

# WORKSHOP CALCULATION AND SCIENCE

NSQF

1<sup>st</sup> Semester

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**COMMON FOR ALL ENGINEERING TRADES**

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Directorate General of Training

**DIRECTORATE GENERAL OF TRAINING  
MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP  
GOVERNMENT OF INDIA**



**NATIONAL INSTRUCTIONAL  
MEDIA INSTITUTE, CHENNAI**

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Post Box No. 3142, CTI Campus, Guindy, Chennai - 600 032

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## **Workshop Calculation & Science (NSQF) - 1st Semester**

**Common for All Engineering Trades**

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## FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, by 2020 to help them secure jobs as part of the National Skills Development Policy. Industrial Training Institutes (ITIs) play a vital role in this process especially in terms of providing skilled manpower. Keeping this in mind, and for providing the current industry relevant skill training to Trainees, ITI syllabus has been recently updated with the help of comprising various stakeholder's viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

The National Instructional Media Institute (NIMI), Chennai, has now come up with instructional material to suit the revised curriculum for **Workshop Calculation & Science 1<sup>st</sup> Semester** NSQF Common for all engineering trades will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

The Executive Director & Staff of NIMI and members of Media Development Committee deserve appreciation for their contribution in bringing out this publication.

Jai Hind

**RAJESH AGGARWAL**

Director General/ Addl. Secretary  
Ministry of Skill Development & Entrepreneurship,  
Government of India.

New Delhi - 110 001

## PREFACE

The National Instructional Media Institute(NIMI) was set up at Chennai, by the Directorate General of Training, Ministry of skill Development and Entrepreneurship, Government of India, with the technical assistance from the Govt of the Federal Republic of Germany with the prime objective of developing and disseminating instructional Material for various trades as per prescribed syllabus and Craftsman Training Programme(CTS) under NSQF levels.

The Instructional materials are developed and produced in the form of Instructional Media Packages (IMPs), consisting of Trade Theory, Trade Practical, Test and Assignment Book, Instructor Guide, Wall charts, Transparencies and other supportive materials. The above material will enable to achieve overall improvement in the standard of training in ITIs.

A national multi-skill programme called SKILL INDIA, was launched by the Government of India, through a Gazette Notification from the Ministry of Finance (Dept of Economic Affairs), Govt of India, dated 27th December 2013, with a view to create opportunities, space and scope for the development of talents of Indian Youth, and to develop those sectors under Skill Development.

The emphasis is to skill the Youth in such a manner to enable them to get employment and also improve Entrepreneurship by providing training, support and guidance for all occupation that were of traditional types. The training programme would be in the lines of International level, so that youths of our Country can get employed within the Country or Overseas employment. The **National Skill Qualification Framework (NSQF)**, anchored at the National Skill Development Agency(NSDA), is a Nationally Integrated Education and competency-based framework, to organize all qualifications according to a series of **levels of Knowledge, Skill and Aptitude**. Under NSQF the learner can acquire the Certification for Competency needed at any level through formal, non-formal or informal learning.

The **Workshop Calculation & Science** 1<sup>st</sup> Semester (common to all Engineering Trades) is one of the book developed as per the NSQF syllabus.

The **Workshop Calculation & Science** (common to all Engineering Trades as per NSQF) 1<sup>st</sup> Semester is the outcome of the collective efforts of experts from Field Institutes of DGT, Champion ITI's for each of the Sectors, and also Media Development Committee (**MDC**) members and Staff of **NIMI**. NIMI wishes that the above material will fulfill to satisfy the long needs of the trainees and instructors and shall help the trainees for their Employability in Vocational Training.

NIMI would like to take this opportunity to convey sincere thanks to all the Members and Media Development Committee (MDC) members.

Chennai - 600 032

**R. P. DHINGRA**  
**EXECUTIVE DIRECTOR**

## ACKNOWLEDGEMENT

The National Instructional Media Institute (NIMI) sincerely acknowledge with thanks the co-operation and contribution of the following Media Developers to bring this IMP for the course **Workshop Calculation & Science 1<sup>st</sup>Semester** as per NSQF.

### MEDIA DEVELOPMENT COMMITTEE MEMBERS

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### NIMI CO-ORDINATORS

Shri. K. Srinivasa Rao	-	Joint Director, NIMI, Chennai - 32.
Shri. G. Michael Johnny	-	Assistant Manager, NIMI, Chennai - 32.

NIMI records its appreciation of the **Data Entry, CAD, DTP Operators** for their excellent and devoted services in the process of development of this IMP.

NIMI also acknowledges with thanks, the efforts rendered by all other staff who have contributed for the development of this book.

## INTRODUCTION

The material has been divided into independent learning units, each consisting of a summary of the topic and an assignment part. The summary explains in a clear and easily understandable fashion the essence of the mathematical and scientific principles. This must not be treated as a replacement for the instructor's explanatory information to be imparted to the trainees in the classroom, which certainly will be more elaborate. The book should enable the trainees in grasping the essentials from the elaboration made by the instructor and will help them to solve independently the assignments of the respective chapters. It will also help them to solve the various problems, they may come across on the shop floor while doing their practical exercises.

The assignments are presented through 'Graphics' to ensure communications amongst the trainees. It also assists the trainees to determine the right approach to solve the problems. The required relevant data to solve the problems are provided adjacent to the graphics either by means of symbols or by means of words. The description of the symbols indicated in the problems has its reference in the relevant summaries.

At the end of the exercise wherever necessary assignments, problems are included for further practice.

### Time allotment:

<b>Duration of 1<sup>st</sup> Semester (26 weeks)</b>	<b>: 52 Hrs</b>
Effective weeks available (22 weeks)	: 44 Hrs
Revision and Test (4 weeks)	: 8 Hrs
<b>Total time allotment</b>	<b>: 52 Hrs</b>

Time allotment for each module has given below. Common to all Engineering Trades, Mechanic Refrigeration and Air Conditioner and Sheet Metal Worker.

S.No	Module	Exercise No.	Time allotment (Hrs)
1	System of units, factors and fraction	1.1.01 - 1.2.09	10 Hrs
2	Square root, Ratio and proportion, percentage	1.3.10 - 1.5.16	12 Hrs
3	Algebra (only for SMW in 1 <sup>st</sup> Semester)	1.6.17 - 1.6.18	4 Hrs
4	Material science, Mass weight and density	1.7.19 - 1.8.26	14 Hrs
5	Speed and velocity, work, power and energy	1.9.27 - 1.10.30	8 Hrs
6	Heat and temperature (only for MR&AC and SMW in 1 <sup>st</sup> Semester)	1.11.31 - 1.12.37	6 Hrs
7	Basic electricity (only for MR&AC in 1 <sup>st</sup> Semester)	1.13.38 - 1.13.41	9 Hrs

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1.13.39	Ohm's law, relation between V.I.R & problems, series & parallel circuits problem	97
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## LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

- **Understand, explain different mathematical calculation & science in the field of study including basic electrical and apply in day to day work. [Different mathematical calculation & science -Units, factors and fractions, square root, ratio and proportion, percentage, material science, mass, weight, density, speed and velocity, work, power & energy, algebra, heat & temperature, basic electricity, pressure].**
- **SMW - Algebra and Heat & temperature.**
- **MR&AC - Heat & temperature and Basic electricity.**



# SYLLABUS

First Semester

Common for All Engineering Trades  
(Except MR&AC and SMW)

Duration: Six Months

S.no.	Title
1	<b>Unit</b> Systems of unit- FPS, CGS, MKS/SI unit, unit of length, Mass and time, Conversion of units.
2	<b>Fractions</b> Fractions, Decimal fraction, L.C.M., H.C.F., Multiplication and Division of Fractions and Decimals, conversion of Fraction to Decimal and vice versa. Simple problems using Scientific Calculator.
3	<b>Square Root</b> Square and Square Root, method of finding out square roots, Simple problem using calculator.
4	<b>Ratio &amp; Proportion</b> Simple calculation on related problems.
5	<b>Percentage</b> Introduction, Simple calculation. Changing percentage to decimal and fraction and vice-versa.
6	<b>Material Science</b> Properties - Physical & Mechanical, Types - Ferrous & Non-Ferrous, difference between Ferrous and Non-Ferrous metals, introduction of Iron, Cast Iron, Wrought Iron, Steel, difference between Iron and Steel, Alloy steel, carbon steel, stainless steel, Non-Ferrous metals, Non-Ferrous Alloys.
7	<b>Mass, Weight and Density</b> Mass, Unit of Mass, Weight, difference between mass and weight, Density, unit of density, specific gravity of metals.
8	<b>Speed and Velocity</b> Rest and motion, speed, velocity, difference between speed and velocity, acceleration, retardation, equations of motions, simple related problems.
9	<b>Work, Power and Energy</b> Work, unit of work, power, unit of power, Horse power of engines, mechanical efficiency, energy, use of energy, potential and kinetic energy, examples of potential energy and kinetic energy.

## Syllabus for Mechanic Refrigeration & Air Conditioner

S.no.	Title
1	<p><b>Mechanic Refrigeration and Air Conditioner</b></p> <p><b>General simplifications</b></p> <p>Fractions, Types of fractions, common fractions, Decimal fractions with examples Addition, subtraction, multiplication and division of fraction . conversion of Fraction to Decimal and vice versa.</p>
2	<p><b>Square &amp; Square root</b></p> <p>Square root of perfect square, Square of whole number and decimal. Applications of Pythagoras theorem and related Problems.</p>
3	<p><b>Unit &amp; Measurements</b></p> <p>Definition, classification of System of units, Fundamental &amp; derived units. C.G.S, M.K.S., F.P.S, &amp; S.I System of units. Metric system of weight and measurement unit and conversion factors, problems.</p>
4	<p><b>Percentage</b></p> <p>Introduction, Simple calculation. Changing percentage to fraction and decimal &amp; vice-versa.</p>
5	<p>Introduction, use of Electricity, Molecule, Atom, and How Electricity is Produced, Electric current, voltage, Resistance and their units. Ohm's law. Relation between V.I.R &amp; Problems. Series &amp; Parallel circuits &amp; Problems. Electrical Power and energy &amp; their units &amp; calculation.</p>
6	<p>Magnetic Induction, Self &amp; Mutual Inductance, EMF generation.</p>
7	<p><b>Material Science</b></p> <p>Properties of metals - Physical &amp; Mechanical, Meaning of tenacity, elasticity, malleability brittleness, hardness, ductility Types – Ferrous &amp; Non-Ferrous, difference between Ferrous and Non-Ferrous metals, introduction of Iron, Cast Iron, Wrought Iron, Steel, difference between Iron and Steel, Alloy steel, carbon steel, stainless steel, Non-Ferrous Alloys. Effect of Alloying elements.</p>
8	<p>Properties and uses of copper, zinc, lead tin, aluminum etc., Properties and uses of Brass, Bronze as bearing material.</p>
9	<p><b>Heat and Temperature</b></p> <p>Measurement of Temperature, Boiling and melting points. Interchange of heat, (Principle of calorimetry) Co-efficient of linear expansion, Related problems.</p>
10	<p><b>Vapours and gases</b></p> <p>Saturated and superheated vapours, Critical pressures and temperatures. Heat transfer conduction, Convection, Radiation. Thermal conductivity and Insulations.</p>

## Syllabus for Sheet Metal Worker

S.no.	Title
	<b>Sheet Metal Worker</b>
1	Introduction and Importance of Science and Calculation to the Trade skill.
2	<ul style="list-style-type: none"> <li>- System of Units: British, Metric and S. I. Units for Length, Mass, Area, Volume, Capacity and time.</li> <li>- Conversions between British and Metric Systems.</li> </ul>
3	<ul style="list-style-type: none"> <li>- Density &amp; Specific gravity.</li> <li>- Mass, weight. Definition and units.</li> </ul>
4	<ul style="list-style-type: none"> <li>- Metals: Properties and uses of cast iron, wrought iron, plain carbon steels and alloy steels.</li> <li>- Difference between metals, non-metals and alloys.</li> </ul>
5	Properties and uses of Copper, Zinc, Lead, Tin and Aluminum.
6	Properties and uses of Brass, Bronze, Rubber, Timber and insulating materials.
7	Concept of heat and temperature. Difference between heat and temperature. Effects of Heat, Thermometric Scales such as a Celsius, Fahrenheit and Kelvin, Temperature measuring Instruments - types of thermometers and pyrometers.
8	<ul style="list-style-type: none"> <li>- Conversions between the above Scales of Temperature.</li> <li>- Units of Heat-Calorie, B.Th.U &amp; C.H.U., joule.</li> <li>- Concept of Specific Heat, Latent Heat, problems on Heat Loss and Heat Gain.</li> </ul>
9	<ul style="list-style-type: none"> <li>- Definition of Force: Units of Force in M.K.S.&amp; S.I. Systems.</li> <li>- Concept of Pressure and its Units in different systems.</li> </ul>
10	<ul style="list-style-type: none"> <li>- General simplifications: BODMAS rule.</li> <li>- Fraction: Addition, Subtraction, multiplication and Division-Problems.</li> <li>- Decimal: Addition, Subtraction, Multiplication, and Division-Problems.</li> </ul>
11	Conversion of Fraction to Decimal and vice-versa.
12	Square roots: The Square and Square root of a Whole Number and Decimal.
13	Percentage: Changing Percent to Decimal and Fraction and vice versa, applied problem.
14	Concept on Ratio and Proportion-Direct and Inverse Proportion, simple applied problems.
15	Algebraic Symbols and Fundamentals Addition, Subtraction, Multiplication and Division-Problems.

