, 100 degree Celsius
   b) 760 mm Hg, 0 degree Celsius
   c) 750 mm Hg, 100 degree Celsius
   d) 750 mm Hg, 0 degree Celsius

3. At NTP, the volume of a g mol of all gases is(in litres)
   a) 22.1
   b) 22.2
   c) 22.3
   d) 22.4

4. Which of the following statement is true?
   a) number of kg moles of a gas = mass / molecular weight
   b) molar volume = total volume of the gas / number of kg moles
   c) both of the mentioned
   d) none of the mentioned

5. The equation of state is a functional relationship between
   a) pressure
   b) molar or specific volume
   c) temperature
   d) all of the mentioned

6. If two properties (out of p,v,T) of a gas are known, the third can be evaluated.
   a) true
   b) false

7. Which of the following statement is true about a gas?
   a) lim(pv) with p tending to 0 is independent of the nature of gas
   b) lim(pv) with p tending to 0 depends only on the temperature
   c) this holds true for all the gases
   d) all of the mentioned

8. Universal gas constant is given by
   a) lim(pv) / 273.16
   b) R
   c) 0.083 litre-atm/gmol K
   d) all of the mentioned

9. The equation of state of a gas is lim(pv)=RT .
   a) true

b) false

10. For which of the following gases, does the product (pv) when plotted against p gives depends only on temperature?
    a) nitrogen
    b) hydrogen
    c) air and oxygen
    d) all of the mentioned

11. State the perfect gas equation
12. Derive the general gas equation.

13. 2kg of gas, occupying 0.7m3, had an original temperature of 150c. It was then heated at constant volume until its temperature became 135o c. Determine the heat transferred to the gas and its find pressure. Take cv= 0.72kj/kgk and R= 0.29kj/kgk

14. Conduct the following experiment
    i. Boyles law
    ii. Charles law
    iii. Joule law

Tools, Equipment, Supplies and Materials for the specific learning outcome

Boyle's law experiment apparatus
Charles' law experiment apparatus
Joule's law experiment apparatus

References (APA)

Rayner Joel (1996) Basic Engineering Thermodynamics (fifth Edition) Addison Wesley Longman limited Edinburg Gate
Singh, O (2009): Applied Thermodynamic (3^{rd} Edition). New age International Limited, New Delhi

8.3.1.5 Learning Outcome No.5 Generate Steam

Learning Activities

Learning Outcome No 5 Generate Steam	
Learning Activities	**Special Instructions**
Generate steam in a boiler Determine the dryness fraction of wet steam generated Determine the thermal efficiency of the boiler	Care and precaution in using steam

Information Sheet: 8.3.1.5
Generate Steam

Steam is generated in a device known as a boiler
Formation of steam

Three distinct stages in production of steam.

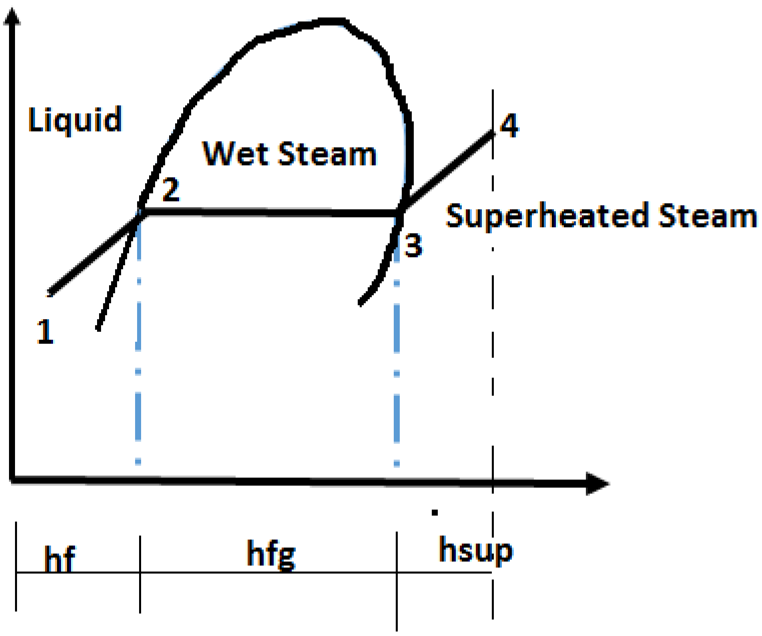
1-2 Warming phase

Temperature of water increases up to saturation temperature. Energy required is called liquid enthalpy

2-3 Transformation phase

Starts from water into dry saturation steam at saturation temperature. Between the two extremes, steam formed will always be we steam. Energy required is called the enthalpy of evaporation. Happens at constant temperature.

3-4 Superheated phase.



Begins with dry saturated steam to super-heated steam. It is accompanied by a rise in temperature. Energy added is called super heat enthalpy.

Dryness fraction

For wet steam, the degree of wetness, should be known. Dryness fraction is a measure of this wetness.

Dryness fraction= $\frac{mass\ of\ drysaturated\ vapour}{mass\ pfwet\ vapour\ continually\ the\ dry\ saturated\ vapour\ .}$

It's denoted by x

$$x = \frac{h - h_x}{h_{fg}}$$

Determination of dryness fraction

The separating calorimeter

The throttling calorimeter

The combined separating and throttling calorimeter.

Dryness fraction $x = \frac{x_{1M}}{M+m}$=$x_1 x_2$

Where

x_1 = dryness fraction at the throttling calorimeter

x_2=dryness fraction at the separating calorimeter
m =Mass of water in separating calorimeter
M = Mass of condensate from throttling calorimeter

Pressure and boiling point
Boiling point increases as pressure increases. This can be obtained from the steam table or the De mollier chart.

Energy balance
In steam plant a quantity of energy is supplied from the fuel in a given time. The purpose of energy balance also called Energy audit is to account for this energy through the plant. The balance is often taken over a period of time and that various energy quantities often expressed as percentages of energy supplied by fuel.
The general distribution through the plant will be as follows:-
Energy to steam
Energy to exhaust
Energy to surrounding
Energy to unburnt fuel

The energy balance also often diagrammatically illustrated, either by a graph or bar client or Sankey diagram.

Self-Assessment

1. Quality indicates the
   a) mass fraction of liquid in a liquid vapour mixture
   b) mass fraction of vapour in a liquid vapour mixture
   c) both of the mentioned
   d) none of the mentioned

2. If 1 kg of liquid-vapour mixture is considered and x is the quality of that mixture, then
   a) mass of vapour is x kg
   b) mass of liquid is (1-x) kg
   c) both of the mentioned
   d) none of the mentioned

3. Which of the following statements is true?
   a) the value of x varies between 0 and 1
   b) for saturated water, x=0
   c) for saturated vapour, x=1
   d) all of the mentioned

4. Total volume of a liquid vapour mixture is given by
   a) volume of the saturated liquid
   b) volume of the saturated vapour
   c) sum of volumes of saturated liquid and saturated vapour
   d) none of the mentioned

5. In fire tube boilers, pressure is limited to
   a. 16 bar
   b. 32 bar
   c. 48 bar
   d. 64 bar

6. The following is an accessory of a boiler.
   a. Pressure gauge
   b. Safety valve
   c. Fusible plug
   d. Superheater

7. The following is a boiler mounting.
   a. Feed pump
   b. Water level gauge
   c. Economizer
   d. Superheater

8. Explain the process of steam formation using a T/h diagram

9. Steam at MN/m2 and dryness fraction 0.95 receives heat at constant pressure until its temperature becomes 350o c. Determine heat received by the steam per kilogram

10. The dryness of steam at a pressure of 2.2 mn/m2 is measured using a throttling calorimeter after throttling the pressure in the calometer is 0.13mn/m2 and the temperature is 1120 c .Determine the dryness fraction of the steam at 2.2mN/m2

11. Operate a boiler to generate steam, observing safety precautions

Tools, Equipment, Supplies and Materials for the specific learning outcome
Boiler
Combined separating and throttling calorimeter

References (APA)
Rayner Joel (1996) Basic Engineering Thermodynamics (fifth Edition) Addison Wesley Longman limited Edinburg Gate**.**

Eastop T. D & McConkey, A (2009). Applied Thermodynamics for \thermodynamics Technologist (3rd) Edition. Dorling Kindersley, New Delhi

8.3.1.6 Learning Outcome No.6 Perform Thermodynamics Reversibility and Entropy

Learning Activities

Learning Outcome No 6 Perform thermodynamics reversibility and entrophy	
Learning Activities	**Special Instructions**
Carry out experiments to demonstrate Reversible process Irreversible process Thermodynamics reversibility is explained Principles of heat engine are explained Second law of thermodynamics is applied Entropy is explained in thermodynamics cycle	Laws of thermodynamics

Information Sheet: 8.3.1.6

Perform Thermodynamics Reversibility and Entropy

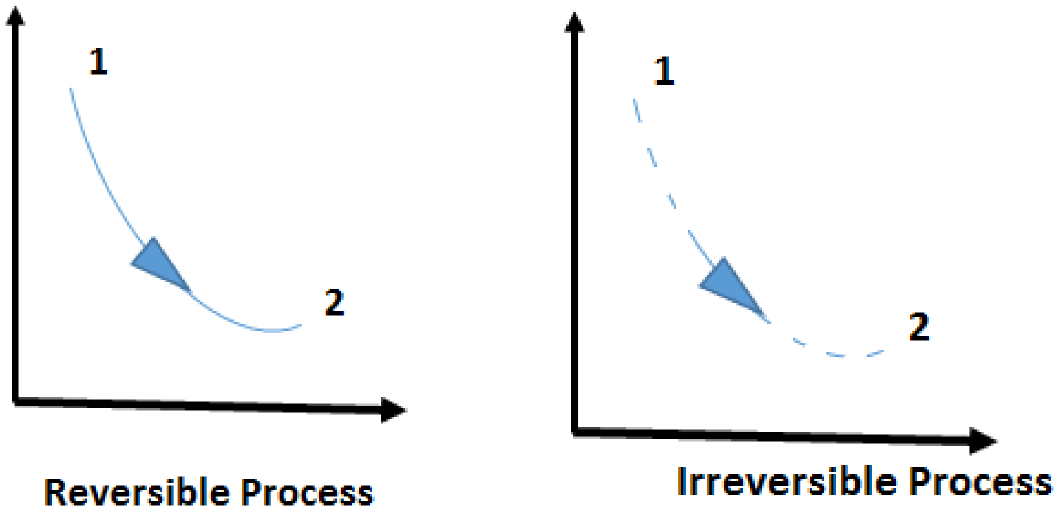


Figure 64: Reversible and Irreversible

When a system changes state in such a way that at any instant during the process the state point can be relocated on the diagram then the process is said to be reversible.

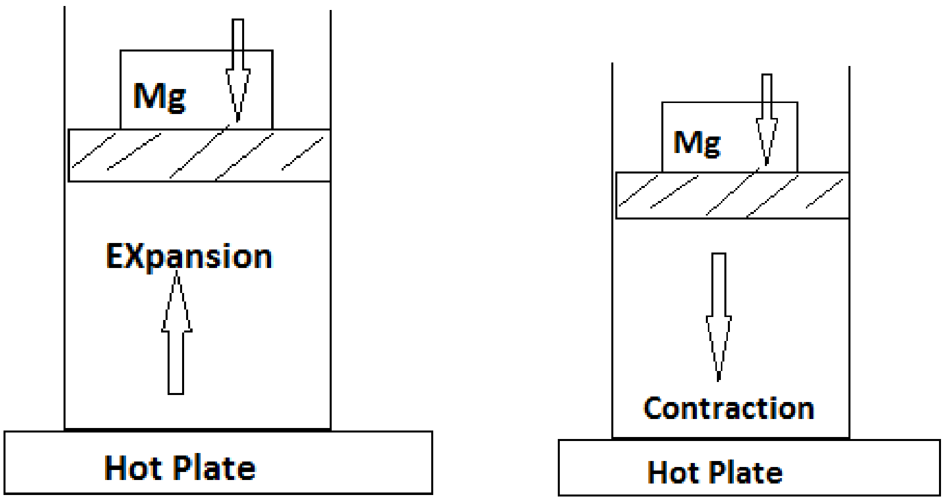


Figure 65: Expansion and Contraction

Reversible process

When a fluid undergoes a reversible process both the fluid and its surroundings can always be restored to their original state. No such process exists in practice. The great majority of thermodynamic process is irreversible.

Entropy

Entropy denoted by S is a state property that serves as a measure of reversibility and of the disorder of the system. It is developed to account for losses in the potential to do useful work and hence accounts for waste in a process.

The heat engine

The heat engine is a system operating in a complete cycle which converts heat input into work output. The piston cylinder heat engine is the most common heat engine.

When gas is heated it expand and push piston .The piston will be returned to its original state by two processes since the pressure in it may be high.

Some heat is taken away by cold plate

Piston is moved down against the gas when pressure is low to its original states

It's not possible to have an efficiency of 100% since some heat are used to overcome friction.