## Summary of Contents

Title of the Contents	Common for all Engineering Trades	MR&AC	SMW
1 Unit	✓	✓	✓
2 Fraction	✓	✓	✓
3 Square root	✓	✓	✓
4 Ratio & Proportion	✓	—	✓
5 Percentage	✓	✓	✓
6 Algebra	—	—	✓
7 Material Science	✓	✓	✓
8 Mass, Weight & Density	✓	—	✓
9 Speed & Velocity	✓	—	—
10 Work, Power & Energy	✓	—	—
11 Heat & Temperature	—	✓	✓
12 Basic Electricity	—	✓	—

## Necessity

All physical quantities are to be measured in terms of standard quantities.

## Unit

A unit is defined as a standard or fixed quantity of one kind used to measure other quantities of the same kind.

## Classification

Fundamental units and derived units are the two classifications.

## Fundamental units

Units of basic quantities of length, mass and time.

## Derived units

Units which are derived from basic units and bear a constant relationship with the fundamental units. E.g. area, volume, pressure, force etc.

## Systems of units

- F.P.S system is the British system in which the basic units of length, mass and time are foot, pound and second respectively.
- C.G.S system is the metric system in which the basic units of length, mass and time are centimeter, gram and seconds respectively.
- M.K.S system is another metric system in which the basic units of length, mass and time are metre, kilogram and second respectively.

- S.I. units are referred to as Systems International units which is again of metric and the basic units, their names and symbols are as follows.

Fundamental units and derived units are the two classifications of units.

Length, mass and time are the fundamental units in all the systems (i.e) F.P.S, C.G.S, M.K.S and S.I. systems.

## Example

**Length:** What is the length of copper wire in the roll, if the roll of copper wire weighs 8kg, the dia of wire is 0.9cm and the density is 8.9 gm/cm<sup>3</sup>?

## Solution

mass of copper wire in the roll = 8kg (or)8000grams

Dia of copper wire in the roll = 0.9cm

Density of copper wire = 8.9 gm/cm<sup>3</sup>

Area of cross section of copper wire

$$= \frac{\pi d^2}{4} = \frac{\pi \times (0.9^2)}{4} = 0.636cm^2$$

Volume of copper wire

$$= \frac{\text{Mass of copper wire}}{\text{Density of copper wire}} = \frac{8000\text{grams}}{8.9 \text{ gm/cm}^3} = 898.88cm^3$$

Length of copper wire

$$= \frac{\text{Volume of copper wire}}{\text{Area of cross section of copper wire}} = \frac{898.88cm^3}{0.636cm^2} = 1413.33 \text{ cm}$$

Length of copper wire = 1413cm.

**Time:** The S.I. unit of time, the second, is another of the base units of S.I it is defined as the time interval occupied by a number of cycles of radiation from the calcium atom. The second is the same quantity in the S.I. in the British and in the U.S. systems of units.

## Fundamental units of F.P.S, C.G.S, M.K.S and S.I

S.No.	Basic quantity	British units		Metric units				International units	
		F.P.S	Symbol	C.G.S	Symbol	M.K.S	Symbol	S.I Units	Symbol
1	Length	Foot	ft	Centimetre	cm	Metre	m	Metre	m
2	Mass	Pound	lb	Gram	g	Kilogram	kg	Kilogram	Kg
3	Time	Second	s	Second	s	Second	s	Second	s
4	Current	Ampere	A	Ampere	A	Ampere	A	Ampere	A
5	Temperature	Fahrenheit	°F	Centigrade	°C	Centigrade	°C	Kelvin	K
6	Light intensity	Candela	Cd	Candela	Cd	Candela	Cd	Candela	Cd

## Derived units of F.P.S, C.G.S, M.K.S and SI system

S.No	Physical quantity	British units		Metric units			International units		
		FPS	Symbol	CGS	Symbol	MKS	Symbol	SI Units	Symbol
1	Area	Square foot	ft <sup>2</sup>	Square centimetre	cm <sup>2</sup>	Square metre	m <sup>2</sup>	Square metre	m <sup>2</sup>
2	Volume	Cubic foot	ft <sup>3</sup>	Cubic centimetre	cm <sup>3</sup>	Cubic metre	m <sup>3</sup>	Cubic metre	m <sup>3</sup>
3	Density	Pound per cubic foot	lb/ft <sup>3</sup>	Gram per cubic centimetre	g/cm <sup>3</sup>	Kilogram per cubic metre	kg/m <sup>3</sup>	Kilogram per cubic metre	Kg/m <sup>3</sup>
4	Speed	Foot per second	ft/s	Centimetre per second	cm/sec	Metre per second	m/sec	Metre per second	m/sec
5	Velocity (linear)	Foot per second	ft/s	Centimetre per second	cm/sec	Metre per second	m/sec	Metre per second	m/sec
6	Acceleration	Foot per square second	ft/s <sup>2</sup>	Centimetre per square second	cm/sec <sup>2</sup>	Metre per square second	m/sec <sup>2</sup>	Metre per square second	m/sec <sup>2</sup>
7	Retardation	Foot per square Second	ft/s <sup>2</sup>	Centimetre per square second	cm/sec <sup>2</sup>	Metre per square second	m/sec <sup>2</sup>	Metre square second	m/sec <sup>2</sup>
8	Angular velocity	Degree per second	Deg/sec	Radian per second	rad/sec	Radian per second	rad/sec	Radian per second	rad/sec
9	Mass	Pound (slug)	lb	Gram	g	Kilogram	kg	Kilogram	kg
10	Weight	Pound	lb	Gram	g	Kilogram weight	kg	Newton	N
11	Force	Pounds	lbf	dynes	dyn	Kilogram force	kgf	Newton	N (kgm/sec <sup>2</sup> )
12	Power	Foot pound per second Horse power	ft.lb/sec hp	Gram.centimetre/sec Erg per second	g.cm/sec erg	kilogram metre per second watt	kg.m/sec W	- watt	- W (J/sec)
13	Pressure, Stress	Pound per square inch	lb/in <sup>2</sup>	Gram per square centimetre	g/cm <sup>2</sup>	Kilogram per square metre	kg/m <sup>2</sup>	Newton per square metre	N/m <sup>2</sup>
14	Energy, Work	Foot.pound	ft.lb	Gram centimetre	g.cm	Kilogram metre	kg.m	joule	J(Nm)
15	Heat	British thermal unit	Btu	calorie	Cal	joule	J	joule	J(Nm)
16	Torque	Pound force foot	lbf.ft	Newton millimetre	N mm	Kilogram metre	kg.m	Newton metre	Nm
17	Temperature	Degree Fahrenheit	°F	Degree Centigrade	°C	Kelvin	K	Kelvin	K
18	Specific heat	BTU per pound degree fahrenheit	Btu/lb °F	Calorie per gram degree Celsius	Cal/g °C	Joule per kilogram kelvin	J/(kgK)	Joule per kilogram kelvin	J/(kgK)

S.No	Physical quantity		British units		Metric units					International units	
	FPS	Symbol	CGS	Symbol	MKS	Symbol	SI Units	Symbol	SI Units	Symbol	
19	Frequency	Cycle per second	Hertz	1/s	Hertz	Hz	Hertz	Hertz	Hertz	Hz	
20	Moment of inertia	Pound force foot square second	Gram square centimetre	lbf.ft.s <sup>2</sup>	Kilogram square metre	g.cm <sup>2</sup>	Kilogram square metre	Kilogram per square metre	Kilogram per square metre	Kg.m <sup>2</sup>	
21	Momentum	Pound second	Gram centimetre per second	lb.s	Kilogram metre per second	g.cm/sec	Kilogram metre per second	Kilogram metre per second	Kilogram metre per second	Kg.m/sec	
22	Moment of force	Pounds foot	Gram centimetre	lbs/ft	Kilogram metre	g.cm	Kilogram metre	Newton metre	Newton metre	Nm	
23	Angle	degree	degree	deg	degree	deg	degree	Radian	Radian	rad	
24	Specific volume	Cubic foot per pound	Cubic centimetre per gram	ft <sup>3</sup> /lbs	Cubic centimetre per kilogram	cm <sup>3</sup> /g	Cubic metre per kilogram	Cubic metre per kilogram	Cubic metre per kilogram	m <sup>3</sup> /kg	
25	Specific resistance	Ohm foot	Ohm centimetre	Ω ft	Ohm meter	Ω cm	Ohm meter	Ohm meter	Ohm meter	Ω m	
26	Specific weight	Pound per cubic foot	Gram per cubic centimetre	lbf/ft <sup>3</sup>	Kilogram per cubic metre	g/cm <sup>3</sup>	Kilogram per cubic metre	Newton per cubic metre	Newton per cubic metre	N/m <sup>3</sup>	
27	Fuel consumption	Miles per gallon	Centimetre per cubic centimetre	m/gal	Kilometre per litre	cm/cm <sup>3</sup>	Kilometre per litre	Metre per cubic metre	Metre per cubic metre	m/m <sup>3</sup>	
28	Dynamic viscosity	Pound force per square foot	Centi poise	lbf/ft <sup>2</sup>	pascal second	cP	pascal second	pascal second	pascal second	P <sub>a.s</sub>	
29	Surface tension	Poundal per foot	dyne per centimetre	pd/ft	Newton per metre	dyn/cm	Newton per metre	Newton per metre	Newton per metre	N/m	
30	Entropy	British thermal unit per degree Fahrenheit	Calorie per degree centigrade	Btu/°F	Joule per kelvin	Cal/°c	Joule per kelvin	Joule per kelvin	Joule per kelvin	J/K	
31	Electric current	Columb per second	Biot	C/s	Ampere	Bi	Ampere	Ampere	Ampere	A	
32	Electric voltage	Volt	Volt	V	Volt	V	Volt	Volt	Volt	V	
33	Electric resistance	Ohm	Ohm	Ω	Ohm	Ω	Ohm	Ohm	Ohm	Ω, (V/A)	
34	Electric conductance	Mho, Siemens	Mho	Ω <sup>-1</sup> , s	Siemens	Ω <sup>-1</sup> , s	Siemens	Siemens	Siemens	s	
35	Light intensity	Candela	Candela	Cd	Candela	Cd	Candela	Candela	Candela	Cd	
36	Specific gravity	No unit	No unit	-	No unit	-	No unit	No unit	No unit	-	

**Units and abbreviations**

Quantity	Units	Abbreviation of unit
Calorific value	kilojoules per kilogram	kJ/kg
Specific fuel consumption	kilogram per hour per newton	kg/hr/N
Length	millimetre, metre, kilometre	mm, m, km
Mass	kilogram, gram	kg, g
Time	seconds, minutes, hours	s, min, h
Speed	centimetre per second, metre per second kilometre per hour, miles per hour	cm/s, m/s km/h, mph
Acceleration	metre-per-square second	m/s <sup>2</sup>
Force	newtons, kilonewtons	N, kN
Moment	newton-metres	Nm
Work	joules	J
Power	horsepower, watts, kilowatts	Hp, W, kW
Pressure	newton per square metre kilonewton per square metre	N/m <sup>2</sup> kN/m <sup>2</sup>
Angle	radian	rad
Angular speed	radians per second radians-per-square second revolutions per minute revolutions per second	rad/s rad/s <sup>2</sup> Rpm rev/s

**Decimal multiples and parts of unit**

Decimal power	Value	Prefixes	Symbol	Stands for
10 <sup>12</sup>	1000000000000	tera	T	billion times
10 <sup>9</sup>	1000000000	giga	G	thousand milliotimes
10 <sup>6</sup>	1000000	mega	M	million times
10 <sup>3</sup>	1000	kilo	K	thousand times
10 <sup>2</sup>	100	hecto	h	hundred times
10 <sup>1</sup>	10.10 <sup>1</sup>	deca	da	ten times
10 <sup>-1</sup>	0.1 10 <sup>-1</sup>	deci	d	tenth
10 <sup>-2</sup>	0.01	centi	c	hundreth
10 <sup>-3</sup>	0.001	milli	m	thousandth
10 <sup>-6</sup>	0.000001	micro	μ	millionth
10 <sup>-9</sup>	0.000000001	nano	n	thousand millionth
10 <sup>-12</sup>	0.000000000001	pico	p	billionth