Self-Assessment

1. The equation W=∫vdp holds good for
   a) work-producing machine like an engine or turbine
   b) work-absorbing machine like a pump or a compressor
   c) both of the mentioned

d) none of the mentioned

2. Only those processes are possible in nature which would give an entropy ____ for the system and the surroundings together.
   a) decrease
   b) increase
   c) remains same
   d) none of the mentioned

3. A process always occurs in such a direction as to cause an increase in the entropy of the universe.
   a) true
   b) false

4. When the potential gradient is ____, the entropy change of the universe is ____
   a) large, zero
   b) infinitesimal, zero
   c) infinitesimal, negative
   d) none of the mentioned

5. At equilibrium, the isolated system exists at the peak of the entropy-hill and
   a) dS=-1
   b) dS=1
   c) dS=infinity
   d) dS=0

6. Which of the following is true?
   a) the KE of a gas is due to the coordinated motion of of all the molecules with same average velocity in same direction
   b) the PE is due to the displacement of molecules from their normal positions
   c) heat energy is due to the random thermal motion of molecules in a disorderly fashion
   d) all of the mentioned

7. Explain the reversible process using a PV diagram
8. 1 kg of steam at 7 bar, entropy, 6.5 kj/kgk is heated reversible at constant pressure until temperature is 2500 C. Calculate the heat supplied and show on a T-s diagram the area which represent the heat flow.

9. Calculate the change of entropy of I kg of air expanding polytropically in a cylinder behind a piston from 6.3 bar and 5500 c to 1.05 bar. The index of expansion is 1.3

10. Perform thermodynamics reversibility and entropy process in a laboratory set-up

Tools, Equipment, Supplies and Materials for the specific learning outcome

Laboratory apparatus for carrying out processes

References (APA)

Eastop T.D & Mc Conkey A. (2009). Applied Thermodynamics for Engineering Technologists (fifth Edition) Dorling Kindersley, New Delhi.
Rajput R. K. (2007). Engineering Thermodynamics (3rd) Laxmi Publication Ltd, New Delhi

8.3.1.7 Learning Outcome No. 7 Understand Ideal Gas Cycle

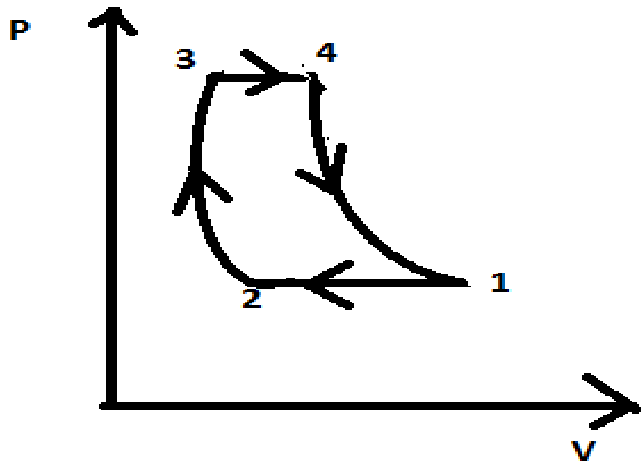
Learning Activities

Learning Outcome No 7. Understand Ideal Gas Cycle	
Learning Activities	**Special Instructions**
Demonstrate various gas cycles on a P-V diagram. Relate gas cycles to various areas of application. Determine thermal efficiency for various gas cycles.	Various Gas cycles

Information Sheet: 8.3.1.7
Understand Ideal Gas Cycle

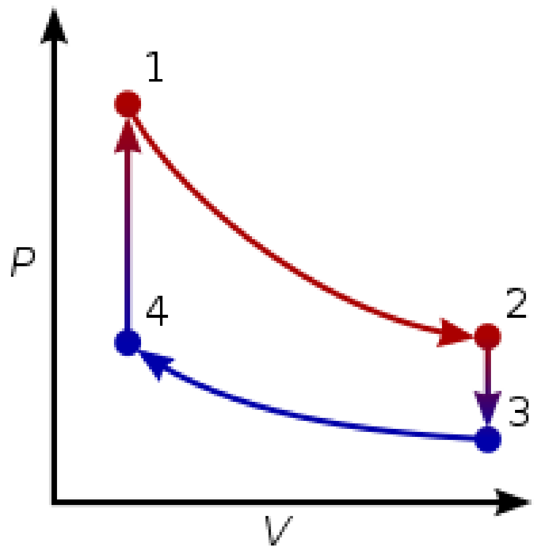
The Cayley cycle

Consists of two constant pressure processes 1-2 and 3-4 and two polytrophic processes 2-3and 4-1



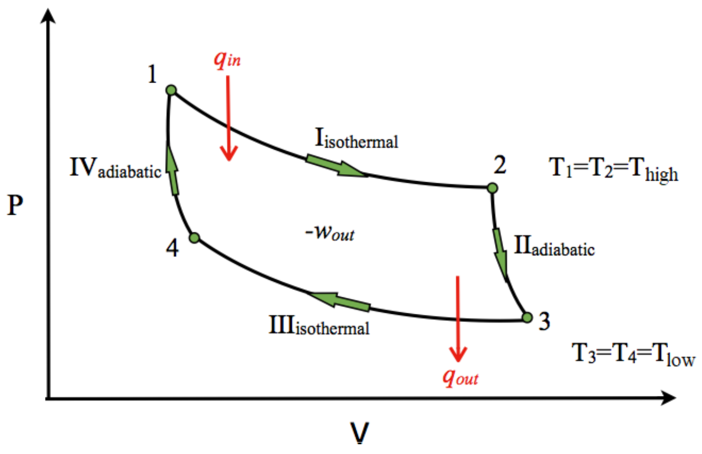
ii. The Stirling cycle

Consists of two isothermal process 1-2 and 3-4 and two constant volume 2-3 and 4-1 process.



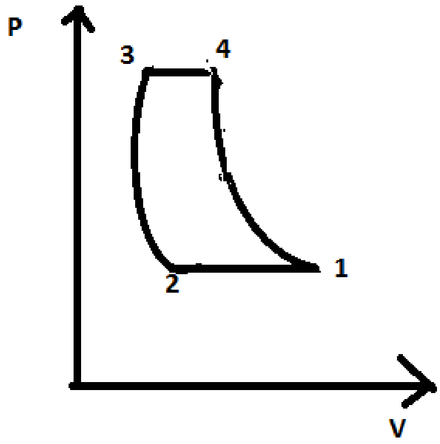
Carnot cycle
Two isothermal processes (PV= C) 1-2 and 3-4 and, two adiabatic process
$pv^{\delta} = c$

2-3 and 4-1



Constant pressure cycle

Two constant pressure process 1-2 and 3-4 and two a diabetics processes 2-3 and 4-1 Read others in Rayner Joel pages 426 -430



Efficiencies

Thermal efficiency = $\frac{Net\ work\ done}{Net\ heat\ received}$

Actual thermal efficiency =$\frac{\boldsymbol{Actual\ work\ done}}{\boldsymbol{Thermal\ energy\ from\ fuel}}$

Relative efficiency = $\frac{\boldsymbol{Axctual\ thermal\ efficiency}}{\boldsymbol{Ideal\ thrmal\ efficiency}}$

Theoretical cycles such as constant volume, constant pressure and the diesel cycles are sometimes referred to as the air standard cycles and the related efficiencies are referred to as air standard efficiencies.

Self-Assessment

1. Explain the need for understanding the ideal gas cycle
2. Derive thermal efficiency for the stirling cycle
3. The overall volume expansion ratio of a carnot cycle is 15. The temperature limits of the cycle are 260o c. Determine
4. The volumetric ratios of the isothermal and adiabatic processes.
5. The thermal efficiency of the cycle Take $\gamma = 1.4$
6. Carry out an experiment to determine ideal gas parameters. This is embedded

Tools, Equipment, Supplies and Materials for the specific learning outcome

Gas power plant	Laptop
Online links	Project

References

Rayner Joel (1996) Basic Engineering Thermodynamics (fifth Edition) Addison Wesley Longman limited Edinburg Gate

Eastop T.D & Mc Conkey A. (2009) Applied Thermodynamics for Engineering Technologists (fifth Edition) Dorling Kindersley, New Delhi.

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8.3.1.8 Learning Outcome No.8 Demonstrate Fuel & Combustion

Learning Activities

Learning Outcome No 8 Demonstrate Fuel & Combustion	
Learning Activities	**Special Instructions**
Carryout experiments to determine calorific value by Bomb Calorimeter Boys calorimeter Carry out fuel gas analysis by use of Orsat Apparatus's	Information of fuel and precaution

Information Sheet: 8.3.1.8

Definition

Fuel refers to a combustible substance capable of releasing heat during its combustion. Fuels classified as solid, liquid or gaseous fuels. Most important element, are carbon are hydrogen and sometimes a small amount of sulphur, oxygen and a small quantity of incombustibles (e.g) water vapour ,nitrogen or ash.
Accurate chemical analysis by mass of the important elements in the fuel is called the ultimate analysis. The elements usually included being carbon, hydrogen, nitrogen and sulphur.

Another analysis gives percentages of inherent moisture, volatile matter and combustibles solids. Fuel may be in solid, gas or liquid form.

Combustion equations

Masses of air and fuel enter combustion chamber where chemical reaction takes places. The information is expressed in the chemical reaction takes place. This information is expected in the

Chemical equation which shows.
Reactants and the products of combustion
Relative quantities of the reactants and products
E.g In combustion of hydrogen

$$2H_2 + 0_2 = 2H_{20}$$

$$C + 0_2 = C_{02}$$

Stoichiometric air fuel ratio

A stoichiometric mixture of air and fuel is one that contains just sufficient oxygen for the complete combustion of fuel. One with excess air is termed weak mixture. One with deficiency of air is termed rich mixture

Percentage excess air $=\frac{\text{Actual A/Fratio}-\text{Stoischimetrica A/F}}{\text{Stoichimmetric A/F ratio}}$

For gaseous fuels the ratios are in volumes and for solid and liquid fuels, ratios are expressed by mass.

$$\text{Mixture strength} = \frac{\text{Stoichiometrick A/F}}{\text{actual A/F ratio}}$$

<u>Calorific value of fuel</u>

The amount of energy released by fuel per/unit during combustion is called calorific value of fuel. Bomb calorimeter is used to measure the value for solid and liquid fuel. Boys or gas calorimeter is used to determine the value for gaseous fuels.

<u>Exhaust gas analysis</u>

The products of combustion are mainly gaseous. A sample is taken for analysis and cooled down to a temperature which is below the saturation temperature of steam present. The steam content is therefore not included in the analysis and hence usually quoted as analysis of dry products. An analysis with steam is called a wet analysis. The analysis of dry flue gas is carried out by means of a piece of equipment called the Orsat Apparatus. Electronic analyser is also used

Self-Assessment

1. In presence of which gas is the fuel burnt to generate energy in form of heat?
   a) Oxygen
   b) Hydrogen
   c) Methane
   d) Nitrogen

2. Which are the main constituents of fuel from given options?
   a) Carbon and Nitrogen
   b) Oxygen and Hydrogen
   c) Carbon and Hydrogen
   d) Helium and Oxygen

3. Which fuel is used widely in steam power plants?
   a) Oil
   b) Gas
   c) Coal
   d) Petroleum

4. What is phenomenon of formation of coal called?
   a) Metamorphism

b) Diagenis'
c) Photosynthesis
d) Protolith

5. On what basis is the coal classified?
   a) Period of formation
   b) Depending on capacity to burn
   c) Region/area where is it formed
   d) Physical and chemical composition

6. What is the use of electrostatic precipitations in steam power plant?
   a) To remove the steam
   b) To draw the coal powder into boiler
   c) To remove the feed water
   d) To remove fly ash

7. Why is 'make-up water' added to drum continuously?
   a) To remove the impurities in tube
   b) To replace the water that has been converted into steam
   c) To keep the system cool externally
   d) To compensate for water loss trough blow down

8. Write a combustion equation for a fuel C_6H_{14}
9. The analysis by volume of a produces gas is as follows. 14%H_2, 2%CH_4 22 % c_0 , 2%0_2, 55% N_2: Find the stoichiometric volume of air required for complete combustion of 1m3 of this gas.
10. Explain the procedure of determining calorific value of a solid fuel
11. Determine the adiabatic flame temperature for the complete combustion of Propane (C3H8) with 250% theoretical air in an adiabatic control volume [T = 1300K].

Tools, Equipment, Supplies and Materials for the specific learning outcome
Orsat apparatus
Bomb calorimeter
Boys calorimeter

References

Rayner Joel (1996) Basic Engineering Thermodynamics (fifth Edition) Addison Wesley Longman limited Edinburg Gate
Eastop T.D & Mc Conkey A. (2009), Applied Thermodynamics for Engineering Technologists (fifth Edition) Dorling Kindersley, New Delhi.
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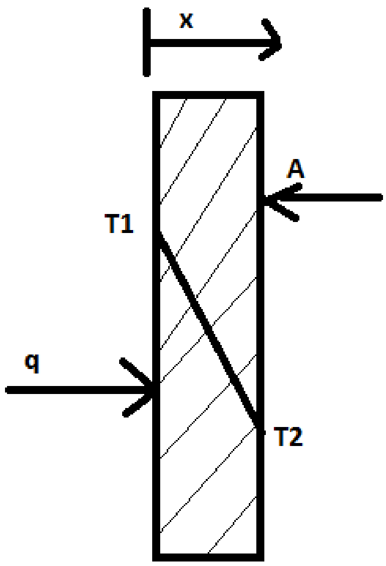
8.3.1.9 Learning Outcome No.9 Perform Heat Transfer

Learning Activities

Learning Outcome No. 9 Perform Heat Transfer	
Learning Activities	**Special Instructions**
Carryout experiments heat transfer through the following in a boiler Conduction Convection Derive conduction equation and apply Fourier's law Derive heat transfer equation from Newton's law of cooling and Fourier's law	Precaution in handling heated items

Information Sheet: 8.3.1.9



Perform Heat Transfer

There are three mechanics of heat transfer

<u>**Conduction**</u> – heat transfer directly through the mechanism of inner-molecular interactions. It needs a matter and does not require any bulk motion of matter.

Conduction rate equation is described by the Fourier law.

$q = -KA\Delta T$

$Q = heat\ flow$

$k = thermal\ conductiviity\ of\ material$

$A = cross\ sectional\ area\ in\ direciton\ of\ flow$

$\Delta T = Temperature\ gradient$

Since this is a vector equation, x direction is considered.

$$q_x = -KAx\frac{dT}{dx}$$

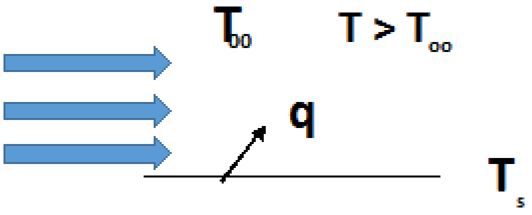
In circular coordinates.

$$q_r = -KAr\frac{dT}{dr}$$

Convection

Heat transfer across a system boundary due to temperature difference by combined mechanisms of inter molecular interactions and bulk transport .it needs fluid matter,

Moving fluid



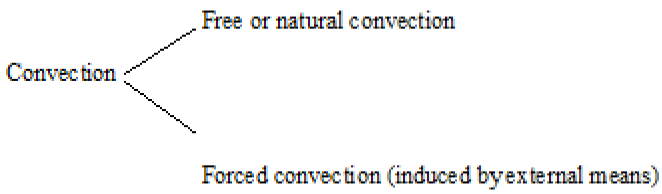
Newton’s law of cooling

$q = hA_s\Delta\mathrm{T}$

q = heat flow from surface
h=heat transfer coefficient

$$A_s = surface\ area$$

$\Delta T = T_s - T_\infty$ = Temperature difference between surface and coolant



Radiation

Heat transfer involves the transfer of heat by electromagnetic radiation that arises due to the temperature of the body. It does not need matter.

Self-Assessment

1. The transfer of heat between two bodies in direct contact is called
   a) radiation
   b) convection
   c) conduction
   d) none of the mentioned

2. Heat flow into a system is taken to be ____, and heat flow out of the system is taken as ____
   a) positive, positive
   b) negative, negative
   c) negative, positive
   d) positive, negative

3. In the equation, dQ=TdX
   a) dQ is an inexact differential
   b) dX is an exact differential
   c) X is an extensive property
   d) all of the mentioned

4. The transfer of heat between a wall and a fluid system in motion is called
   a) radiation
   b) convection
   c) conduction
   d) none of the mentioned

5. For solids and liquids, specific heat
   a) depends on the process
   b) is independent of the process
   c) may or may not depend on the process
   d) none of the mentioned

6. The specific heat of the substance is defined as the amount of heat required to raise a unit mass of the substance through a unit rise in temperature.
   a) true
   b) false

7. Heat and work are
   a) path functions
   b) inexact differentials
   c) depend upon the path followed
   d) all of the mentioned

8. Explain the following modes of heat transfer
   i. Conduction
   ii. Convection
   iii. Radiation

9. Derive the Fourier equation for heat conclusion
10. Demonstrate a method for determine the effectiveness of a tagging materials in boilers.

Tools, Equipment, Supplies and Materials for the specific learning outcome

Boiler

Temperature measuring instruments

References

Rayner Joel (1996) Basic Engineering Thermodynamics (fifth Edition) Addison Wesley Longman limited Edinburg Gate

Eastop T.D & Mc Conkey A. (2009). Applied Thermodynamics for Engineering Technologists (fifth Edition) Dorling Kindersley, New Delhi.

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8.3.1.10 Learning Outcome No. 10 Understand Heat Exchangers

Learning Activities

Learning Outcome No 10 Understand Heat Exchangers	
Learning Activities	**Special Instructions**
Demonstrate the working of heat exchanger using a model. Operate a heat exchangers and take appropriate readings of temperatures of the fluids	Materials used for exchangers

Information Sheet: 8.3.1.10

Understand Heat Exchangers

Heat exchangers are devices used to transfer heat between two and more fluid steams at different temperatures. Heat exchangers are used in power generation, chemical /processing, electronics cooling, air conditioning, refrigeration and automotive applications.

Classifications of heat exchangers

Recuperations and generators.
Transfer process: Direct contact or indirect contact
Geometry of construction: tubes, plates and extended surfaces
Heat transfer mechanism: single phase or two phase flow
Flow arrangements: parallel flow, counter flow or cross flow.

Recuperations heat exchangers

Heat exchangers are ones where fluids are separated by a heat transfer surface and ideally they do not mix or leak examples are parallel flow and counter flow heat exchangers. Heat equations to solve heat exchanges problems.
For heat exchanger $Q = \cup A\Delta Tm$
Where;
Q =heat transfer rate
∪= overall heat transfer coefficient
A=total surface area
Δ Tm= mean temperature difference

The overall heat transfer coefficient is defined in terms of individual thermal resistances in series

$$\frac{1}{\cup A} = \frac{1}{(\eta_0 hA)_i} + \frac{1}{Skw} + \frac{1}{(\eta_0 hA)_0}$$

Where η_0 =Surface efficiency for inner and outer surfaces

S =Shape factor for separating

LMTD (Log mean temperature difference is derived in all basic heat transfer texts)

$$\Delta T_{LMTD} = \frac{\Delta T_2 - \Delta T_1}{ln\frac{\Delta T_2}{\Delta T_1}}$$

Where $\Delta T_1 and\ \Delta T_2$ represent the temperature different at each end of the heat exchanger.

Self-Assessment

1. Which among the following surface promote heat transfer?
   a) Plain
   b) Shiny
   c) Corrugated
   d) Wet

2. ________ Heat exchanger is needed for cream than for milk, if capacities and temperature programs are identical.
   a) Larger
   b) Smaller
   c) Similar
   d) Stagnant

3. Which of the following material is used for heat transfer in the dairy industry?
   a) Iron
   b) Platinum
   c) Copper
   d) Stainless steel

4. The rate of buildup of fouling does not depend on which of the following?
   a) Milk quality and Air content of the product
   b) Temperature difference between product and heating medium
   c) Pressure conditions in the heating section
   d) Thickness of stainless steel

5. State various types of heat exchangers
6. Derive the equation for the rate of heat flow in a counter flow heat exchangers
7. Carry out an experiment to determine the performance of particular heat exchangers

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Boiler

- Temperature measuring instruments

References

Rayner Joel (1996) Basic Engineering Thermodynamics (fifth Edition) Addison Wesley Longman limited Edinburg Gate

Eastop T.D & Mc Conkey A. (2009). Applied Thermodynamics for Engineering Technologists (fifth Edition) Dorling Kindersley, New Delhi.

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8.3.2 Learning Outcome No.11 Understanding Air Compressors

Learning Activities

Learning Outcome No 11 Understanding Air Compressors	
Learning Activities	**Special Instructions**
Derive equations for various compressor work Apply the equations for reciprocating air compressor to solve compressor problems	Information of compressors

Information Sheet: 8.3.2

Understanding Air Compressors

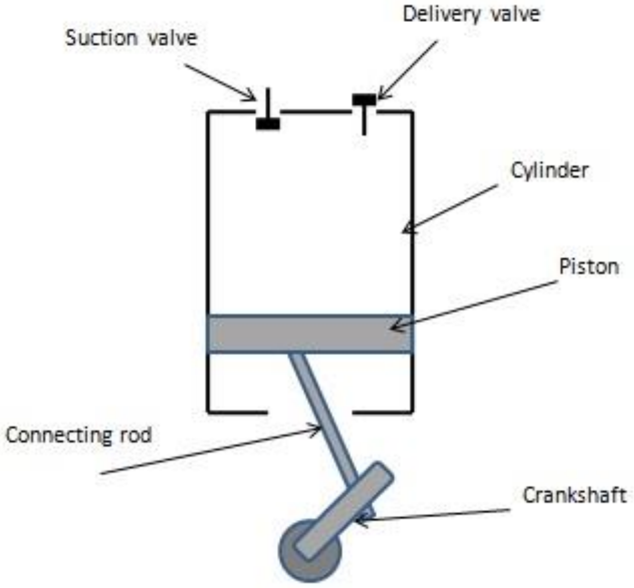
The air compressors are of two general types.

Reciprocating compressors

Rotary compressors.

Reciprocating air compressors

Air is locked up in cylinder and is compressed by the piston which moves reducing the space in the cylinder.



Rotary compressors

Compression is achieved through a rotary action of a member either by reducing space or by forcing air into a reservoir where back pressure results to high pressures: include centrifugal compressors, axial flow, roots, blower vane etc.

Equations of reciprocating air compressors.

Work must be put to a compressor to keep it running. Every effort is made to reduce this work input

Isothermal compressions the ideal but cannot be achieved in practice.

$$isothermal\ efficiency = \frac{isothermal\ work}{Actual\ work}$$

$$\oint w = \frac{n}{(n-1)} P_1 V_1 \left[\left(\frac{p_2}{p_1} \right) \quad \frac{n-1}{n} \right]$$

$$= \frac{n}{(n-1)}\ mRT_1 \left[(\frac{P_2{}^{\left(\frac{n-1}{n}\right)} - 1}{P_1} \right]$$

Volumetric efficiency

$$\int vol = \frac{effective\ swept\ volume}{swept\ volume}$$

Clearance ratio= $\frac{clearnance\ volume}{swept\ volume}$

For two stage machine

$$\emptyset W = \frac{2n}{(n-1,} P_1 V_1 (\frac{p_3}{p_1})^{\frac{n-1}{n}} - 1)$$

For example an x stage machine

$\frac{p_2}{p_1} = \frac{p_3}{p_2} = \ldots\ldots\ldots = \frac{px+1}{p_x} = k$

$$k = \sqrt[x]{\frac{px+1}{p_1}} = \sqrt[x]{(pressure\ ratio\ through\ compressor)}$$

Self-Assessment

1. Rotary compressors are used where ____ quantities of gas are needed at relatively ____ pressure.
   a) large, high
   b) large, low
   c) small, high
   d) small, low

2. Rotary compressor can be classified as
   a) displacement compressor
   b) steady-flow compressor
   c) both of the mentioned
   d) none of the mentioned

3. In steady-flow compressor, compression occurs by
   a) transfer of kinetic energy
   b) transfer of potential energy
   c) trapping air
   d) all of the mentioned

4. In displacement compressor, compression occurs by
   a) transfer of kinetic energy
   b) transfer of potential energy
   c) trapping air
   d) all of the mentioned

5. The rotary positive displacement machines are ____ and compression is ____
   a) cooled, isothermal
   b) uncooled, isothermal
   c) cooled, adiabatic
   d) uncooled, adiabatic

6. Define the following terms in relation to compressors
   i. Isothermal efficiency
   ii. Volumetric efficiency

7. Derive the equation of cycle work for a reciprocating single acting compressor.

8. A Single stage reciprocating compressor takes 1m3 of air per minute at 1.013 bas and 150c and delivers it at 7 bar assuming that the law of compression is $PV^{1.35}$=C, and that clearance is negligible, calculate indicated power

Tools, Equipment, Supplies and Materials for the specific learning outcome.