**SI units and the British units:**

Quantity	SI unit → British unit	British unit → SI unit
Length	1 m = 3.281 ft 1 km = 0.621 mile	1 ft = 0.3048 m 1 mile = 1.609 km
Speed	1 m/s = 3.281 ft/s 1 km/h = 0.621 mph	1 ft/s = 0.305 m/s 1 mph = 1.61 km/h
Acceleration	1 m/s <sup>2</sup> = 3.281 ft/s <sup>2</sup>	1 ft/s <sup>2</sup> = 0.305 m/s <sup>2</sup>
Mass	1 kg = 2.205 lb	1 lb = 0.454 kg
Force	1 N = 0.225 lbf	1 lbf = 4.448 N (1 million newtons)
Torque	1 Nm = 0.738 lbf ft	1 lbf ft = 1.355 Nm
Pressure	1 N/m <sup>2</sup> = 0.000145 lbf/in <sup>2</sup> 1 Pa = 1 N/m <sup>2</sup> 1 bar = 14.5038 lbf/in <sup>2</sup>	1 lbf/in <sup>2</sup> = 6.896 kN/m <sup>2</sup> 1 lbf/in <sup>2</sup> = 6.895 kN/m <sup>2</sup>
Energy, work	1 J = 0.738 ft lbf 1 J = 0.239 calorie 1 kJ = 0.948 Btu (1 therm = 100 000 Btu) 1 kJ = 0.526 CHU	1 ft lbf = 1.355 J 1 calorie = 4.186 J 1 Btu = 1.055 kJ 1 CHU = 1.9 kJ
Power	1 kW = 1.34 hp	1 hp = 0.7457 kW
Fuel consumption	1 km/L = 2.82 mile/gallon	1 mpg = 0.354 km/L
Specific fuel consumption	1 kg/kWh = 1.65 lb/bhp h 1 litre/kWh = 1.575 pt/bhp h	1 lb/bhp h = 0.606 kg/kWh 1 pt/bhp h = 0.631 litre/kWh
Calorific value	1 kJ/kg = 0.43 Btu/lb 1 kJ/kg = 0.239 CHU/lb	1 Btu/lb = 2.326 kJ/kg 1 CHU/lb = 4.188 kJ/kg

## Units in measuring practice with definitions

Quantity	Unit	Explanation
Force	F Newton	N 1 Newton is equal to the force which imports an acceleration of $1\text{m/s}^2$ to a body of mass 1 kg $1\text{N} = 1\text{ kg m/s}^2$
Pressure	P Newton per square metre	$\frac{\text{N}}{\text{m}^2}$ 1 Newton per square metre (1 pascal) is equal to the pressure with which the force of 1 N is exercised perpendicular to the area of $1\text{ m}^2$
Normal stress tensile or compressive stress, Shear stress	Pascal [ Newton per square metre ]	Pa $1\text{Pa} = 1\text{ N/m}^2$ . 1 Bar (bar) is the special name for 100 000 Pa. $\frac{\text{N}}{\text{m}^2}$ 1 Newton per square metre (1 pascal) to the mechanical stress with which the force of 1 n is exercised on the area of $1\text{ m}^2$ . In many branches of engineering the mechanical stress and strength are specified in $\text{N/m}^2$ . $1\text{ N/m}^2 = 1000\ 000\ \text{Pa} = 1\ \text{MPa}$
Heat Energy Quantity of heat	W Joule	J 1 Joule is equal to the work that is done when the point of application of the force of 1 N is shifted by 1 m in the direction of the force. $1\ \text{J} = 1\ \text{Nm} = 1\ \text{Ws} = 1\ \text{kgm}^2/\text{s}^2$ $3600\ 000\ \text{J} = 1\ \text{kWh}$
Moment of a force (torque)	M [ Newton metre joule ]	Nm J 1 Newton is equal to the moment of a force which results from the product of the force of 1 N and the lever arm of 1 m. $1\ \text{Nm} = 1\ \text{J} = 1\ \text{Ws} = 1\ \text{kgm}^2/\text{s}^2$
Power Energy flow Heat flow	P Watt $\emptyset$	W 1 Watt is equal to the power with which the energy of 1 J is converted during the time of 1s. The unit watt is also called volt ampere in the specification of apparent electric power $1\ \text{W} = 1\ \text{J/s} = 1\ \text{Nm s} = 1\ \text{VA}$
Specific heat value	$H_{\mu}$ [ Joule per kilogram ]	$\frac{\text{J}}{\text{kg}}$ 1 Joule per kilogram is equal to the quantity of heat which on complete burning of the mass of 1 kg releases the energy of 1 J
Fuel consumption	P [ gram per kilowatt-hour ]	$\frac{\text{g}}{\text{kwh}}$ 1 gram per kilowatt-hour is equal to the fuel consumption of the mass of 1 g for the work of 1 kWh.
Temperature	T Kelvin	K The kelvin is defined as the fraction $\frac{1}{273.16}$ of the thermodynamic temperature of the triple point of water.
Electric current	I Ampere	A 1 Ampere is the strength of a current which would bring about an electrodynamic force of 0.2.10 N per 1 m length between two parallel conductors placed at a distance of 1 m.

Electric voltage	V	Volt	V	1 Volt is equal to the electric voltage between two points of a metallic conductor in which a power of 1 W is expended for a current of 1 A strength.
Electric resistance	R	Ohm	$\Omega$	1 Ohm is equal to the electric resistance between two points of a metallic conductor in which an electric current of 1 A flows at a voltage of 1 V.
Electric conductance	G	Siemens	S	1 Siemens is equal to the electric conductance of a conductor of electric resistance of 1ohm
Quantity of electricity	Q	Coulomb ampere-second	C As	1 Coulomb is equal to the quantity of electricity which flows through the conductor cross-section during the time of 1 s at an electric current of 1A.

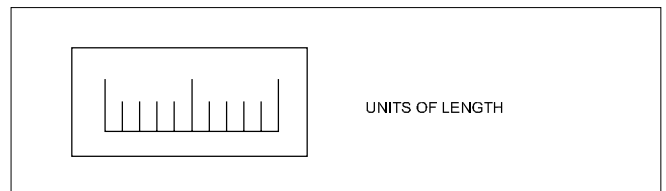
### Prefixes for decimal multiples and submultiples

Use	
1 Megapascal	= 1 MPa = 1000000 Pa
1 Kilowatt	= 1 kW = 1000 W
1 Hectolitre	= 1 hL = 100 L
Decanewton	= 1 daN = 10 N
Decimetre	= 1 dm = 0.1 m
1 Centimetre	= 1 cm = 0.01 m
1 Millimetre	= 1 mm = 0.001 m
1 Micrometre	= 1 $\mu$ m = 0.000001 m

### Conversion factors

1 inch	= 25.4 mm
1 mm	= 0.03937 inch
1 metre	= 39.37 inch
1 micron	= 0.00003937"
1 kilometre	= 0.621 miles
1 pound	= 453.6 gr
1 kg	= 2.205 lbs
1 metric ton	= 0.98 ton

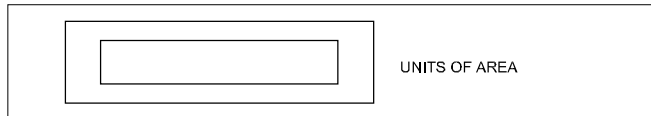
### Units of physical quantities



### Units of length

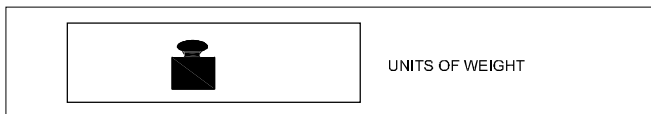
Micron	1 $\mu$	= 0.001 mm
Millimetre	1 mm	= 1000 $\mu$
Centimetre	1 cm	= 10 mm
Decimetre	1 dm	= 10 cm
Metre	1 m	= 10 dm
Kilometre	1 km	= 1000 m
Inch	1"	= 25.4 mm
Foot	1'	= 0.305 m
Yard	1 Yd	= 0.914 m
Nautical mile	1 NM	= 1852 m
Geographical mile	1	= 1855.4 m

## Units of area



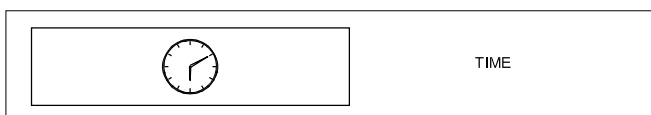
Square millimetre	1 mm <sup>2</sup>	
Square centimetre	1 cm <sup>2</sup>	= 100 mm <sup>2</sup>
Square decimetre	1 dm <sup>2</sup>	= 100 cm <sup>2</sup>
Square metre	1 m <sup>2</sup>	= 100 dm <sup>2</sup>
Are	1 a	= 100 m <sup>2</sup>
Hectare	1 ha	= 100 a
Square kilometre	1 km <sup>2</sup>	= 100 ha
Square inch	1 sq.in	= 6.45 cm <sup>2</sup>
Square foot	1 sq.ft	= 0.093 m <sup>2</sup>
Square yard	1 sq.yd	= 0.84 m <sup>2</sup>
Square metre	1 m <sup>2</sup>	= 10.76 ft <sup>2</sup>
Acre	1	= 40.5 a
1 Acre = 100 cent	1 Hectare = 2.47 acres	
1 Cent = 436 Sq. ft.	1 acre = 0.4047 Hectare	
1 Ground = 2400 Sq.ft.	1 Hectare = 10000 sq. metre	

## Units of weight

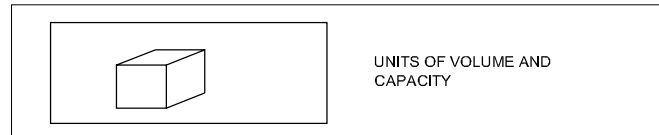


Milligram - force	1 mgf	
Gram-force	1 gf	1000 mgf
Kilogram-force	1 kgf	= 1000 gf
Tonne	1 t	= 1000 kgf
Ounce	1	= 28.35 gf
Pound	1 lbs	= 0.454 kgf
Long ton	1	= 1016 kgf
Short ton	1	= 907 kgf

## Time



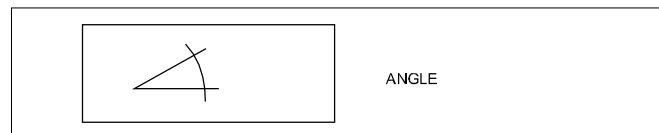
Second	1 s	
Minute	1 min	60 s
Hour	1 hr	= 60 min



## Units of volume and capacity

Cubic millimetre	1 mm <sup>3</sup>	
Cubic centimetre	1 cm <sup>3</sup>	= 1000 mm <sup>3</sup>
Cubic decimetre	1 dm <sup>3</sup>	= 1000 cm <sup>3</sup>
Cubic metre	1 m <sup>3</sup>	= 1000 dm <sup>3</sup>
Litre	1 l	= 1 dm <sup>3</sup>
Hectolitre	1 hl	= 100 l
Cubic inch	1 cu. in	= 16.387 cm <sup>3</sup>
Cubic foot	1 cu. ft	= 28317 cm <sup>3</sup>
Gallon (British)	1 gal	= 4.54 l
1 cubic metre	1 m <sup>3</sup>	= 1000 litres
1000 Cu.cm	1000 cm <sup>3</sup>	= 1 litre
1 cubic foot	1 ft <sup>3</sup>	= 6.25 Gallon
1 litre	1lt	= 0.22 Gallon

## Angle



### 1 Centesimal unit

1 Right Angle = 100 grade (100<sup>g</sup>)

1 grade (1<sup>g</sup>) = 100 Minute (100')

1 minute (1') = 100 second (100'')

### 2 Sexagesimal unit

1 Right angle = 90 Degree (90°)

1 Degree (1°) = 60 minutes (60')

1 minute (1') = 60 seconds (60'')

### 3 Circular unit

#### Radian

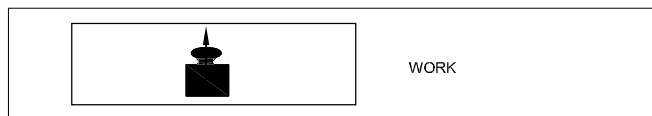
Relationship between Radian and Degree

$$1 \text{ Radian} = \frac{180^\circ}{\pi}$$

$$180^\circ = \pi \text{ Radian};$$

$$1 \text{ Degree} = \frac{\pi}{180} \text{ Radian}$$

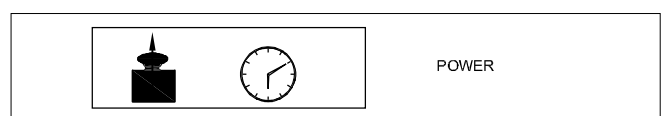
## Work



WORK

Kilogram-force	1 kgfm	= 9.80665 J
Metre	1 kgfm	= 9.80665 Ws
Joule	1 J	= 1 Nm
Watt-second	1 Ws	= 0.102 kgfm
Kilowatt hour	1 kWh	= 3.6 x 10 <sup>6</sup> J
		= 859.8456 kcal <sub>IT</sub>
I.T.Kilocalorie	1 kcal <sub>IT</sub>	= 426.kgfm