Various types of compressors

Pressure and temperature measuring instruments

References

Rayner Joel (1996) Basic Engineering Thermodynamics (fifth Edition) Addison Wesley Longman limited Edinburg Gate

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8.3.2.1 Learning Outcome No.12 Understand Gas Turbines

Learning Activities

Learning Outcome No12 UNDERSTAND GAS TURBINES	
Learning Activities	**Special Instructions**
Demonstrate the use of gas turbine plant to determine the efficiency of the plant Identify closed cycle and open cycle turbine plants	Information about various turbines

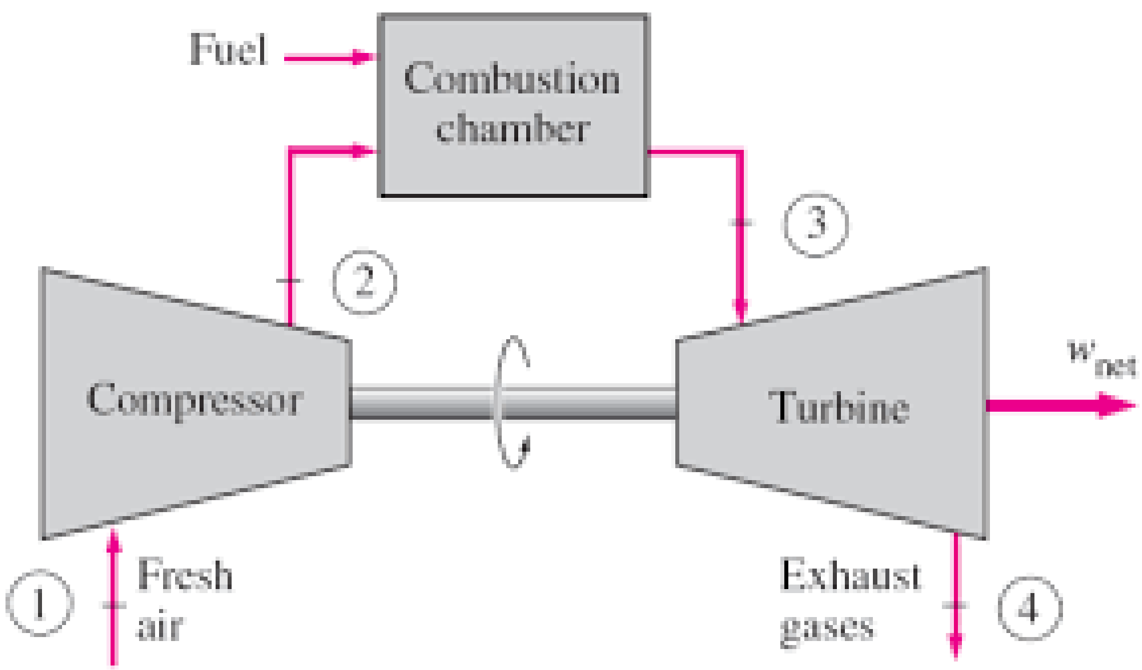
8.3.2.1 Information Sheet

Understand Gas Turbines

Definition

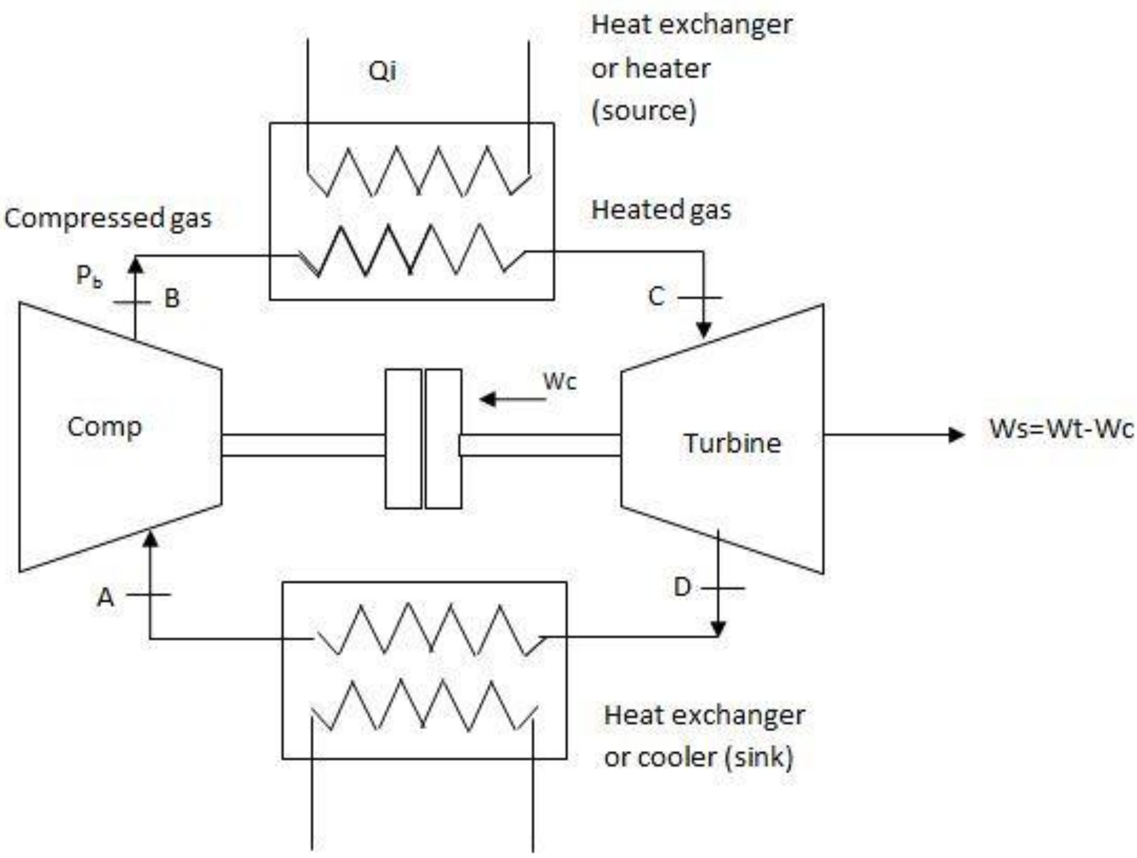
Gas turbines are used in a very wide range of services such as powering aircraft, industrial plants for driving pump, compressors and small electric generators. Compared with steam, plant they have advantages that they and their total systems are small in size, mass and initial cost per unit output. They are quick starting and also smooth running.

Open cycle



Open gas –turbine cycle
The gas enters compressors where it's compressed it then enters combustion chambes or reactor where it receives heat at constant pressure from there it expands through the turbine the turbine supplies compressor power.

Closed cycle
The gas is heated in the reactor, expanded through the turbine and then cooled in a heat exchanges and compressed back to the reactor.



Closed turbine cycle

$$W_T = \overset{o}{m} cp(T_4 - T_3)$$

In terms of pressure ratio across turbine rpt

$$r_{pt} = \frac{p_3}{p_4}$$

Is related to absolute temperature ratio by

$\frac{T_3}{T_4} = r_{pt}^{(k-1)k}$ Where $k = \frac{cp}{cv}$

$$\therefore WT = \dot{M}C_P T_3(1 - \frac{1}{r_{pt}^{(k-1)/k}}$$

Cycle thermal efficiency

$$\int_{th} = 1 - \frac{1}{r_p^{(k-1)k}}$$

Self-Assessment

1. In gas turbine, intercooler is placed
   a) before low pressure compressor
   b) in between low pressure compressor and high pressure compressor
   c) in between high pressure compressor and turbine
   d) None of the mentioned

2. In gas turbine, the function of Re-heater is to
   a) Heat inlet air
   b) Heat exhaust gases
   c) Heat air coming out of compressor
   d) Heat gases coming out of high pressure turbine

3. The 'work ratio' increases with
   a) increase in turbine inlet pressure
   b) decrease in compressor inlet temperature
   c) decrease in pressure ratio of the cycle
   d) all of the mentioned

4. In the centrifugal compressor, total pressure varies
   a) directly as the speed ratio
   b) square of speed ratio
   c) cube of the speed ratio
   d) any of the mentioned

5. The efficiency of multistage compressor is _____ than a single stage.
   a) lower
   b) higher

c) equal to
d) any of the mentioned

6. Explain the use of gas turbine in the industry
7. Derive turbine work equation for gas turbine
8. Outline a procedure to determine the efficiency of a gas turbine.

Tools, Equipment, Supplies and Materials for the specific learning outcome

Various types of compressors
Pressure and temperature measuring instruments

References

Abdulkarem A. Mishael (2017): power plant (editions): Chapter 6 Gas turbines & combined cycles,
Rayner Joel (1996) Basic Engineering Thermodynamics (fifth Edition) Addison Wesley Longman limited Edinburg Gate
Eastop T.D & Mc Conkey A. (2009) Applied Thermodynamics for Engineering Technologists (fifth Edition) Dorling Kindersley, New Delhi .
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8.3.2.2 Learning Outcome No.13 Understand the Impulse Steam Turbines

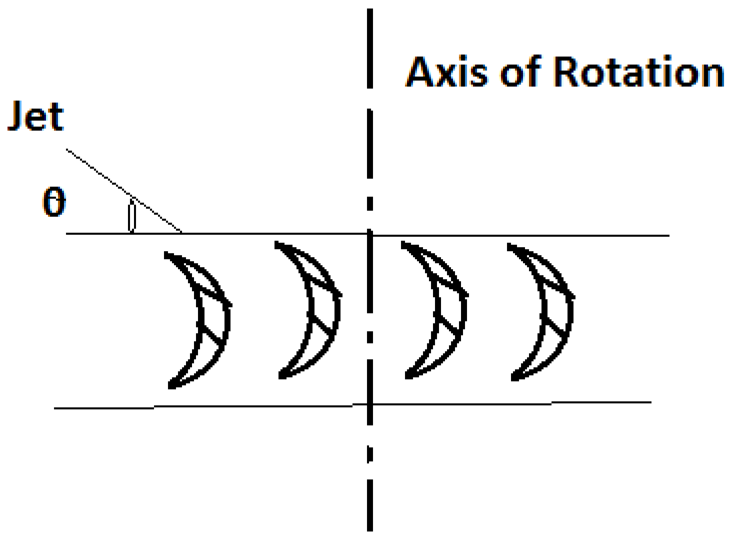
Learning Activities

Learning Outcome No 13 Understand The Impulse Steam Turbines	
Learning Activities	**Special Instructions**
Demonstrate the operation of an impulse steam turbine Principles of operations of the impulse steam turbines is described Impulse steam turbine equation is derived and applied	Special types of turbines

Information Sheet: 8.3.2.2

Understand Impulse Steam Turbine

Most steam turbine plant use impulse steam turbines. The steam supplied to a single wheel impulse turbines expands completely in the nozzles and leaves with a high absolute velocity. The steam is delivered to the wheel at an angle.



For impulse momentum the force, is equal to the change in momentum of the fluid in the direction of motion.

$F = \frac{\dot{m}}{g_c^4}(V_{s1}\text{Cos}\theta - V_{s2}\ Cos\delta)$

Where $V_{s1=}$ absolute velocity of fluid leaving nozzle

V_{s2}=absolute velocity of fluid leaving blade.

θ= nozzle angle

δ= fluid exit angle

$\vartheta_{c=}$Conversion factor.

0

$F = \frac{m}{g_c}(V_{w1} - V_{w2})$

Where V_w is velocity of whirl

Thus

0

$$\overset{0}{W} = \frac{\overset{0}{m} V_B}{g_c} \backslash V_{si}\cos\theta\text{-}V_{s2}cord)$$

Blade efficiency defined as ration of blade work to the initial energy of jet.

$$\eta_B = 2\left[\left(\frac{V_B}{V_{s1}}\right)cos\theta - \frac{V_B}{V_{s1}}\left(\frac{V_{s2}}{V_{s1}}\right)cos\right]$$

Single –stage impulse turbine

It is also called the de Laval turbine after its inventor. It consists of a single motor to which impulse blades are attached steam is fed through one or several convergent- governing of the turbines by shutting off one or more of them.

Compound –impulse turbines

In a single stage impulse turbine, he speed is too high beyond the maximum allowable safety limits due to centrifugal stress on the motor material. The large velocities also result in large fiction losses and a reduction in turbine efficiency. To overcome these differences, two methods have been utilized, both called compounding

Velocity –compounded turbine

Pressure –compounded turbine.

Self-Assessment

1. Derive the blade efficiency equation for an impulse steam turbine.

2. The velocity of steam leaving the nozzles of an impulse turbine is 900m/s and the nozzle angle is 20^0. The blade velocity is 300m/s and the blade velocity coefficient is 0.7. Calculate for a mass flow of 1kg/s and symmetrical blading

   i. The blade inlet angle
   ii. The driving force on the wheel

3. Demonstrate the operation of an impulse steam turbine

Tools, Equipment, Supplies and Materials for the specific learning outcome

Impulse steam turbine plant with tempera rue and pressure measuring instruments attached

References (APA)

Abdulkarem A. Mishael (2017). Power plant (edition 1): chapter -4 –steam Turbine

Eastop T.D & Mc Conkey A (2009). Applied Thermodynamics for Engineering Technologist (fifth Edition) Darling, Kindersley, New Delhi

CHAPTER 9: FLUID MECHANICS PRINCIPLES

9.1 Introduction to fluid mechanics

Fluid mechanic principles entails the application of principles of mechanics of fluids and the effects of forces to solve problems relating to changes in pressure, velocity, temperature and density as they affect operation/ functionality of mechanical systems. Fluid mechanic principles are widely applied in various engineering industries e.g. automobile industry in the design and operation of hydraulic systems, tyres and general brake system. This unit of competency covers flow of fluids, effects of forces, fluid dimensional analysis, and operation of fluid systems. The primary training resources in this course include scientific calculators, standalone hydraulic brake system, relevant stationeries, complete pump system, standalone tire suspension units, models of aero foils, boiler system, and steam water line circuit. Upon the completion of this unit, a trainee should be competent to troubleshoot mishaps, calculate the flow rates of fluid in various systems, and calculate effects of forces in mechanical systems. This course prepares a trainee to pursue fluid mechanics as a career in the field of mechanical engineering/manufacturing.

9.2 Performance Standard

The trainee should be able to; identify, formulate, and solve engineering problems including: Measure flow rates and calculate losses in various mechanical systems as per standard principles of operations, measure the effects of various types of forces in fluid systems as per standard principles of operations, perform experiments to demonstrate application of dimensional analysis principles as standard operating parameters, and operate hydraulic mechanical systems as per standard operating procedures.

9.3 Learning Outcome

9.3.1 List of Learning Outcomes

a. Understand the flow of fluids
b. Demonstrate knowledge in viscous flow
c. Perform the dimensional analysis
d. Operate fluid pumps

9.3.1.1 Learning Outcome: No.1 Understand the flow of fluids

Learning Activities

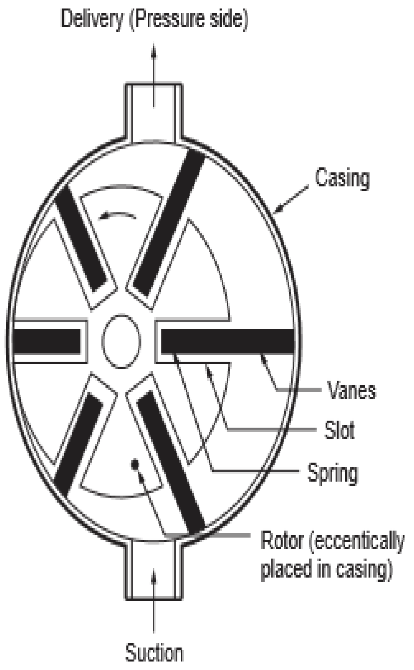
<table>
<tr><td colspan="2">Learning Outcome No 1: Understand the flow of fluids</td></tr>
<tr><td>Learning Activities</td><td>Special Instructions</td></tr>
<tr><td>


Figure 16.6.3 Vane pump
Activity 1: calculate waste/losses of fluid in a leaking pump
Obtain the measuring instruments
Check accuracy and calibrate measuring instruments
Measure flow rates of fluids at different specific points
Perform calculations of the fluid losses
</td><td>Provide manufacturer’s manuals for the specific measuring instrument</td></tr>
</table>

Information Sheet: 9.3.1.1

Introduction

Fluid mechanic is the study of the behavior of liquids and gases, and particularly the forces that they produce. There are five relationships that are most useful in fluid mechanics problems: kinematic, stress, conservation, regulating, and constitutive.

Definition of key terms

A fluid- is a material that continuously deforms under a constant load

Kinematics-is the study of motion without regard to force. This is usually the first step in the analysis or design of a mechanism

Dynamics-is the combination of kinetics and kinematics in fluids

Conservation forces-is a force with the property that the work done in moving a particle between two points is independent of the path it takes. It is dependent only on the position of the object. If a force is conservative, it is possible to assign a numerical value for the potential at any point. When an object moves from one location to another, the force changes the potential energy of the object by an amount that does not depend on the path taken. Gravity and spring forces are examples of conservative forces.

Non-conservative forces transfer energy from the back to the potential energy of the system to regain it during reverse motion. Instead, they transfer the energy from the system in an energy form which cannot be used by the force to transfer it back to the object in motion e.g friction.

PE=mgh

Newton's laws of motion- these are three physical laws that, together, laid the foundation for classical mechanics. They describe the relationship between a body and the forces acting upon it, and its motion in response to those forces. The three laws are summarized as follows:

First law: in an inertial frame of reference, an object either remains at rest or continues to move at constant velocity, unless acted upon by a force.

Second law: in an inertial frame of reference, the vector sum of the forces **F** on an object is equal to the mass m of that object multiplied by the acceleration **a** of the object: **F**=ma. (assumed m is constant)

Third law: when one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction on the first body

Reynolds (Re) number. This dimensionless number characterizes the nature of a fluid flow and relative contribution of inertia and viscous dissipation. In practice, flows with the same Reynolds number will display the same properties. For an object of typical length L moving at typical velocity U, in a fluid of dynamic viscosity μ and density Þ, the Reynolds number is

$$Re=UL\text{Þ}/\mu$$

It also reads Re=UL/v using the kinematic viscosity v=μ/Þ

Bernoulli's principle states that an increase in the speed of a fluid occurs simultaneously with a decrease in pressure or a decrease in fluid's potential energy. This principle can be applied to various types of fluid flow, resulting in various forms of Bernoulli's equation.

Derivations of the Bernoulli's equation

Bernoulli's equation for incompressible fluids ;

can be derived by either integrating Newtonian's second law of motion or by applying the law of conservation of energy between two sections along a streamline, ignoring viscosity, compressibility, and thermal effects.

Derivation through integrating Newton's second law of motion

By first ignoring gravity and considering constrictions and expansions in pipes that are otherwise straight, as seen in Venturi effect.
Let the x axis be directed down the axis of the pipe.
Define a parcel of fluid moving through a pipe with cross-section area A, the length of the parcel is dx, and the volume of the parcel A dv. If mass density is Þ, the mass of the parcel is density multiplied by its volume m=ÞAdx. The change in pressure over distance dx is dp and flow velocity v=dx/dt .the change in pressure over distance dx is dp and flow velocity v=dx/dt

Apply Newton's second law of motion (force = mass × acceleration) and recognizing that the effective force on the parcel of fluid is –Adp. If pressure decreases along /the length of the pipe, dp is negative but the force resulting in flow is positive along the x axis.

m dv/dt=F
ÞA.dv/dt =-Adp
Þdv/dt=-dp/dx

In steady flow the velocity field is constant with respect to time, v=v(x)=v[x(t)], so v itself is not directly a function of time t. it is only when the parcel moves through x that the cross sectional area changes: v depends on t the cross-sectional position x(t)

Dv/dt=dv/dx.dx/dt
=dv/dx.v
=d/dx(v^2/2)

With density Þ constant, the equation of motion can be written as

d/dx (Þ.v^2/2+p)=0

by intergrating with respect to x

V2/2+p/Þ=C

Where C is a constant, referred to as the Bernoulli's constant.

Illustrations of Bernoulli's Viscous flow: Newton's law of viscosity. Types of fluids. Effect of temperature on viscosity. Effect of pressure on viscosity. Surface tension and capillaries.

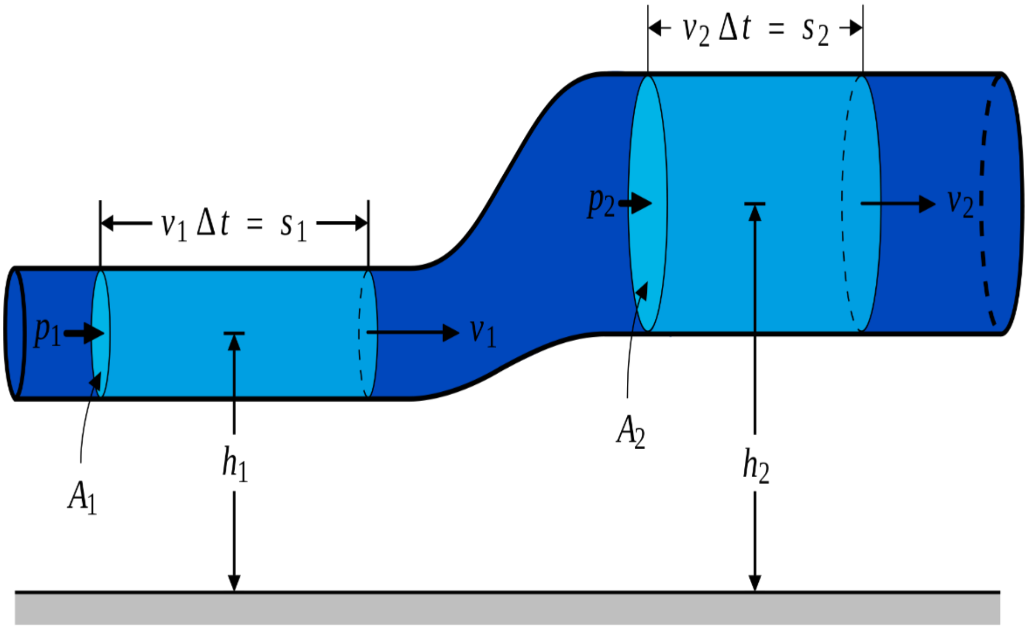


Figure 74: Bernoulli's Principles Source Douglas (2011)
Viscous flow equations. Bernoulli's equation

Dimensional analysis: introduction. Dimensional homogeneity. Fundamental dimensions. Methods of dimensional analysis. Limitations of dimensional analysis. Model analysis. Dimensionless numbers and their significance. Reynolds model law

Operate fluid pumps: classification of pumps. Comparison of rotodynamic and reciprocating pumps. Characteristics of pumps. Description and principle of operation. Flow rate and power. Pumps equations.

For further study refer to fluid mechanics and machinery (second edition) by Kothandaraman C.P or fluid mechanics and hydraulic principle by Rajput Er. R. K

Self-Assessment (assessment questions/evaluation question for the learning

1. In which method of fluid flow analysis do we describe the motion parameters at a point?
   a) Langragian method
   b) Eulerian Method
   c) Control volume analysis
   d) None of the mentioned

2. Which method is most commonly used in fluid mechanics for analysis?
   a) Langragian method
   b) Eulerian Method
   c) Control volume analysis
   d) None of the mentioned

3. In unsteady flow, the flow parameters change with respect to position.
   a) True
   b) False

4. Uniform flow is defined as the type of flow in which acceleration is zero i.e velocity is constant.
   a) True
   b) False

5. In laminar flow fluid particles flow along a streamline.
   a) True
   b) False

6. Eddies formed in the turbulent flow are major cause of the energy loss in the turbulent flow.
   a) True
   b) False

7. For compressible flow specific gravity remains same.
   a) True
   b) False

8. When the flow particles flow in zigzag manner and rotate about their own axis it is what type of flow?
   a) Turbulent flow
   b) errotational flow
   c) Rotational flow
   d) None of the mentioned

9. If the velocity is function of two space coordinates along with time then fluid flow is three dimensional in nature.
   a) True
   b) False

10. What is unit for flow rate for gases?
   a) m3/s
   b) litres/s
   c) cm3/s

d) kgf/s

11. If 5 m3 of certain oil weighs 45 kN calculate the specific weight, specific gravity and mass density of the oil. Mass density=9/0.98, =0.917

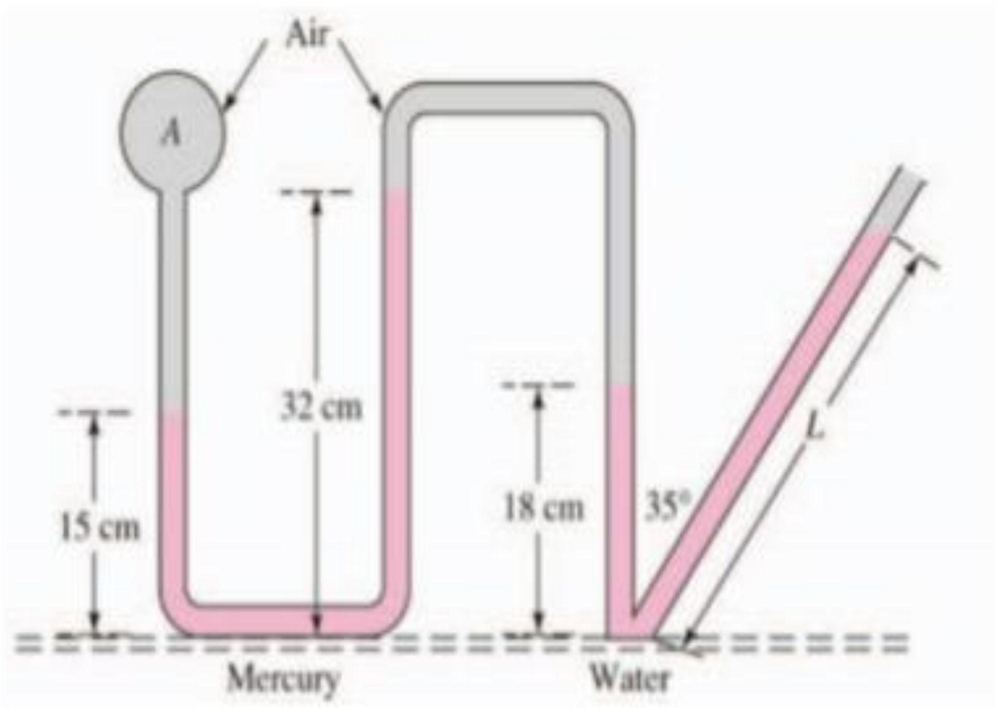


Figure *75:* Hydrostatics. (Douglas. 2000)

12. The system above is open to atmospheric pressure (105 Pa) on its right side. a) If L=120 cm, what is the air pressure in container A? b) Conversely, if pA = 135 kPa, what is the length L? Assume the density of water and mercury are 1,000 kg/m3 and 13,560 kg/m3, respectively.