## Power



POWER

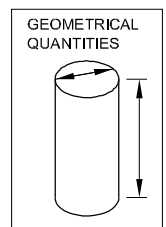
Kilogram-force metre/second	
1 kgfm/s	= 9.80665 W
Kilowatt	1 kW = 1000 W = 1000 J/s
	= 102 kgfm/s (approx.)
Metric horse power	1 HP = 75 kgfm/s
	= 0.736 kW
1 Calorie	= 4.187J
I.T.Kilocalorie/hour	= 1 kcal <sub>IT/h</sub> = 1.163 W

## Pressure

Pascal	1 Pa	= 1 N/m <sup>2</sup>	1 atm	= 101325 Pa
Bar	1 bar = 10N/cm <sup>2</sup>	= 100000 Pa–Torr	1 torr	= $\frac{101325}{760} \approx 133.32$ pa
Atmosphere	1 atm	= 1 kgf/cm <sup>2</sup>	1 kgf/cm <sup>2</sup>	= 735.6 mm of mercury

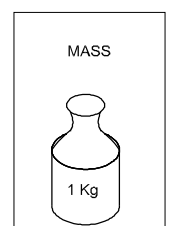
## Geometrical quantities

Symbol	Physical quantity	Conventional Units	S.I.Units	Symbol S.I. units
l	Length	m	Metre	m
h	Height	m	Metre	m
b	Width, breadth	m	Metre	m
r	Radius	m	Metre	m
d	Diameter	m	Metre	m
d,δ	Wall thickness	m	Metre	m
S	Length of path	m	Metre	m
A (S)	Area	m <sup>2</sup>	Square metre	m <sup>2</sup>
V(v)	Volume	m <sup>3</sup>	Cubic metre	m <sup>3</sup>
α,β,γ etc	Angle	°	Radian (1 rad = 57.3°)	rad
λ	Wave length	km	Kilometre	km
I, I <sub>a</sub>	Second moment of area	cm <sup>4</sup>	Metre to the fourthpower	m <sup>4</sup>



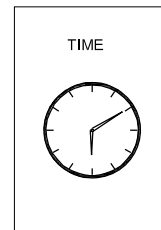
## MASS

m	Mass	kg	Kilogram	kg
ρ	Density	g/cm <sup>3</sup>	Kilogram per cubicmetre	kg/m <sup>3</sup>
I, J	Moment of inertia	kg, m <sup>2</sup>	Newton metre	



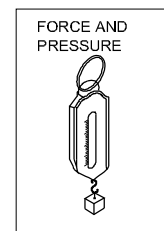
## TIME

T	Time or time interval	s	Second	s
nu	Rotational frequency	l/min	Reciprocal second	l/s
u,v,w,c	Velocity speed	m/min	Metre per second	m/s
$\omega$	Angular velocity	rad/s	Radian per second	rad/s
g	Acceleration of freefall	m/s <sup>2</sup>	Metre per second squared	m/s <sup>2</sup>
a	Acceleration	m/s <sup>2</sup>	Metre per second squared	m/s <sup>2</sup>
	Retardation	m/s <sup>2</sup>	Metre per second squared	m/s <sup>2</sup>



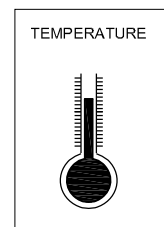
## FORCE AND PRESSURE

F	Force	kgf	Newton (1kgf = 9.80665N)	N
G(P,W)	Weight	kgf	Newton	N
$\gamma$	Specific weight	kgf/m <sup>3</sup>	Newton per cubic metre	N/m <sup>3</sup>
M	Moment of force (force x distance)	kgf.m	Newton metre	N.m
p	Pressure (force/ area)	kgf/cm <sup>2</sup>	pascal, Newton per square metre	Pa,N/m <sup>2</sup>
p	Normal stress	kgf/mm <sup>2</sup>	bar (1 bar = 10 N/m)	
$\tau$ p	Shear stress	kgf/mm <sup>2</sup>	bar	
E	Modulus of elasticity	kgf/mm <sup>2</sup>	Newton per square metre	N/m <sup>2</sup>
G	Shear modulus	kgf/mm <sup>2</sup>	Newton per square metre	N/m <sup>2</sup>
$\mu$	Co-efficient of friction	No Unit		



## TEMPERATURE

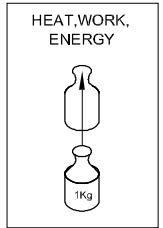
Scale	Freezing point	Boiling point
Centigrade (°C)	0°C	100°C
Faranheit (°F)	32°F	212°F
Kelvin (K)	273K	373K
Reaumur (°R)	0°R	80°R



$$\frac{^{\circ}\text{R}}{80} = \frac{^{\circ}\text{C}}{100} = \frac{\text{K} - 273}{100} = \frac{^{\circ}\text{F} - 32}{180}$$

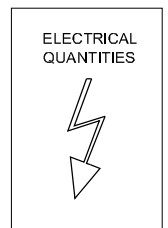
## HEAT, WORK, ENERGY, FORCE

A,W	Work	kgfm	Joule (1 Joule=1 N.m)	J (Nm)
P	Power	kgfm/s	Watt	W (J/s)
E,W	Energy	kgfm	Joule	J (Nm)
$\eta$	Efficiency	-	-	-
W,A,E,Q	Quantity of heat	kcal	Joule	J
C	Specific heat	kcal/kg <sup>o</sup> C	Joule per newton per degree Kelvin	J/N. <sup>o</sup> K
	Thermal conductivity	kcal/mh <sup>o</sup> C	Joule per metre per second per degree Kelvin	J/ms <sup>o</sup> K
<b>Force</b> In C.G.S. System : Force (Dyne) = Mass (gm)XAcceleration (cm/sec <sup>2</sup> )				
In F.P.S. System : Force (Poundal) = Mass (lb) X Acceleration (ft./sec <sup>2</sup> )				
In M.K.S System : Force (Newton) = Mass (Kg) x Acceleration (mtr./sec <sup>2</sup> )				
	1 Dyne		= 1 gm x1 cm/sec <sup>2</sup>	
	1 Poundal		= 1 lb x 1 ft/sec <sup>2</sup>	
	1 Newton		= 1 kg x 1 mtr/sec <sup>2</sup> = 10 <sup>5</sup> dynes	
	1gm weight		= 981 Dynes	
	1 lb weight		= 32 Poundals	
	1 kg weight		= 9.81 Newtons	



## ELECTRICAL QUANTITIES

V	Electric potential	V	Volt	V(W/A)
E	Electromotive force	V	Volt	V(W/A)
I	Electric current	A	Ampere	A
R	Electric resistance	$\Omega$	Ohm	$\Omega$ (V/A)
e	Specific resistance	$\Omega$ m	Ohm metre	Vm/A
G	Conductance	$\Omega^{-1}$	Siemens	S



## Conversions of length, mass, force, work, power and energy    Exercise 1.1.04

1 Convert the following as indicated

- a 5 yards into metres                    \_\_\_\_\_
- b 15 miles into kilometres                \_\_\_\_\_
- c 7 metres into yards                        \_\_\_\_\_
- d 320 kilometres into miles                \_\_\_\_\_

2 Convert

- a 5 pounds into kilograms                 \_\_\_\_\_
- b 8.5 kilograms into pounds                \_\_\_\_\_
- c 5 ounces into grams                        \_\_\_\_\_
- d 16 tons into kilograms                    \_\_\_\_\_

3 Convert

- a 40 inches into centimetres                \_\_\_\_\_
- b 12 feet into metres                         \_\_\_\_\_
- c 5 metres into inches                        \_\_\_\_\_
- d 8 metres into feet                            \_\_\_\_\_

4 Convert

- a 234 cubic metres into gallons            \_\_\_\_\_
- b 2 cubic feet into litres                     \_\_\_\_\_
- c 2.5 gallons into litres                     \_\_\_\_\_
- d 5 litres into gallons                        \_\_\_\_\_

5 Answer the following questions

- a  $120^{\circ}\text{C} = \text{_____}^{\circ}\text{F}$ .
- b  $8 \text{ mm} = \text{_____} \text{ inches}$   
 $12 \text{ mm} = \text{_____} \text{ inches}$

6 Convert and find out

A car consumes fuel at the rate of one gallon for a travel of 40 miles.

The same car travels a distance of 120 kilometer. what is the consumption of fuel in litres.

7 Write equivalent British units for the given metric units

- a Seconds, minutes, Hours
- b Grams, Kilograms
- c Litres, Cubic meters
- d Square centimeter, Square kilometer

8 Expand the abbreviations of the following

- a km/l
- b  $\text{N/m}^2$
- c KW
- d  $\text{m/s}^2$
- e RPM

9 Convert the following S.I. units as required.

a Length

- i  $3.4 \text{ m} = \text{_____} \text{ mm}$
- ii  $1.2 \text{ m} = \text{_____} \text{ cm}$
- iii  $0.8 \text{ m} = \text{_____} \text{ mm}$
- iv  $0.02 \text{ km} = \text{_____} \text{ cm}$
- v  $10.2 \text{ km} = \text{_____} \text{ mile}$
- vi  $6 \text{ m} = \text{_____} \text{ km}$
- vii  $18 \text{ m} = \text{_____} \text{ mm}$
- viii  $450 \text{ m} = \text{_____} \text{ km}$
- ix  $85 \text{ cm} = \text{_____} \text{ km}$
- x  $0.06 \text{ km} = \text{_____} \text{ mm}$

b Mass

- i  $650 \text{ g} = \text{_____} \text{ kg}$
- ii  $300 \text{ cg} = \text{_____} \text{ g}$
- iii  $8 \text{ g} = \text{_____} \text{ dg}$
- iv  $120 \text{ mg} = \text{_____} \text{ g}$
- v  $8 \text{ dag} = \text{_____} \text{ mg}$
- vi  $2.5 \text{ g} = \text{_____} \text{ mg}$
- vii  $2.5 \text{ g} = \text{_____} \text{ kg}$
- viii  $350 \text{ mg} = \text{_____} \text{ mg}$
- ix  $20 \text{ cg} = \text{_____} \text{ mg}$
- x  $0.05 \text{ Mt} = \text{_____} \text{ kg}$

c Force

- i  $1.2 \text{ N} = \text{_____} \text{ kg}$
- ii  $2.6 \text{ N} = \text{_____} \text{ kg}$
- iii  $800 \text{ N} = \text{_____} \text{ KN}$
- iv  $14.5 \text{ kg} = \text{_____} \text{ N}$
- v  $25 \text{ kg} = \text{_____} \text{ N}$

d Work, energy, amount of heat

- i  $2 \text{ Nm} = \text{_____} \text{ Ncm}$
- ii  $50 \text{ Ncm} = \text{_____} \text{ Nm}$
- iii  $120 \text{ KJ} = \text{_____} \text{ J}$
- iv  $40 \text{ J} = \text{_____} \text{ KJ}$
- v  $40 \text{ J} = \text{_____} \text{ KJ}$
- vi  $300 \text{ wh} = \text{_____} \text{ kwh}$



e Power

- i 200 mW = \_\_\_\_\_ W
- ii 0.2 kW = \_\_\_\_\_ W
- iii 300 kW = \_\_\_\_\_ mW
- iv  $2.10^6$  W = \_\_\_\_\_ mW
- v  $6.10^{-4}$  kW = \_\_\_\_\_ W
- vi 2 W = \_\_\_\_\_ kW
- vii 350 W = \_\_\_\_\_ kW
- viii 0.08 W = \_\_\_\_\_ kW
- ix  $2 \times 10^{-3}$  kW = \_\_\_\_\_ W
- x 0.04 W = \_\_\_\_\_ mW

f Convert as required.

- i 3 Nm = \_\_\_\_\_ J
- ii 2 J = \_\_\_\_\_ Ws
- iii 12 J = \_\_\_\_\_ KJ
- iv 3 Nm/s = \_\_\_\_\_ J/s
- v 8 J/s = \_\_\_\_\_ J/s
- vi 5 N = \_\_\_\_\_ KN
- vii 5 Ws = \_\_\_\_\_ Ws
- viii 3 KJ = \_\_\_\_\_ Nm
- ix 18 J/s = \_\_\_\_\_ W
- x 12 W = \_\_\_\_\_ J/s
- xi kJ/s = \_\_\_\_\_ Nm/s

**Prime Numbers and whole Numbers**

**Factor**

A factor is a small number which divides exactly into a bigger number.e.g.