13. Some of you may have noticed that dams are much thicker at their bottom (e.g. see prob. 2). For example, in the Hoover dam example we considered in the class the thickness of the dam at the top is about 45 feet while the thickness at the bottom is about 660 feet. Can you explain why dams are built that way?
14. A 10-kg hollow copper ball, a 10-kg solid copper ball and a 10-kg solid copper cube are submerged in a liquid. Will the buoyancy forces acting on these three bodies be the same or different? Explain and justify your answer quantitatively

15. Conduct an experiment to determine fluid flow
16. Measure Flow rate in pipes
17. Determine Losses in pipes
18. Determine Causes of losses in pipes

19. Apply Flow losses equations in problem solving

Tools, Equipment, Supplies and Materials for the specific learning outcome

- Fluid mechanics principle textbook
- Models and charts
- Stand-alone brake system
- Pumps
- Aero foil

References (APA)

Rajput .RK., 1998, Fluid mechanics and Hydraulic Machinery, by S.Chand and company ltd, Ram Nagar, New Delhi-110055

Graebel, W.P. Advanced Fluid Mechanics, University of Michigan

Buddhi. N. Hewakandamby, 2012, A first course in fluids mechanics for engineers, VENTUS,

Internet www/htts.fluidmechanics.co.ke

Douglas, D. F (1992) Solution of Problems in Fluid Mechanics, Prt 1 The pitman

9.3.1.2 Learning Outcome No.2 Demonstrate knowledge in viscous flow

Learning activities

Learning Outcome No 2: Demonstrate knowledge in viscous flow	
Learning Activities	**Special Instructions**
Measure the viscosity of different liquid Using the following Tools and equipment may include: ruler stopwatch graduated cylinder marble or steel ball calculators Internet access, to research viscosities for one worksheet question thick, somewhat clear household fluids, such as motor oil, corn syrup, pancake syrup, shampoo, liquid soap (perhaps a different fluid for each 1-2 groups), enough of each liquid to fill a graduated cylinder for each group that tests it scale	Provide manufacturer's manuals for the specific measuring instrument -provide viscosity activity worksheet

Information Sheet: 9.3.1.2

Introduction

Viscous flow entails the application of fluid flow principles to solve problems of fluid forces on projectiles. Competencies in viscous flow principles are in great demand in the field of mechanical engineering, military, automobile industries, airplane construction, construction of marine vessels, and in the field medical engineering. to measure and calculate the internal forces in fluid like friction which causes the resistance to flow . This property of fluid is known as viscosity which is primarily due to cohesion and molecular momentum exchange between fluid layers. Viscous flow play a major in industries in the practical processes like polymer processing which determines the success of the operation, production of lubricating fluids, melting of metals, leak testing packages and testing the rate of flow in pipes. This learning outcome covers the Newtonian's law of viscosity, types of fluids and the effects of temperature and pressure on viscosity. The primary training resources in this outcome include scientific calculators, viscous flow air meters, and horse pipe and air compressor machine. Upon the completion of this outcome, the trainee should be competent in understanding how fluids behave under various conditions to help him/her to select the optimal fluids to operate in devices or to design devices that are able to successfully operate in environments that contain fluids and apply the viscous flow equations in problem solving involving leakages in pipes.

These outcome describes how a fluid resists forces. Fluids with low viscosity have a low resistance to flow, and therefore the molecules flow quickly and are easy to move through. Fluids with high viscosity flow more slowly and are harder to move through. One example of a high-viscosity fluid is honey.

When an object free falls through a fluid, at some point the force due to gravity is balanced by the resistance to shear by the fluid. This is called **terminal velocity,** and is the point at which the falling object maintains a constant velocity.

Trainee to watch video; https://www.youtube.com/

Definition of terms
Shear - A type of force that occurs when two objects slide parallel to one another
Terminal velocity - The point at which the force exerted by gravity on a falling object is equaled by a fluid's resistance to that force
Viscosity – is the ability of fluid to resist forces
Further reading; also trainee to define the following terms,
Kinematics, strain, stress, torque, velocity
Reference www.teachingengineering.org/lesson

Illustrations of laminar flow

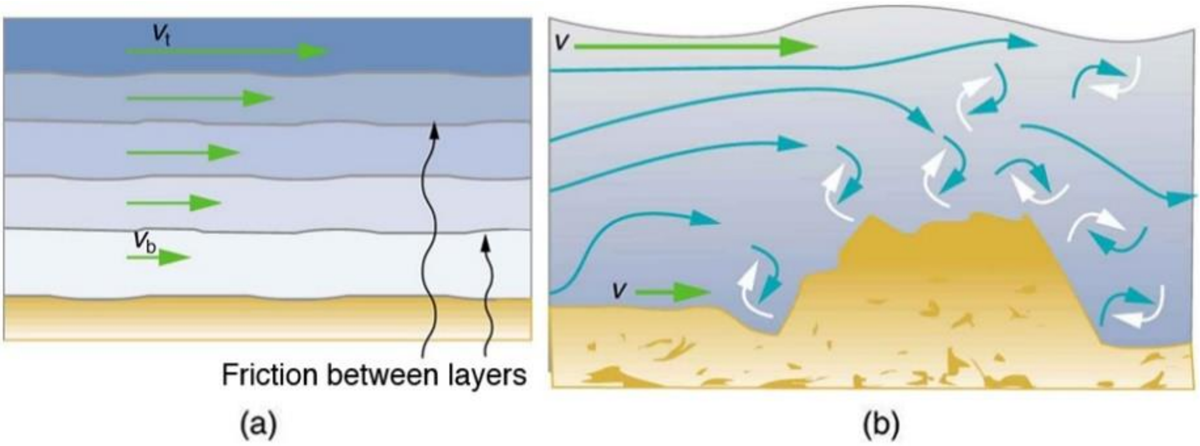


Figure 76: Laminar Flow Source, Rajput (2013)

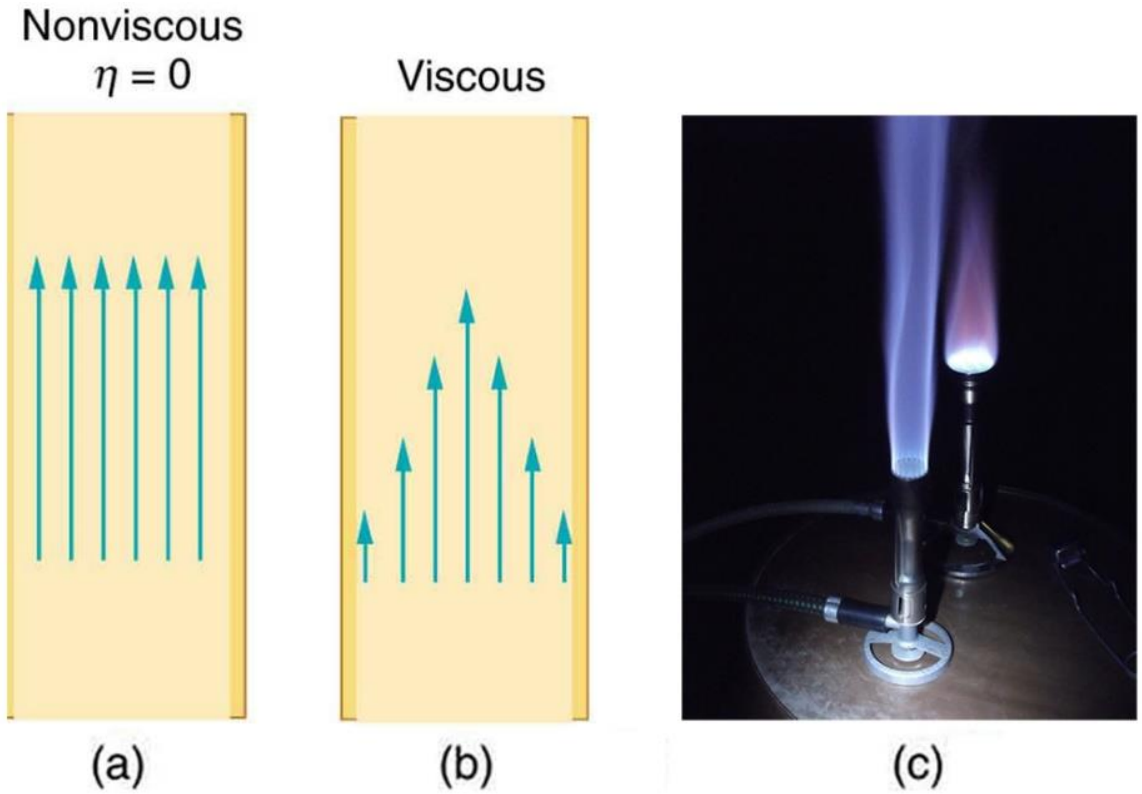


Figure 77: Non-viscous Vs Viscous

Source Douglas (2000)

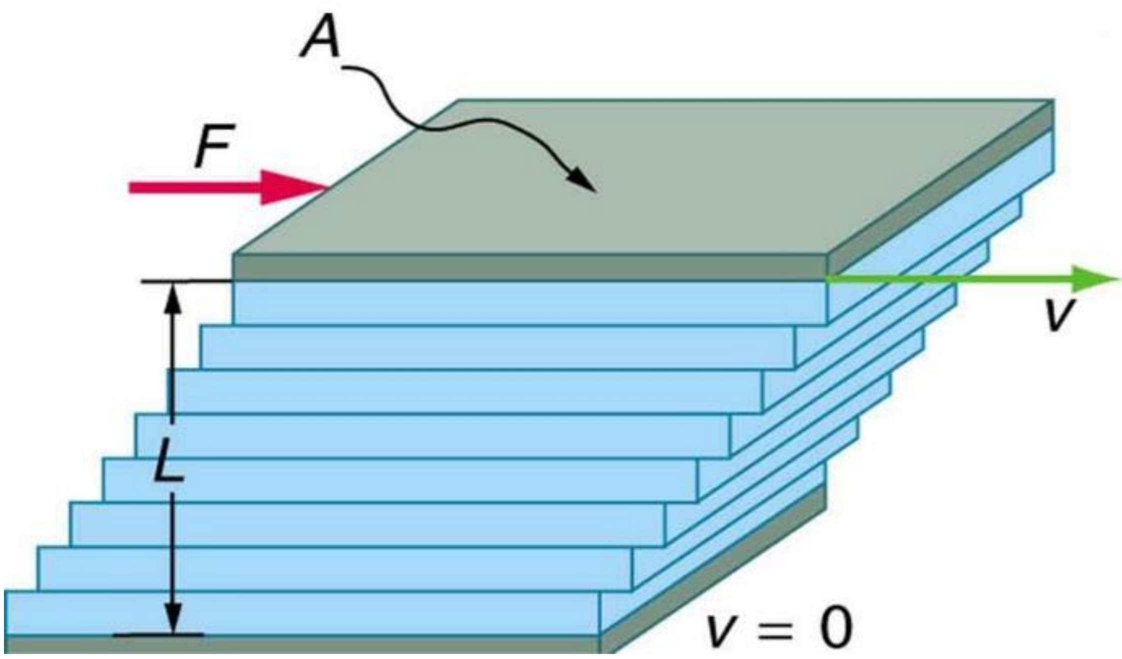


Figure 78: Laminar Flow Adapted from Douglas, 2000

The graphic shows laminar flow of fluid between two plates of area . The bottom plate is fixed. When the top plate is pushed to the right, it drags the fluid along with it.

Procedure

Before the Activity

Gather materials and make copies of the viscosity activity worksheet.

Be sure the ball sinks slowly enough in all of the fluids that a velocity measurement can be obtained. If the ball falls too quickly, it is hard to accurately start and stop the stopwatch.

Divide the class into groups of three students each. Hand out the worksheets.

With the Students

Have each group choose a fluid to measure the viscosity of (or assign each group a fluid).

Have students calculate the density of the fluid.

Weigh the empty graduated cylinder.

Fill the cylinder with fluid, and record the volume.

Weigh the full graduated cylinder. Subtract the mass of the empty graduated cylinder to determine the mass of the fluid.

The density of the fluid is the mass over the volume.

$$\rho_f = \frac{mass\ of\ fluid\ [kg]}{volume\ of\ fluid\ [cm^3]}$$

Note: 1 cm^3=1 ml.

Have students measure the density of the sphere.

Measure the radius of the ball. Record as r [cm].

Calculate the volume of the sphere: $Vol_s = \frac{4}{3}\pi r^3$

Alternatively, place the sphere in a graduated cylinder half filled with water; the displacement of the water is equal to the volume of the sphere.

Weigh the sphere, and calculate the density:

$$\rho_s = \frac{mass\ of\ sphere\ [kg]}{volume\ of\ sphere\ [cm^3]}$$

Have students drop the ball into the fluid, timing the ball as it falls a measured distance.

(Note: Ideally students would wait for the ball to reach a constant velocity, however for this activity we assume the ball reaches terminal velocity very quickly, so that students can measure the time from when the ball enters the fluid until it reaches the cylinder bottom. For less-viscous, "thinner," fluids, this may be very quick).

Calculate the velocity of the ball falling through the fluid.

$$V_s = \frac{distance\ ball\ drops\ [cm]}{length\ of\ time\ for\ ball\ to\ drop\ [s]}$$

Calculate the viscosity of the fluid using the following equation,

$$\mu = \frac{4}{9}\frac{r^2 g(\rho_s - \rho_f)}{V_s}$$

Where g is acceleration due to gravity (981 [cm/s^2]). The answer should be in units of kg/cm s, or mPa-s. For comparison, the viscosity of water is approximately 1 mPa-s.

For accuracy, have students repeat the experiment and calculate an average viscosity.

Have groups share, compare and discuss their results as a class by either writing the results in a table on the board or on a class overhead projector.

Content;

Viscous flow: Newton’s law of viscosity. Types of fluids. Effect of temperature on viscosity. Effect of pressure on viscosity. Surface tension and capillaries. Viscous flow equations. Bernoulli’s equation. Laminar and turbulent flow.

For further study refer to fluid mechanics and machinery **(**second edition) by Kothandaraman C.P or fluid mechanics and hydraulic principle by Rajput Er. R. K

Conclusion

Trainee assignment

Considering the fluids available for activity testing, ask students to estimate which liquid they think will have the highest viscosity. Which will have the lowest? Write their predictions.

Trainer

Have students share and discuss their measured/calculated viscosities with the class. Compare and discuss the class results with the predictions made before beginning the activity.