To find the factors of 24, 72, 100 numbers

$$24 = 2 \times 2 \times 2 \times 3$$

$$72 = 2 \times 2 \times 2 \times 3 \times 3$$

$$100 = 2 \times 2 \times 5 \times 5$$

The numbers 2,3,5 are called factors.

**Definition of a prime factor**

Prime factor is a number which divides a prime number into factors.e.g.

$$57 = 3 \times 19$$

The numbers 3 and 19 are prime factors.

They are called as such, since 3 & 19 also belong to prime number category.

**Definition of H.C.F**

The Highest Common Factor

The H.C.F of a given group of numbers is the highest number which will exactly divide all the numbers of that group.e.g.

To find the H.C.F of the numbers 24, 72, 100

$$24 = 2 \times 2 \times 2 \times 3$$

$$72 = 2 \times 2 \times 2 \times 3 \times 3$$

$$100 = 2 \times 2 \times 5 \times 5$$

The factors common to all the three numbers are

$$2 \times 2 = 4. \text{ So HCF} = 4.$$

**Definition of L.C.M**

Lowest common multiple

The lowest common multiple of a group of numbers is the smallest number that will contain each number of the given group without a remainder.e.g.

- Factorise the following numbers

$$7, 17, 20, 66, 128$$

7, 17 - These two belong to Prime numbers. Hence no factor except unity and itself.

Factors of 20 =  $2 \times 2 \times 5$

$$\begin{array}{r|l} 2 & 20 \\ 2 & 10 \\ & 5 \end{array}$$

Factors of 66 =  $2 \times 3 \times 11$

$$\begin{array}{r|l} 2 & 66 \\ 3 & 33 \\ & 11 \end{array}$$

Factors of 128 =  $2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2$

$$\begin{array}{r|l} 2 & 128 \\ 2 & 64 \\ 2 & 32 \\ 2 & 16 \\ 2 & 8 \\ 2 & 4 \\ & 2 \end{array}$$

- Select prime numbers from 3 to 29

$$3, 5, 7, 11, 13, 17, 19, 23, 29$$

- Find the HCF of the following group of numbers HCF of 78, 128, 196

$$78 = 2 \times 3 \times 13$$

$$\begin{array}{r|l} 2 & 78 \\ 3 & 39 \\ & 13 \end{array}$$

128 =  $2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2$

$$\begin{array}{r|l} 2 & 128 \\ 2 & 64 \\ 2 & 32 \\ 2 & 16 \\ 2 & 8 \\ 2 & 4 \\ & 2 \end{array}$$

196 =  $2 \times 2 \times 49$

$$\begin{array}{r|l} 2 & 196 \\ 2 & 98 \\ & 49 \end{array}$$

HCF = 2

- Find LCM of 84, 92, 76

$$\text{LCM} = \begin{array}{r|l} 2 & 84, 92, 76 \\ 2 & 42, 46, 38 \\ 3 & 21, 23, 19 \\ & 7, 23, 19 \end{array}$$

$$\text{LCM} = 2 \times 2 \times 3 \times 7 \times 23 \times 19 = 36708$$

- To find out the LCM of 36, 108, 60

$$\begin{array}{r|l} 2 & 36, 108, 60 \\ 2 & 18, 54, 30 \\ 3 & 9, 27, 15 \\ 3 & 3, 9, 5 \\ & 1, 3, 5 \end{array}$$

LCM of the number

$$36, 108, 60 = 2 \times 2 \times 3 \times 3 \times 3 \times 5 = 540$$

The necessity of finding LCM and HCF arises in subtraction and addition of fractions.

**Description**

A minimal quantity that is not a whole number. For e.g. .

$\frac{1}{5}$  A vulgar fraction consists of a numerator and denominator.

**Numerator/Denominator**

The number above the line in a vulgar fraction showing how many of the parts indicated by the denominator are taken is the numerator. The total number of parts into which the whole quantity is divided and written below the line in a vulgar fraction is the denominator. e.g.

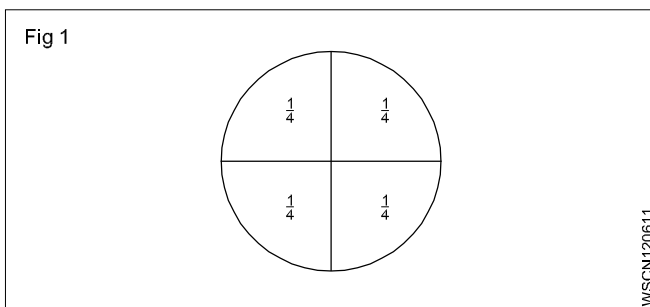
$$\frac{1}{4}, \frac{3}{4}, \frac{7}{12}$$

1,3,7 - numerators                      4,12 - denominators

**Fraction: Concept**

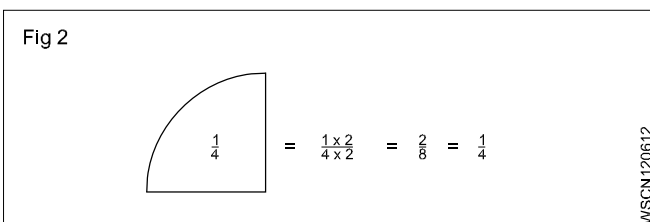
Every number can be represented as a fraction.e.g.

$\frac{1}{4} = \frac{5}{4}$ , A full number can be represented as an apparent fraction.e.g. (Fig 1)



**Fraction: Value**

The value of a fraction remains the same if the numerator and denominator of the fraction are multiplied or divided by the same number.(Fig 2)

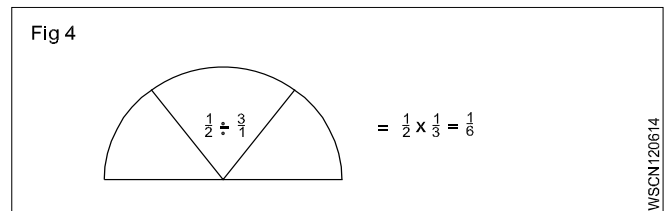
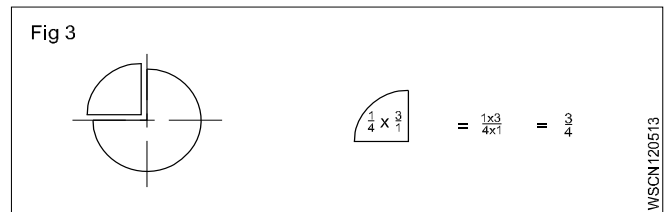


**Multiplication**

When fractions are to be multiplied, multiply all the numerators to get the numerator of the product and multiply all the denominators to form the denominator of the product. (Fig 3)

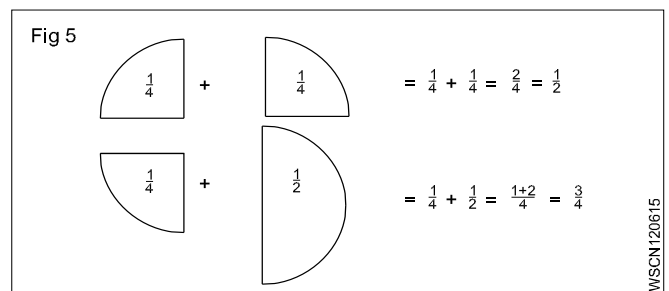
**Division**

When a fraction is divided by another fraction the dividend is multiplied by the reciprocal of the divisor. (Fig 4)



**Addition and Subtraction**

The denominators of the fractions should be the same when adding or subtracting the fractions. Unequal denominators must first be formed into a common denominator. It is the lowest common denominator and it is equal to the product of the most common prime numbers of the denominators of the fractions in question.(Fig 5)



**Examples**

- Multiply  $\frac{3}{4}$  by  $\frac{2}{3}$ ,

$$\frac{3}{4} \times \frac{2}{3} = \frac{6}{12} = \frac{1}{2}$$

- Divide  $\frac{3}{8}$  by  $\frac{3}{4}$ ,

$$\frac{3}{8} \div \frac{3}{4} = \frac{3}{8} \times \frac{4}{3} = \frac{1}{2}$$

- Add  $\frac{3}{4}$  and  $\frac{2}{3}$ ,

$$\frac{3}{4} + \frac{2}{3} = \frac{9}{12} + \frac{8}{12} = \frac{17}{12} = 1\frac{5}{12}$$

- sub  $\frac{7}{16}$  from  $\frac{17}{32}$

$$\frac{17}{32} - \frac{7}{16} = \frac{17}{32} - \frac{14}{32} = \frac{(17 - 14)}{32} = \frac{3}{32}$$

## Types of fractions

- Proper fractions are less than unity. Improper fractions have their numerators greater than the denominators.
- A mixed number has a full number and a fraction.

## Addition of fraction

$$\text{Add } \frac{1}{2} + \frac{1}{8} + \frac{5}{12}$$

To add these fractions we have to find out L.C.M of denominators 2,8,12.

Find L.C.M of 2,8,12

Step 1 L.C.M

$$\begin{array}{r|l} 2 & 2,8,12 \\ 2 & 1,4,6 \\ & 1,2,3 \end{array}$$

Factors are 2,2,2,3

Hence L.C.M =  $2 \times 2 \times 2 \times 3 = 24$

Step 2

$$\begin{aligned} \frac{1}{2} + \frac{1}{8} + \frac{5}{12} &= \frac{12}{24} + \frac{3}{24} + \frac{10}{24} \\ &= \frac{12+3+10}{24} = \frac{25}{24} = 1\frac{1}{24} \end{aligned}$$

## Subtraction of fraction

$$\text{subtract } 9\frac{15}{32} \text{ from } 17\frac{9}{16} \text{ or } (17\frac{9}{16} - 9\frac{15}{32})$$

Step 1: Subtract whole number first  $17 - 9 = 8$

Step 2: L.C.M of 16,32 = 32

Since number 16 divides the number 32

$$\text{Subtracting fractions} = \frac{3}{32}$$

Adding with whole number from Step 1

$$\text{we get } 8 + \frac{3}{32} = 8\frac{3}{32}$$

## Common fractions

Problems with plus and minus sign

Example

$$\text{solve } 3\frac{3}{4} + 6\frac{7}{8} - 4\frac{5}{16} - \frac{9}{32}$$

Rule to be followed

- 1 Add all whole numbers
- 2 add all + Numbers
- 3 Add all - Numbers
- 4 Find L.C.M of all denominators

Solution

Step 1: Add whole numbers =  $3 + 6 - 4 = 5$

$$\text{Step 2: Add fractions} = \frac{3}{4} + \frac{7}{8} - \frac{5}{16} - \frac{9}{32}$$

L.C.M of 4,8,16,32 is 32

$$\begin{aligned} & \frac{24 + 28 - 10 - 9}{32} \\ &= \frac{52 - 19}{32} \\ &= \frac{33}{32} = 1\frac{1}{32} \end{aligned}$$

Step 3: Adding again with the whole number

$$\text{we get } 5 + 1\frac{3}{32} = 6\frac{3}{32}$$

## Brackets and their solution

Sometimes fractions are added and subtracted with brackets, to express two or more expressions. The problems with brackets are solved by using a rule called 'BODMAS' rule.

BODMAS rule:

- B - Brackets - 1<sup>st</sup>
- O - of - 2<sup>nd</sup>
- D - Division - 3<sup>rd</sup>
- M - Multiplication - 4<sup>th</sup>
- A - Addition - 5<sup>th</sup>
- S - Subtraction - Last to be done

Problem with brackets

$$\text{solve } 6 \left[ 5 \left\{ 4 + 91 + \left( \frac{1}{2} - \frac{1}{4} \right) \right\} \right]$$

Steps to be followed

- ( ) 1 Solve inside bracket ( )
- 2 Solve multiplication and division together
- 3 Solve addition and subtraction together
- { } 4 Solve curly bracket before the final stage
- [ ] 5 Solve square bracket at the final stage.

## Examples

### Common fractions

#### • Multiply

$$\text{a } \frac{3}{8} \text{ by } \frac{4}{7} = \frac{3}{8} \times \frac{4}{7} = \frac{3}{14}$$

$$\text{b } \frac{2}{3} \times \frac{3}{4} \times \frac{5}{8} = \frac{5}{16}$$

#### • Division

$$\text{a } \frac{5}{16} \div \frac{5}{32} = \frac{5}{16} \times \frac{32}{5} = 2$$

$$\text{b } 4\frac{2}{3} \div 3\frac{1}{7} = \frac{14}{3} \div \frac{22}{7} = \frac{14}{3} \times \frac{7}{22} = \frac{49}{33} = 1\frac{16}{33}$$

#### • Addition

$$\frac{1}{2} + \frac{1}{4} + \frac{1}{8}$$

$$\text{L.C.M} = 2, 4, 8 = 8$$

$$\frac{1}{2} + \frac{1}{4} + \frac{1}{8} = \frac{4+2+1}{8} = \frac{7}{8}$$

#### • Subtraction

$$5\frac{1}{4} - 3\frac{3}{4} = 5 - 3 + \frac{1}{4} - \frac{3}{4}$$

$$= 2 + \frac{1}{4} - \frac{3}{4} = 2 - \frac{2}{4}$$

$$= \frac{9}{4} - \frac{3}{4} = \frac{9-3}{4}$$

$$= \frac{6}{4} = \frac{3}{2} = 1\frac{1}{2}$$

## Bracket problem

1 solve by use 'BODMAS' rule

$$10 \left[ 8 \left\{ 6 + 11 - 2 + \left( \frac{7}{8} - \frac{1}{2} \right) \right\} \right]$$

$$= 10 \left[ 8 \left\{ 15 + \frac{3}{8} \right\} \right]$$

$$= 10 \left[ 8 \times 15 \frac{3}{8} \right]$$

$$= 10 \times 8 \times \frac{123}{8} = 1230$$

2 solve by use 'BODMAS' rule

$$6 \left[ 5 \left\{ 4 + 9 - 1 + \left( \frac{1}{2} - \frac{1}{4} \right) \right\} \right]$$

$$= 6 \left[ 5 \left\{ 4 + 9 - 1 + \frac{1}{4} \right\} \right]$$

$$= 6 \left[ 5 \times 12 \frac{1}{4} \right]$$

$$= 6 \left[ 5 \times \frac{49}{4} \right]$$

$$= \frac{1470}{4}$$

$$= 367 \frac{2}{4}$$

$$= 367 \frac{1}{2}$$

**Description**

Decimal fraction is a fraction whose denominator is 10 or powers of 10 or multiples of 10 (i.e.) 10, 100, 1000, 10000 etc. Meaning of a decimal number:-

12.3256 means

$$(1 \times 10) + (2 \times 1) + \frac{3}{10} + \frac{2}{100} + \frac{5}{1000} + \frac{6}{10000}$$

**Representation**

The denominator is omitted. A decimal point is placed at different positions of the number corresponding to the magnitude of the denominator

Ex.  $\frac{5}{10} = 0.5, \frac{35}{100} = 0.35, \frac{127}{10000} = 0.0127, \frac{3648}{1000} = 3.648$

**Addition and subtraction**

Arrange the decimal fractions in a vertical order, placing the decimal point of each fraction to be added or subtracted, in succession one below the other, so that all the decimal points are arranged in a straight line. Add or subtract as you would do for a whole number and place the decimal point in the answer below the column of decimal points.

Decimal fractions less than 1 are written with a zero before the decimal point. Example:  $45/100 = 0.45$  (and not simply .45)

Add  $0.375 + 3.686$

$$\begin{array}{r} 0.375 \\ 3.686 \\ \hline 4.061 \end{array}$$

Subtract 18.72 from 22.61

$$\begin{array}{r} 22.61 \\ 18.72 \\ \hline 3.89 \end{array}$$

**Multiplication**

Ignore the decimal points and multiply as whole numbers. Find the total number of digits to the right of the decimal point. Insert the decimal point in the answer such that the number of digits to the right of the decimal point equals to the sum of the digits found to the right of the decimal points in the problem.

Multiply 2.5 by 1.25

=  $25 \times 125 = 3125$ . The sum of the figures to the right of decimal point is 3. Hence the answer is 3.125.

**Division**

Move the decimal point of the divisor to the right to make it a full number. Move the decimal point in the dividend to the same number of places, adding zeroes if necessary. Then divide.

Divide 0.75 by 0.25

$$\begin{array}{r} 0.25 \overline{)0.75} \\ \underline{0.75} \phantom{00} \\ 0.75 \phantom{00} \\ \underline{0.75} \phantom{00} \\ 0.00 \phantom{00} \\ 0.00 \phantom{00} \\ \hline 3 \end{array}$$

**Move the decimal point in the multiplicand to the right to one place if the multiplier is 10, and to two places if the multiplier is 100 and so on. When dividing by 10 move the decimal point one place to the left, and, if it is by 100, move them point by two places and so on.**

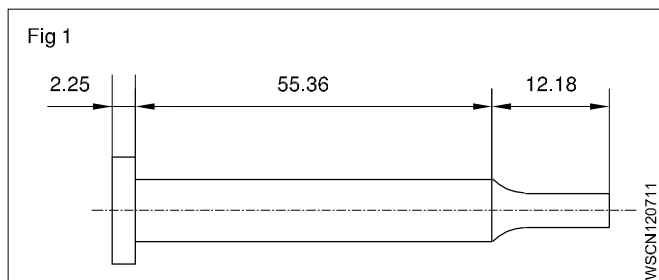
**Example**

Allowing 3 mm for cutting off each pin how many pins, can be made from a 900 mm long bar? How much material will be left out?

Length of pin

$$= 2.25 + 55.36 + 12.18$$

$$= 69.79 \text{ mm}$$



Length of the bar = 900 mm

**Step 1**

Let the number of pins to be made =  $x$

Length of  $x$  number of pins =  $x \times 69.79 \text{ mm}$

**Step 2**

Waste for each pin = 3 mm

Waste for  $x$  number of pins =  $3 \times x \text{ mm} = 3x \text{ mm}$

Adding step (1) + step (2) and equating to length of bar  
 $69.79x \text{ mm} + 3x \text{ mm} = 900 \text{ mm}$

$$x(69.79\text{mm} + 3\text{mm}) = 900\text{mm}$$

$$x(72.79\text{mm}) = 900\text{mm}$$

$$x = 900 \div 72.79$$

Hence Number of pins to be made = 12

Secondly

Left out materials

= Total length of bar - Length for 12 pins+ wastage of cutting

$$= 900\text{mm} - (12 \times 69.79 + 12 \times 3)\text{mm}$$

$$= 900 - (837.48 + 36)\text{mm}$$

$$= 900 - 873.48\text{mm}$$

$$= 26.52\text{mm}$$

Left out material 26.52 mm

Conversion of Decimals into fractions and vice-versa

- Convert decimal into fractions

### Example

Convert 0.375 to a fraction

Now place 1 under the decimal point followed by as many zeros as there are numbers

$$0.375 = \frac{375}{1000} = \frac{15}{40} = \frac{3}{8}$$

$$0.375 = \frac{3}{8}$$

- Convert fraction into decimal

### Example

- Convert  $\frac{9}{16}$  to a decimal

Proceed to divide  $\frac{9}{16}$  in the normal way of division but put zeros (as required) after the number 9 (Numerator)

$$\begin{array}{r}
 0.5625 \\
 16 \overline{)90000} \\
 \underline{80} \\
 100 \\
 \underline{96} \\
 40 \\
 \underline{32} \\
 80 \\
 \underline{80} \\
 0
 \end{array}$$

$$\frac{9}{16} = 0.5625$$

- Convert  $\frac{7}{8}$  to a decimal

$$\begin{array}{r}
 0.875 \\
 8 \overline{)7000} \\
 \underline{64} \\
 60 \\
 \underline{56} \\
 40 \\
 \underline{40} \\
 0
 \end{array}$$

$$\frac{7}{8} = 0.875$$

### Recurring decimals

While converting from fraction to decimals, some fractions can be divided exactly into a decimal. In some fractions the quotient will not stop. It will continue and keep recurring. These are called recurring decimals.

### Examples

- convert  $\frac{1}{3}, \frac{2}{3}, \frac{1}{7}$

$$a \quad \frac{1}{3} = \frac{10000}{3} = 0.3333 \text{ – Recurring}$$

$$b \quad \frac{2}{3} = \frac{20000}{3} = 0.666 \text{ – Recurring}$$

$$c \quad \left( \frac{1}{7} = \frac{10000}{7} = 0.142857142 \text{ – Recurring} \right)$$

These are written as below with a dot over the figure

$$0.3333 \longrightarrow 0.\dot{3}$$

$$0.6666 \longrightarrow 0.\dot{6}$$

$$0.14857142 \longrightarrow 0.1\dot{4}857\dot{1}42$$

Note the dots marked over numbers.

We normally carry the decimal points upto 4 places in Engineering calculations.

### Approximations in Measured Value calculations

In Measured Value calculations 4 places of decimals are sufficient and in many dimensions of parts even 3 decimal places are near enough to complete the maintenance job operations.

### Method of writing approximations in decimals

1.73556 = 1.7356 Correct to 4 decimal places  
5.7343 = 5.734 Correct to 3 decimal places  
0.9345 = 0.94 Correct to 2 decimal places

### Multiplication and division by 10,100,1000

#### Multiplying decimals by 10

A decimal fraction can be multiplied by 10, 100, 1000 and so on by moving the decimal point to the right by as many places as there are zeros in the multiplier.

- $4.645 \times 10 = 46.45$  (one place)
- $4.645 \times 100 = 464.5$  (two places)
- $4.645 \times 1000 = 4645$  (three places)

#### Dividing decimals by 10

A decimal fraction can be divided by 10, 100, 1000 and so on, by moving the decimal point to the left by as many places as required in the divisor by putting zeros

#### Examples

- $3.732 \div 10 = 0.3732$  (one place)
- $3.732 \div 100 = 0.03732$  (two places)
- $3.732 \div 1000 = 0.003732$  (three places)

#### Examples

- Rewrite the following number as a fraction

453.273

453.273

$$= (4 \times 100) + (5 \times 10) + (3 \times 1) + \frac{2}{10} + \frac{7}{100} + \frac{3}{100}$$
$$= 453 \frac{273}{1000}$$

- Write the representation of decimal places in the given number 0.386

3 - 1st decimal place

8 - 2nd decimal place

6 - 3rd decimal place

- Write approximations in the following decimals to 3 places.

a 6.9453  $\longrightarrow$  6.945

b 8.7456  $\longrightarrow$  8.746

- Convert fraction to decimal

$$\frac{21}{24} = \frac{7}{8} = 0.875$$

- Convert decimal to fraction

$$0.0625 = \frac{625}{10000} = \frac{5}{80} = \frac{1}{16}$$

---

## ASSIGNMENT

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- 1 Write down the following decimal numbers in the expanded form.

a 514.726

b 902.524

- 2 Write the following decimal numbers from the expansion.

a  $500 + 70 + 5 + \frac{3}{10} + \frac{2}{100} + \frac{9}{1000}$

b  $200 + 9 + \frac{1}{10} + \frac{3}{100} + \frac{5}{1000}$

- 3 Convert the following decimals into fractions in the simplest form.

a 0.72

b 5.45

c 3.64

d 2.05

- 4 Convert the following fraction into decimals

a  $\frac{3}{5}$

b  $\frac{10}{4}$

c  $24 \frac{54}{1000}$

d  $\frac{12}{25}$

e  $\frac{8}{25}$

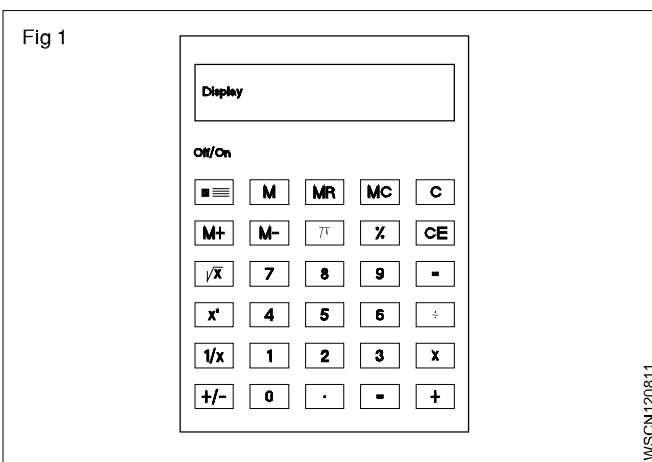
f  $1 \frac{3}{25}$



A pocket calculator allows to spend less time in doing tedious calculations. A simple pocket calculator enables to do the arithmathical calculations of addition subtraction, multiplication and division, while a scientific type of calculator can be used for scientific and technical calculations also.

No special training is required to use a calculator. But it is suggested that a careful study of the operation manual of the type of the calculator is essential to become familiar with its capabalities. A calculator does not think and do. It is left to the operator to understand the problem, interpret the information and key it into the calculator correctly.

**Constructional Details (Fig 1)**



The key board is divided into five clear and easily recogniz able areas and the display

• **Data entry keys**

The entry keys are from  $\boxed{0}$  .....to  $\boxed{9}$

and a key for the decimal point  $\boxed{.}$  .