Check on the safety as per the work place procedure

Self-Assessment

1. Which among the following does not depend on the friction factor?
   a) Pipe diameter
   b) Fluid density
   c) Viscosity
   d) Weight

2. Which among the following is the formula for friction factor (f)?
   a) f = 0.079*Re0.25
   b) f = 0.079/Re0.25
   c) f = 0.079/Re0.5
   d) f = 0.079*Re0.5

3. How do we calculate losses for a larger range of Reynolds number?
   a) Moody chart
   b) Bar chart
   c) Scatter chart
   d) Column histogram

4. Darcy- Weisbach equation gives relation between___________
   a) Pressure and temperature
   b) Mass, volume and pressure
   c) Head loss and pressure loss

d) Pressure loss only

5. Which among the following is formula for friction factor of circular pipes?
   a) 16/Re
   b) 64/Re
   c) Re/16
   d) Re/64

6. Loss of head due to friction is ___________
   a) Directly proportional to hydraulic radius
   b) Inversely proportional to velocity
   c) Inversely proportional to hydraulic radius
   d) Directly proportional to gravitational constant

7. The formula for hydraulic diameter is______
   a) 4A/P
   b) 4AP
   c) 4AV
   d) 4V

8. What are the reasons for minor head loses in a pipe?
   a) Friction
   b) Heat
   c) Valves and bends
   d) Temperature

9. What happens to the head loss when the flow rate is doubled?
   a) Doubles
   b) Same
   c) Triples
   d) Four times

10. Relative roughness is__________
    a) ϵ/D
    b) ϵ*D
    c) ϵ/Dm
    d) ϵgD

11. A plate 0.05 mm distant from a fixed plate moves at 1.2 m/s and requires a force of 2.2 N/m2 to maintain this speed. Find the viscosity of the fluid between the plates. (Answer 9.16x10-4 poise)

12. Explain viscous flow between parallel surfaces

13. Derive and apply viscous flow equations between parallel surfaces
14. Derive and apply viscous flow equations in circular pipes

Tools, Equipment, Supplies and Materials for the specific learning outcome

- ruler
- stopwatch
- graduated cylinder
- marble or steel ball
- Internet access, to research viscosities for one worksheet question
- scale

References (APA)

Rajput,.RK. 1998, Fluid mechanics and Hydraulic Machinery, by S.Chand and company ltd, Ram Nagar, New Delhi-110055

Graebel, W.P. Advanced Fluid Mechanics, University of Michigan

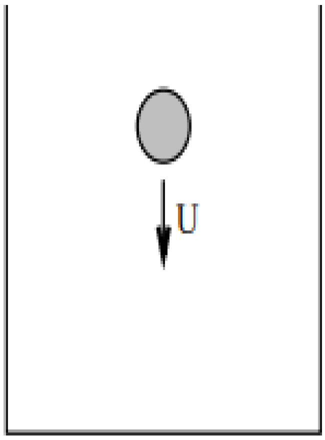
Buddhi. N. Hewakandamby, 2012, A first course in fluids mechanics for engineers, VENTUS,

Internet www/htts.fluidmechanics.co.ke

Douglas, D. F (1992) Solution of Problems in Fluid Mechanics, Prt 1 The pitman

9.3.1.3 Learning Outcome No.3 Perform the dimensional analysis

Learning Activities

<table>
<tr><td colspan="2">Learning Outcome No.3: Perform the dimensional analysis</td></tr>
<tr><td>Learning Activities</td><td>Special Instructions</td></tr>
<tr><td>sphere falling in a tank containing a liquid

Tools and equipment required
Transparent measuring cylinder
A sphere
Liquid
Micrometer screw gauge
Activity;
Take cylinder of known diameter
Pour liquid in it
Drop sphere of different radius
Note the velocity of sphere</td><td>-Provide manufacturer’s manuals for the specific measuring instrument</td></tr>
</table>

Information Sheet:9.3.1.3

Introduction

Dimensional analysis is a very powerful tool used in fluid mechanics to predict physical parameters that influence the flow in fluid mechanics, heat transfer in thermodynamics, and mechanical operations of machine systems and to design unit operations in engineering processes so as to obtain the relationship between the average transfer rates (mass, heat, momentum) and the applied forces that are used to drive the transport (concentration difference, temperature difference, velocity difference) . It reduces the number of variables in the problem by combining dimensional variables to form non-dimensional parameters so as to obtain a functional relationship among the various variables involved in terms of non-dimensional parameters. This elements covers the dimensional homogeneity, methods of dimensional analysis, limitations of dimensional analysis and forces influencing hydraulic phenomena. The primary resources in this element include measuring tools calibrated according to ISO standards, scientific calculators, SMP tables and portable objects. Upon the completion of this unit, a trainee should be competent to troubleshoot mishaps, calculate the flow rates of fluid in various systems, and calculate effects of forces in hydraulic phenomena. This course prepares a trainee to pursue fluid mechanics as a career in the field of mechanical engineering/manufacturing and chemical engineering

These outcome involves the identification of the transport properties that include fluid velocity, heat flux, mass flux, and the material properties which include viscosity, thermal conductivity, specific heat, density, etc. which are relevant to the problem, and list out all these quantities along with their dimensions.

Definition of terms;

The variable; is any quantity including dimensional and non-dimensional constants in a physical situation under investigation.

Dimensional Homogeneity: If an equation truly expresses a proper relationship among variables in a physical process, then it will be dimensionally homogeneous. The equations are correct for any system of units and consequently each group of terms in the equation must have the same dimensional representation. This is also known as the law of dimensional homogeneity.

Dimensional variables: These are the quantities, which actually vary during a given case and can be plotted against each other.

Dimensional constants: These are normally held constant during a given run. But, they may vary from case to case.

Trainee to find the definition of the following terms;

Pure constants

Pi-terms

Further reading;

Fluid mechanics and machinery **(**second edition) by Kothandaraman C. P. or fluid mechanics and hydraulic principle by Rajput, R. K

Experiment; to find the value of critical velocity in pipes by Reynolds experiment

Apparatus

- -Reynolds apparatus consisting of piping system
- -measuring tank
- -differential manometer
- -stop watch

Procedure

Open the supply valve and allow the water to flow through one pipe of which the diameter is measured/ noted.

Connect the two rubber pipe leads from the manometer to pad-locks on the pipe at certain distance apart (distance actually measured).

Admit water through pipe to the rubber leads and adjust the supply of water by the supply valve till a suitable reading is available on the manometer.

Read the loss of head on the manometer. Collect the water discharging from the pipe in the measuring tank and note the rise of water level in tank.

Repeat the experiment at different velocities by varying the rate of flow of water in the pipe and tabulate the readings. Use these results to plot a curve (between hf and v). The point where the graph changes from straight line to curve will give the critical velocity.

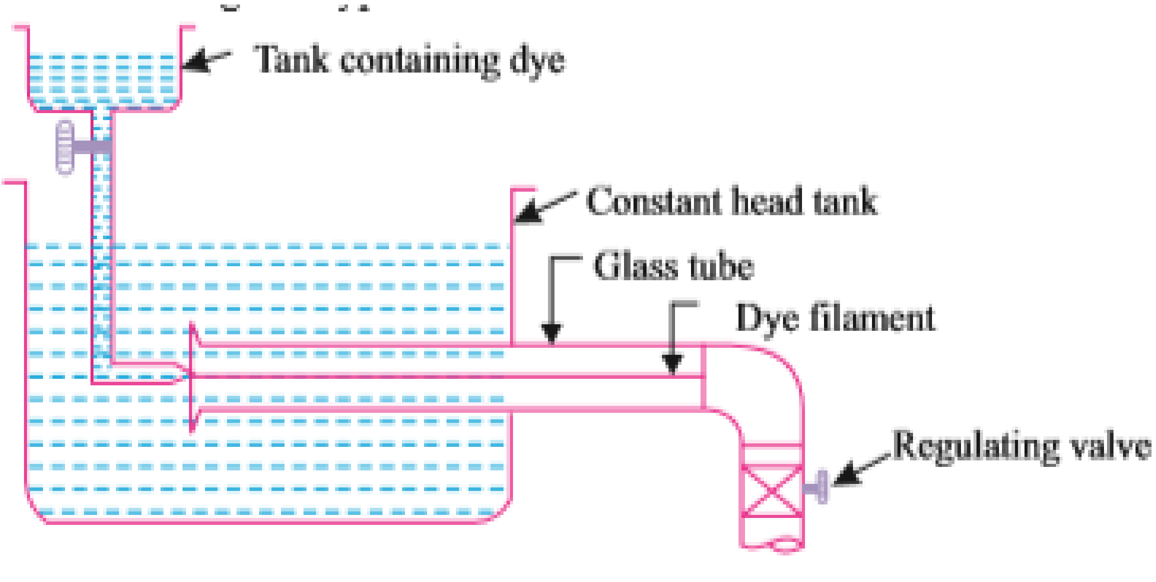


Fig. 9. Reynolds apparatus.

Dimensionless numbers and their significance. Reynolds model law

Figure 79: Reynolds apparatus- (Source, Rajput 1998)

For further study refer to fluid mechanics and machinery (second edition) by Kothandaraman C.P or fluid mechanics and hydraulic principle by Rajput. R. K

Conclusion

Trainee to do the assignment;

The efficiency η of a fan depends on the density ρ, the dynamic viscosity μ of the fluid, the angular velocity ω, diameter D of the rotor and the discharge Q. Express η in terms of dimensionless parameters.

Trainer

To check whether the assignment is done as per the standards

For further reading fluid mechanics and machinery (second edition) by Kothandaraman C.P or fluid mechanics and hydraulic principle by Rajput. R. K

Self-Assessment

1. Ratio of actual velocity to sonic velocity is known as
   a) Mach number
   b) Peclet number
   c) Reynolds number
   d) Grashof number

2. The value of Prandtl number for air is about
   a) 0.1
   b) 0.4
   c) 0.7
   d) 1.1

3. Let us say Mach number (greater than one), the flow is
   a) Sonic
   b) Subsonic
   c) Supersonic
   d) No flow

4. Free convection heat flow does not depend on
   a) Density
   b) Coefficient of viscosity
   c) Gravitational force

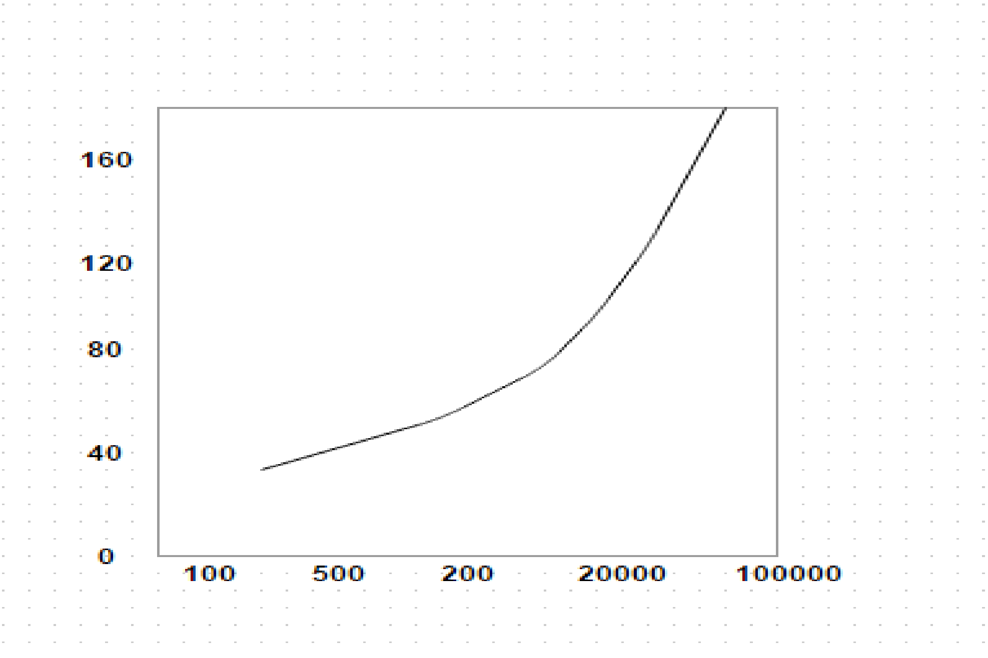
d) Velocity

5. Which dimensionless number has a significant role in forced convection?
   a) Prandtl number
   b) Peclet number
   c) Mach number
   d) Reynolds number

6. The non-dimensional parameter known as Stanton number is used in
   a) Forced convection heat transfer
   b) Condensation heat transfer
   c) Natural convection heat transfer
   d) Unsteady state heat transfer

7. The Prandtl number will be lowest for
   a) Water
   b) Liquid metal
   c) Lube oil
   d) Aqueous solution

8. The dimensionless parameter l 3 p 2 β g d t/μ 2 is referred to as



a) Stanton number
b) Schmidt number
c) Grashof number
d) Peclet number
Figure depicts the variation of which two numbers?

a) Nusselt number and Reynolds number
b) Stanton number and Reynolds number
c) Peclet number and Grashof number
d) Nusselt number and Stanton number

9. Heat is loss from a 100 mm diameter steam pipe placed horizontally in ambient air at 30 degree Celsius. If the Nusselt number is 25 W/m2 K and thermal conductivity of the air is 0.03 W/m K, then heat transfer coefficient will be
   a) 7.5 W/m2 K
   b) 16.5 W/m2 K
   c) 25 W/m2 K
   d) 30 W/m2 K

10. The resistance force R of a supersonic plane during flight can be considered as dependent upon the length of the aircraft l, velocity V, air viscosity μ, air density ρ and bulk modulus of air K. Express the functional relationship between these variables and the resisting force.