• **Clearing keys**

These keys have the letter 'C'

$\boxed{C}$   $\boxed{CLR}$  Clear totally

$\boxed{CE}$  Clear entry only

$\boxed{CM}$  ,  $\boxed{MC}$  Clear memory

$\boxed{+}$  Addition key

$\boxed{-}$  Subtraction key

$\boxed{\times}$  Multiplication key

$\boxed{\div}$  Division key

$\boxed{=}$  Equals key to display the result

• **Function keys**

$\boxed{\pi}$  Pi key

$\boxed{\sqrt{x}}$  Square root key

$\boxed{\%}$  Percentage key

$\boxed{+/-}$  Sign change key

$\boxed{x^2}$  Square key

$\boxed{\frac{1}{x}}$  Reciprocal key

• **Memory keys**

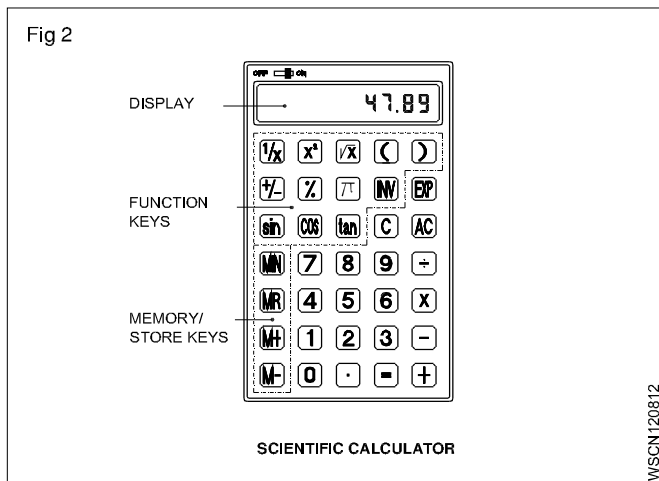
$\boxed{M}$  Store the display number

$\boxed{M+}$  The displayed value is added to the memory

$\boxed{M-}$  The displayed value is subtracted from the memory

$\boxed{MR}$   $\boxed{RCL}$  The stored value is recalled on to the display

Further functional keys included in Scientific calculators are as shown in Fig 2.



$\boxed{\text{Sin}}$   $\boxed{\text{Cos}}$   $\boxed{\text{Tan}}$   $\boxed{[ ]}$  For trigonometric functions and for brackets

$\boxed{\text{Exp}}$  Exponent key

$\boxed{\text{INV}}$  Some of the keys have coloured lettering above or below them. To use a function in coloured lettering, press INV key. INV will appear on the display. Then press the key that the coloured lettering identifies. INV will disappear from the display.

$\boxed{\log}$ ,  $\boxed{\text{INV}}$ ,  $\boxed{10^x}$  to obtain the logarithm of the displayed number and the antilogarithm of the displayed value.

$\boxed{\text{INV}}$   $\boxed{\text{R-P}}$  to convert displayed rectangular coordinates into polar coordinates.

$\boxed{\text{INV}}$   $\boxed{\text{P-R}}$  to convert displayed polar coordinates into rectangular coordinates.

### • The display

The display shows the input data, interim results and answers to the calculations.

**The arrangement of the areas can differ from one make to another. Keying in of the numbers is done via an internationally agreed upon set of ten keys in the order that the numbers are written.**

### Rules and Examples:

- **Addition:** Example  $18.2 + 5.7$

Sequence	Input	Display
Input of the 1st term of the sum	$\boxed{1} \boxed{8} \boxed{.} \boxed{2}$	18.2
Press + key	$\boxed{+}$	18.2
Input 2nd term of the sum. the first term goes into the register	$\boxed{5} \boxed{.} \boxed{7}$	5.7
Press the = key	$\boxed{=}$	23.9

- **Subtraction:** Example  $128.8 - 92.9$

Sequence	Input	Display
Enter the subtrahend	$\boxed{1} \boxed{2} \boxed{8} \boxed{.} \boxed{8}$	18.2
Press - key	$\boxed{-}$	128.8
Enter the minnend. The subtrahend goes into the register	$\boxed{9} \boxed{2} \boxed{.} \boxed{9}$	92.9
Press the = key	$\boxed{=}$	35.9

- **Multiplication:** Example  $0.47 \times 2.47$

Sequence	Input	Display
Enter multiplicand	$\boxed{.} \boxed{4} \boxed{7}$	0.47
Press x key	$\boxed{\times}$	0.47
Enter multiplier, multiplicand goes to register	$\boxed{2} \boxed{.} \boxed{4} \boxed{7}$	2.47
Press = key	$\boxed{=}$	1.1609

- **Division:** Example  $18.5/2.5$

Sequence	Input	Display
Enter the dividend	$\boxed{1} \boxed{8} \boxed{.} \boxed{5}$	18.5
Press ÷ Key	$\boxed{\div}$	18.5
Enter the divisor goes to the register	$\boxed{2} \boxed{.} \boxed{5}$	2.5
Press = key	$\boxed{=}$	7.4

- **Multiplication & Division:**  
Example : 2.5 x 7.2 / 4.8 x 1.25

Sequence	Input	Display
Enter 2.5	2 . 5	2.5
Press x key	x	2.5
Enter 7.2	7 . 2	7.2
Press ÷ key	÷	18
Enter 4.8	4 . 8	4.8
Press x key	x	3.75
<b>Remember:</b> Before input of the first value under the fraction line, the x key must be operated	1 . 2 5 =	1.25 3.0
Enter 1.25		
Press = key		

- Store in memory Example (2+6) (4+3)

Sequence	Input	Display
Workout for the first bracket	2 + 6 =	2 2 6 8
Store the first result in x	STO , M or M+	8 8
Workout for the 2nd bracket	4 + 3 =	4 4 3 7
Press x key	x	7
Recall memory	RCL or MR	8
Press = key	=	56

- **Percentage:** Example 12% of 1500

Sequence	Input	Display
Enter 1500	1 5 0 0	1500
Press x key	x	1500
Enter 12	1 2	12
Press INV %	INV %	12
Press = key	=	180

- **Square root:** Example  $\sqrt{2} + \sqrt{3 \times 5}$

Sequence	Input	Display
Enter 2	2	2
Press $\sqrt{a}$ key	$\sqrt{a}$	2
Press + key	+	.
Press bracket key	(	.
Enter 3	3	3
Press $\sqrt{a}$ key	$\sqrt{a}$	.
Press x key	x	.
Enter 5	5	5
Press $\sqrt{a}$ key	$\sqrt{a}$	.
Press bracket close key	)	.
Press = key	=	5.2871969
	2 $\sqrt{a}$ + ( 3 $\sqrt{a}$ x 5 $\sqrt{a}$ ) =	5.2871969

$$\sqrt{2} + \sqrt{3 \times 5} = 5$$

- **Common logarithm:** Example log 1.23

Sequence	Input	Display
	1 . 2 3 log =	0.0899051

- **Power:** Example  $123 + 30^2$

Sequence	Input	Display
	1 2 3 + 3 0 INV X <sup>2</sup> =	1023

- Before starting the calculations be sure to press the 'ON' key and confirm that '0' is shown on the display.
- Do not touch the inside portion of the calculator. Avoid hard knocks and unduly hard pressing of the keys.
- Maintain and use the calculator in between the two extreme temperatures of 0° and 40° C.

- Never use volatile fluids such as lacquer, thinner, benzene while cleaning the unit.
- Take special care not to damage the unit by bending or dropping.
- Do not carry the calculator in your hip pocket.

## ASSIGNMENT

1 Using calculator solve the following

- $625 + 3467 + 20 + 341 + 6278 =$  \_\_\_\_\_
- $367.4 + 805 + 0.7 + 7.86 + 13.49 =$  \_\_\_\_\_
- $0.043 + 1.065 + 13.0 + 34.76 + 42.1 =$  \_\_\_\_\_
- $47160 + 1368.4 + 0.1 + 1.6901 + 134.267 =$  \_\_\_\_\_

2 Using calculator simplify the following

- $24367 - 4385 =$  \_\_\_\_\_
- $9.643 - 0.7983 =$  \_\_\_\_\_
- $4382.01 - 381.3401 =$  \_\_\_\_\_
- $693.42 - 0.0254 =$  \_\_\_\_\_

3 Using calculator find the values of the following

- $23 \times 87 =$  \_\_\_\_\_
- $1376 \times 0.81 =$  \_\_\_\_\_
- $678 \times 243 =$  \_\_\_\_\_
- $0.75 \times 0.24 =$  \_\_\_\_\_

4 Using calculator solve the following

- $22434 \div 3 =$  \_\_\_\_\_
- $4131 \div 243 =$  \_\_\_\_\_
- $469890 \div 230 =$  \_\_\_\_\_
- $3.026 \div 0.89 =$  \_\_\_\_\_

5 Solve the following

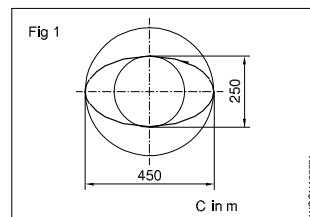
- $\frac{1170 \times 537.5}{13 \times 215} =$  \_\_\_\_\_
- $\frac{28.2 \times 18 \times 3500}{1000 \times 3 \times 0.8} =$  \_\_\_\_\_

6 Solve the following

- $\frac{(634 + 128) \times (384 - 0.52)}{8 \times 0.3} =$  \_\_\_\_\_

$$b \frac{(389 - 12.2) \times (842 - 0.05 - 2.6)}{(3.89 - 0.021) \times (28.1 + 17.04)} =$$

7



$$2a = 450 \text{ mm (major axis)}$$

$$2b = 250 \text{ mm (minor axis)}$$

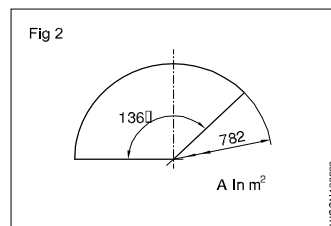
Perimeter of the ellipse

$$C = \text{_____ metre}$$

Hint C =

$$\pi \sqrt{2(a^2 + b^2)}$$

8



$$r = 782 \text{ mm}$$

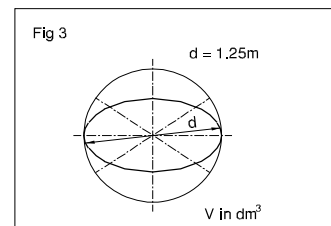
$$\alpha = 136^\circ$$

Area of the sector

$$A = \text{_____}$$

$$\text{Hint } A = \frac{\pi \times r^2}{4} \times \frac{\alpha}{360^\circ}$$

9

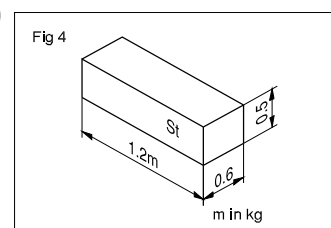


$$d = 1.25 \text{ metre}$$

$$V = \text{_____ dm}^3$$

$$\text{Hint } V = \frac{4}{3} \pi r^3$$

10



$$L = 1.2 \text{ metres}$$

$$B = 0.6 \text{ metre}$$

$$H = 0.5 \text{ metre}$$

'r' of steel

$$= 7.85 \text{ kg/dm}^3$$

$$m = \text{_____ kg}$$

$$(\text{mass 'm' } = V \times r)$$

1 Convert the following into improper fractions.

a  $1\frac{2}{7} = \underline{\hspace{2cm}}$

b  $4\frac{3}{5} = \underline{\hspace{2cm}}$

c  $3\frac{3}{5} = \underline{\hspace{2cm}}$

d  $5\frac{7}{8} = \underline{\hspace{2cm}}$

e  $3\frac{1}{3} = \underline{\hspace{2cm}}$

f  $5\frac{3}{4} = \underline{\hspace{2cm}}$

g  $7\frac{3}{7} = \underline{\hspace{2cm}}$

h  $182\frac{1}{74} = \underline{\hspace{2cm}}$

2 Convert the following into mixed numbers.

a  $\frac{12}{11} = \underline{\hspace{2cm}}$

b  $\frac{36}{14} = \underline{\hspace{2cm}}$

c  $\frac{18}{10} = \underline{\hspace{2cm}}$

d  $\frac{25}{3} = \underline{\hspace{2cm}}$

e  $\frac{84}{13} = \underline{\hspace{2cm}}$

f  $\frac{32}{21} = \underline{\hspace{2cm}}$

g  $\frac{18}{16} = \underline{\hspace{2cm}}$

h  $\frac{75}{4} = \underline{\hspace{2cm}}$

3 Place the missing numbers.

a  $\frac{11}{13} = \frac{x}{91} \underline{\hspace{2cm}}$

b  $\frac{3}{5} = \frac{42}{x} \underline{\hspace{2cm}}$

c  $\frac{9}{14} = \frac{x}{98} \underline{\hspace{2cm}}$

4 Simplify.

a  $\frac{45}{60} = \underline{\hspace{2cm}}$

b  $\frac{8}{12} = \underline{\hspace{2cm}}$

c  $\frac{12}{14} = \underline{\hspace{2cm}}$

d  $\frac{56}{72} = \underline{\hspace{2cm}}$

e  $\frac{6}{14} = \underline{\hspace{2cm}}$

f  $\frac{3}{4} \times \frac{5}{7} \times \frac{11}{3} \times \frac{2}{4} \times \frac{14}{6} = \underline{\hspace{2cm}}$