11. Explain the concept Dimensional analysis
12. Describe the principle of dimensional homogeneity
13. State the Fundamental dimensions
14. Define dimensional units
15. Identify Physical quantities
16. Apply Dimensional analysis is in problem solving

Tools, Equipment, Supplies and Materials for the specific learning outcome

- measuring tools calibrated according to ISO standards,
- scientific calculators,
- SMP tables and
- portable objects
- Internet
- Reynolds apparatus

References (APA)

Er.RK.Rajput, 1998, Fluid mechanics and Hydraulic Machinery, by S.Chand and company ltd, Ram Nagar, New Delhi-110055

W.P. Graebel, Professor Emeritus, Advanced Fluid Mechanics, University of Michigan

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9.3.1.4 Learning Outcome No 4: Operate fluid pumps

Learning Activities

Learning Outcome No. 4: Operate fluid pumps	
Learning Activities	**Special Instructions**
Experiment; to obtain the performance of a reciprocating pump Apparatus: A single-acting reciprocating pump with all the necessary Components A vacuum gauge and pressure gauge A discharge measurement unit Activity; Place the pump above the liquid Pull the plunger in an outward motion to decrease pressure in the chamber Push back plunger, -it will increase the pressure chamber and the inward pressure of the plunger will then open the discharge valve and release the fluid into the delivery pipe at a high velocity	Provide manufacturer's manuals for the specific measuring instrument -prime the pump to remove the air completely before starting up the pump -after each change in the valve opening let the flow stabilize before taking readings

Information Sheet: 9.3.1.4

Introduction

A pump is a device that provides energy to a fluid in a fluid system by converting the mechanical energy so as to increase the pressure energy or kinetic energy, or both of the fluid. The pump is widely used employed for various tasks which include pumping of oil, lifting of heavy loads, lifting viscous fluids in(paper pulp, muddy and sewage water, oil, sugar and molasses), lubricating the machine parts, exhaustion of latrines, pumping of water from underground sources which is clean and removing water from flooded area to safe life. This elements of competency covers the classification of pumps, comparison of rotor dynamic and reciprocating pumps, characteristics of pumps, description and principle of operation. The primary training resources in this course include scientific calculators, standalone hydraulic brake system, relevant stationeries, complete pump system, pointer gauge, hydraulic wave and hele-shaw apparatus. Upon the completion of this element, a trainee should be competent to troubleshoot mishaps, calculate the flow rates of fluid in various systems, and calculate effects of forces in mechanical systems. This course prepares a trainee to pursue fluid mechanics as a career in the field of mechanical engineering.

Pump is a contrivance which provides energy to a fluid in a fluid system by converting the mechanical energy to increase the pressure energy of the fluid in a system. In pumps flow takes place from the low pressure towards the higher pressure unlike in turbines where flow takes place from the higher pressure side to the low pressure side. Pumps are classified into two broad categories based on the transfer of mechanical energy.

Definition of terms

Head (h) [H] – Head is the expression of the energy content of a liquid in reference to an arbitrary datum. It is expressed in units of energy per unit weight of liquid. The measuring unit for head is meters (feet) of liquid.

Total head (H) [H_{tx}]– This is the measure of energy increase, per unit weight of liquid, imparted to the liquid by the pump, and is the difference between total discharge head and total suction head. This is the head normally specified for pumping applications because the complete characteristics of a system determine the total head required.

Rate of flow [Q] – The rate of flow of a pump is the total volume throughput per unit of time at suction conditions. The term capacity is also used.

Best Efficiency Point (BEP) – The rate of flow and total head at which the pump efficiency is maximum at a given speed and impeller diameter.

Displacement (D) – For a positive displacement pump it is the theoretical volume per revolution of the pump shaft.

Trainee to find what meant by the following terms;

Net Positive Suction Head Available
Net Positive Suction Head Required Net Positive Suction Head
Suction specific speed
Impeller

Further reading; for further study refer to fluid mechanics and machinery (second edition) by Kothandaraman C.P or fluid mechanics and hydraulic principle by Rajput Er. R. K

Illustration

Component Parts of A Centrifugal Pump

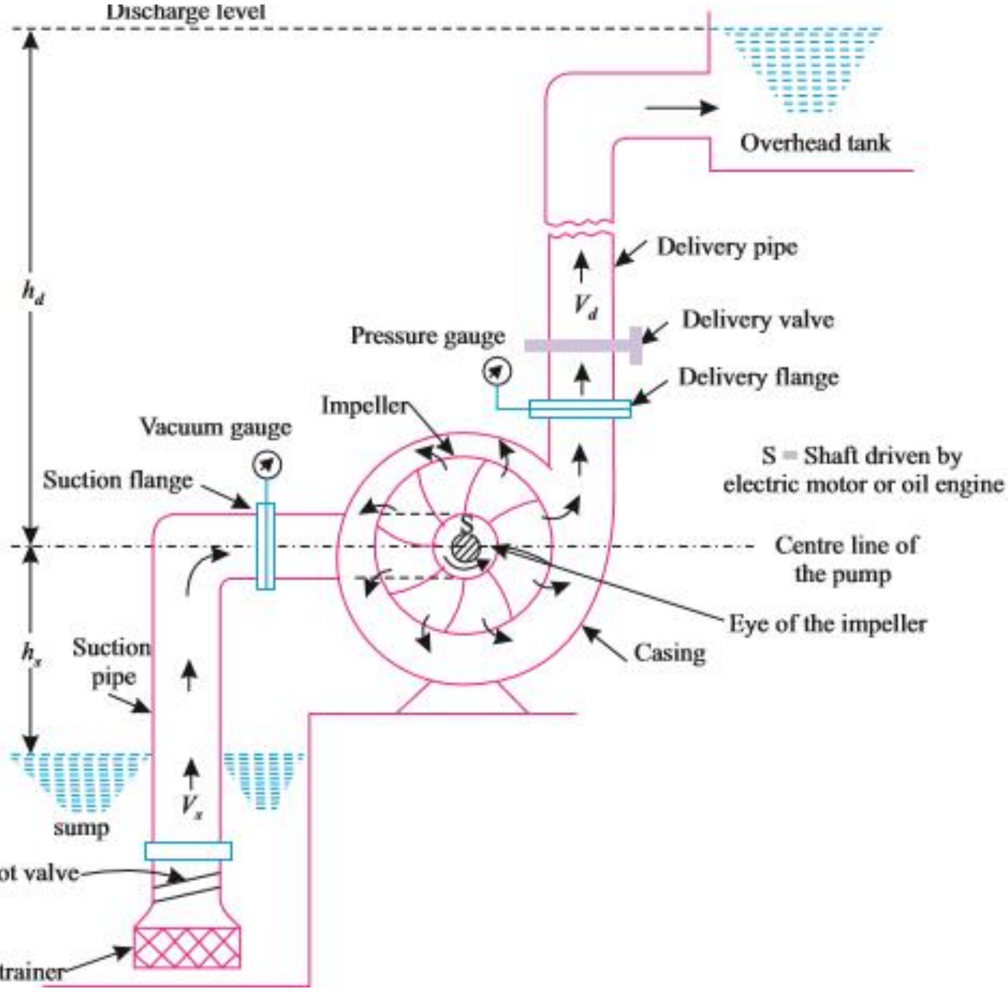

Figure 80: Centrifugal pump. Source: Rajput (1998)

Impeller. It is a wheel (or rotor) with a series of backward curved vanes/ blades mounted on a shaft which is usually coupled to an electric motor.

Casing. It is an airtight chamber surrounding the pump impeller. It contains suction and discharge arrangements, supporting for bearings, and facilitates to house the rotor assembly. It has provision to fix stuffing box and house packing materials which prevent external leakage.

The essential purposes of the casing are:

To guide water to and from the impeller, and

To partially convert the kinetic energy into pressure energy.

Suction pipe- pipe which connects the Centre/eye of the impeller to sump from which liquid is to be lifted. It is provided with a strainer at its lower end to prevent the entry of solid particles, debris etc. into the pup. The lower end of the pipe is also fitted with a non-return foot valve which does not permit the liquid to drain out of the suction pipe when pump is not working and also helps in priming.

Delivery pipe -pipe which is connected at the lower end to the outlet of the pump. It delivers the liquid to the required height. It is provided with a regulating valve to regulate the supply of water.

Working principle of a centrifugal pump

The delivery valve is closed and the pump is primed that is, suction pipe, casing and portion of the delivery pipe up to the delivery valve are completely filled with the liquid (to be pumped) so that no air pocket is left.

Keeping the delivery valve still closed the electric motor is started to rotate the impeller. The rotation of the impeller causes strong suction or vacuum just at the eye of the casing.

The speed of the impeller is gradually increased till the impeller rotates at its normal speed and develops normal energy required for pumping the liquid.

After the impeller attains the normal speed the delivery valve is opened when the liquid is continuously sucked (from sump well) up the suction pipe, it passes through the eye of casing and enters the impeller at its centre or it enters the impeller vanes at their inlet tips. This liquid is impelled out by the rotating vanes and it comes out at the outlet tips of the vanes into the casing. Due to impeller action the pressure head as well as velocity heads of the liquid are increased (some of this velocity heads is converted into pressure head in the casing and in the diffuser blades/vanes if they are also provided

From casing, the liquid passes into pipe and is lifted to the required height (and discharged from the outlet or upper end of the delivery pipe).

So long as motion is given to the impeller and there is supply of liquid to be lifted the process of lifting the liquid to the required height remains continuous.

When pump is to be stopped the delivery valve should be first closed, otherwise there may be some backflow from the reservoir.

Operate fluid pumps: classification of pumps. Comparison of rotor dynamic and reciprocating pumps. Characteristics of pumps. Description and principle of operation. Flow rate and power. Pumps equations.

For further study refer to

Kothandaraman, C. P. & Rajput. R. K Fluid mechanics and machinery (second edition) fluid mechanics hydraulic principle

Trainee assignment;

A centrifugal pump running at 750 r.p.m. discharges water at 0.1 m3/s against a head of 10 m at its best efficiency. A second pump of the same homologous series, when working at 500 r.p.m., is to deliver water at 0.05 m3/s at its best efficiency. What will be the design head of the second pump and what is the scale ratio between the first and the second? (Ans 3.67m, 1.32)

Kothandaraman, C. P. & Rajput. R. K Fluid mechanics and machinery (second edition) fluid mechanics hydraulic principle

Self-Assessment

1. A reciprocating pump is a class of _________
   a) Negative displacement
   b) Positive displacement
   c) Zero displacement
   d) Infinite displacement

2. The simplest application of the reciprocating pump is___________
   a) Piston pump
   b) Plunger
   c) Diaphragm pump
   d) Bicycle pump

3. Power operated deep well reciprocating pump is divided into__________
   a) Single and double acting
   b) Single and multi-stage
   c) Piston and plunger

d) Conductive and nonconductive

4. Which among the following is not an example of a reciprocating pump?
   a) Hand pump
   b) Wind mill
   c) Axial piston pump
   d) Turbine blades

5. Pump converts mechanical energy into _________
   a) Pressure energy only
   b) Kinetic energy only
   c) Pressure and kinetic energy
   d) Potential energy

6. Which among the following is not a positive displacement pump?
   a) Centrifugal
   b) Reciprocating
   c) Rotary
   d) Ionization pump

7. How do we measure the flow rate of liquid?
   a) Coriolis method
   b) Dead weight method

8. Which among the following is called as the velocity pump?
   a) Centrifugal
   b) Reciprocating
   c) Rotary
   d) Ionization pump

9. Discharge capacity of a reciprocating pump is lower than that of reciprocating pump.
   a) True
   b) False

10. Which among the following is a high-pressure pump?
   a) Centrifugal
   b) Reciprocating
   c) Rotary
   d) Ionization pump

11. Describe the principle of operation of pumps
12. Derive reciprocating pump equation
13. Derive centrifugal pump equation
14. Apply Pump equations in problem solving

15. A centrifugal pump, in which water enters radially, delivers water to a height of 165 mm. The impeller has a diameter of 360 mm and width 180 mm at inlet and the corresponding dimensions at the outlet are 720 mm and 90 mm respectively; its rotational speed is 1200 r.p.m. The blades are curved backward at 30° to the tangent at exit and the discharge is 0.389 m3/s. Determine:

i. Theoretical head developed,
ii. Manometric efficiency Pressure rise across the impeller assuming losses equal to 12 percent of velocity head at exit,
iii. Pressure rise and the loss of head in the volute casing,
iv. The vane angle at inlet, and
v. Power required to drive the pump assuming an overall efficiency of 70%. What would be corresponding mechanical efficiency?

(ans 193.4m, 85.3%, 1.91m/s, 93.02m, 17.63, 4.80, 899.5kW, 82%)

Tools, Equipment, Supplies and Materials for the specific learning outcome

- A current meter
- Pointer gauge
- Hydraulic wave
- Hele-shaw
- pump

References (APA)

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