5 Multiply.

a  $5 \times \frac{2}{3} = \underline{\hspace{2cm}}$

b  $\frac{3}{4} \times 2 = \underline{\hspace{2cm}}$

c  $\frac{3}{4} \times \frac{5}{6} = \underline{\hspace{2cm}}$

d  $3\frac{1}{4} \times 3 = \underline{\hspace{2cm}}$

e  $2\frac{1}{4} \times 3\frac{1}{4} = \underline{\hspace{2cm}}$

f  $5 \times 6\frac{1}{4} = \underline{\hspace{2cm}}$

6 Divide

a  $\frac{1}{4} \div \frac{3}{4} = \underline{\hspace{2cm}}$

b  $6 \div \frac{3}{4} = \underline{\hspace{2cm}}$

c  $\frac{3}{4} \div \frac{2}{7} = \underline{\hspace{2cm}}$

d  $3\frac{1}{6} \div 4 = \underline{\hspace{2cm}}$

e  $5\frac{1}{2} \div 2\frac{1}{7} = \underline{\hspace{2cm}}$

f  $8 \div 3\frac{1}{4} = \underline{\hspace{2cm}}$

7 Place the missing numbers.

a  $\frac{2}{3} = \frac{1}{12} \times \underline{\hspace{2cm}}$

b  $\frac{14}{24} = \frac{1}{12} \times \underline{\hspace{2cm}}$

c  $\frac{7}{8} = \frac{1}{12} \times \underline{\hspace{2cm}}$

d  $\frac{2}{36} = \frac{1}{12} \times \underline{\hspace{2cm}}$

e  $\frac{52}{36} = \frac{1}{12} \times \underline{\hspace{2cm}}$

f  $3\frac{11}{24} = \frac{1}{12} \times \underline{\hspace{2cm}}$

g  $\frac{3}{4} = \frac{1}{12} \times \underline{\hspace{2cm}}$

h  $\frac{7}{6} = \frac{1}{12} \times \underline{\hspace{2cm}}$

8 Add the followings:

a  $\frac{3}{4} + \frac{7}{12} = \underline{\hspace{2cm}}$

b  $\frac{7}{8} + \frac{3}{4} = \underline{\hspace{2cm}}$

c  $\frac{3}{5} + \frac{4}{5} + \frac{3}{8} = \underline{\hspace{2cm}}$

d  $6\frac{1}{4} + 1\frac{7}{12} + 3\frac{7}{9} = \underline{\hspace{2cm}}$

9 Subtract

a  $\frac{4}{5} - \frac{2}{5} = \underline{\hspace{2cm}}$

b  $\frac{5}{6} - \frac{3}{4} = \underline{\hspace{2cm}}$

10 Simplify

a  $2\frac{6}{7} - \frac{3}{8} - \frac{1}{3} - 1\frac{1}{16} = \underline{\hspace{2cm}}$

b  $2\frac{2}{7} - \frac{5}{6} + 8 = \underline{\hspace{2cm}}$

c  $3\frac{7}{9} - \frac{3}{5} + 1\frac{3}{4} - 2 + \frac{1}{2} = \underline{\hspace{2cm}}$

11 Express as improper fractions

a  $5\frac{3}{4}$

b  $3\frac{5}{64}$

c  $1\frac{5}{12}$

12 Reduce to mixed number or whole number

a  $\frac{163}{4}$

b  $\frac{12}{4}$

c  $\frac{144}{60}$

13 Reduce to lowest terms

a  $\frac{12}{64}$

b  $\frac{12}{48}$

c  $\frac{144}{60}$

14 Addition of decimals

- a  $4.56 + 32.075 + 256.6245 + 15.0358$
- b  $462.492 + 725.526 + 309.345 + 626.602$

15 Subtract the following decimals

- a  $612.5200 - 9.6479$
- b  $573.9246 - 215.6000$
- c  $968.325 - 16.482$
- d  $5735.4273 - 364.2342$

16 Add and subtract the following

- a  $56.725 + 48.258 - 32.564$
- b  $16.45 + 124.56 + 62.7 - 3.243$

17 Multiplication of decimals

- a By 10, 100, 1000
  - i 3.754
  - ii  $8.964 \times 100$
  - iii  $2.3786 \times 1000$
  - iv  $0.005 \times 1000$
- b By whole numbers
  - i  $8.4 \times 7$
  - ii  $56.72 \times 8$
- c By another decimal figure (use calculator)
  - i  $15.64 \times 7.68$
  - ii  $2.642 \times 1.562$

18 Divide the following

- a  $\frac{62.5}{25}$
- b  $\frac{14.4}{9}$
- c  $\frac{64.56}{10}$
- d  $\frac{0.42}{100}$
- e  $\frac{48.356}{1000}$
- f  $\frac{25.5}{15}$

19 Division

- a  $\frac{16.8}{1.2}$
- b  $\frac{1.68}{1.2}$

c  $\frac{0.168}{1.2}$

d  $\frac{1.54}{1.1}$

e  $\frac{27.2}{1.6}$

f  $31.5 \div 10.5$

g  $1.54 \div 1.1$

h  $4.41 \div 2.1$

20 Change the fraction into a decimal

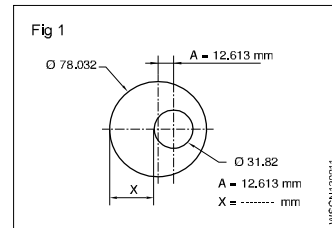
i  $1 \frac{5}{8}$

ii  $\frac{12}{25}$

21 Find the value

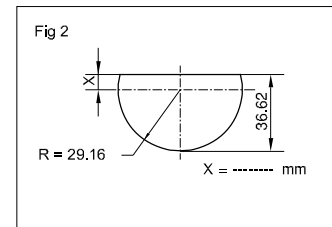
$20.5 \times 40 \div 10.25 + 18.50$

22



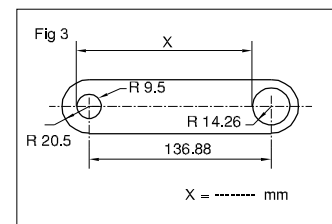
A = 12.613 mm  
X = \_\_\_\_\_ mm.

23



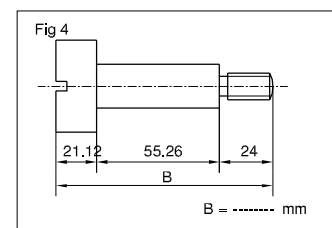
X = \_\_\_\_\_ mm.

24



X = \_\_\_\_\_ mm.

25



B = \_\_\_\_\_ mm.

- a basic number
- 2 exponent

$\sqrt{\quad}$  radical sign indicating the square root.

$\sqrt{a^2}$  square root of 'a' squared

$a^2$  radicand

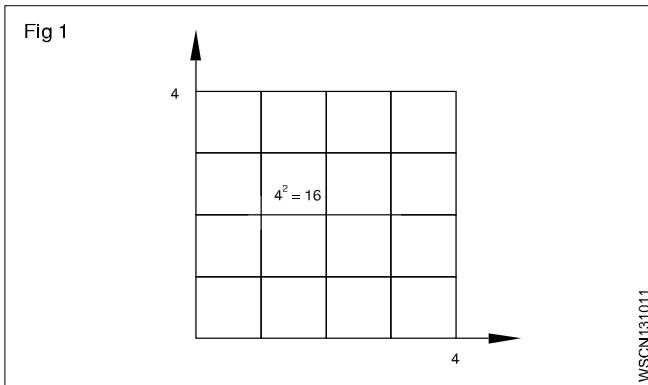
## Square number

The square of a number is the number multiplied by itself.

Basic number x basic number = Square number

$$a \times a = a^2$$

$$4 \times 4 = 4^2 = 16$$



## Splitting up

A square area can be split up into sub-areas. The largest square of 36 is made up of a large square 16, a small square 4 and two rectangles 8 each.

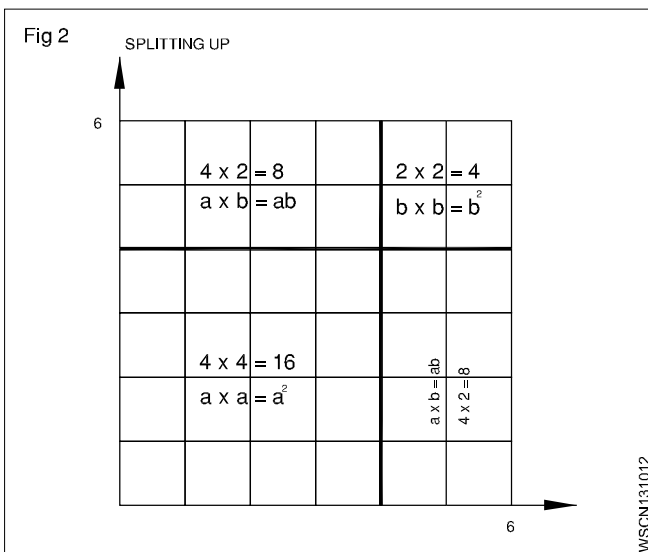
Large square  $4 \times 4 = 16$   $a^2$

Two rectangles  $2 \times 4 \times 2 = 16$   $2ab$

Small square  $2 \times 2 = 4$   $b^2$

Sum of sub-areas =  $36 = a^2 + 2ab + b^2$

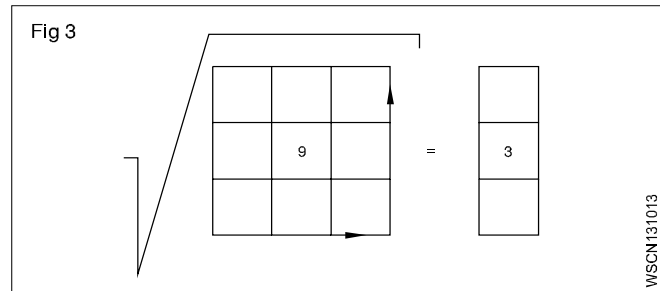
$$\sqrt{36} = \sqrt{a^2 + 2ab + b^2}$$



Result: In order to find the square root, we split up the square numbers.

## Extracting the square root procedure

- Starting from the decimal point form groups of two figures towards right and left. Indicate by a prime symbol.  $\sqrt{46,24.00}$
- Find the root of the first group, calculate the difference, bring down the next group.
- Multiply the root by 2 and divide the partial radicand.
- Enter the number thus calculated in the divisor for the multiplication.



If there is a remainder, repeat the procedure.

$$\begin{array}{r} 68 \\ 6 \overline{)46,24} \\ \underline{36} \\ 128 \overline{)1024} \\ \underline{1024} \\ 0 \end{array}$$

$$\begin{array}{r} 68 \\ 6 \overline{)46,24} \\ \underline{36} \\ 1024 \\ \underline{1024} \\ 0 \end{array}$$

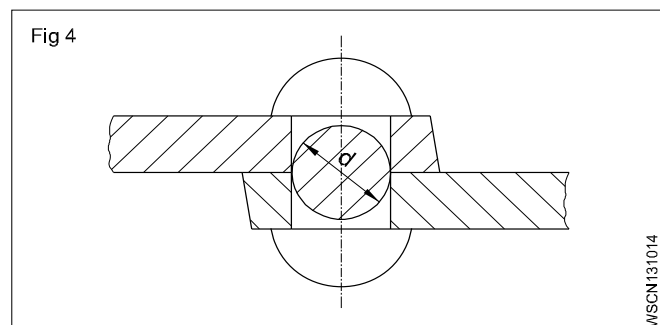
$$\sqrt{46,24} = 68$$

**Basic number x basic number = Square**

**$\sqrt{\text{Square number}} = \text{basic number}$**

## Example

The cross-sectional of a rivet is  $3.46 \text{ cm}^2$ . Calculate the diameter of the hole.



Rivet cross-section is the hole cross-section.

To find  $d_1$ ,

Given that Area =  $3.46 \text{ cm}^2$

Area =  $0.785 \times d^2$  (formula)

$$3.46 \text{ cm}^2 = d^2 \times 0.785$$

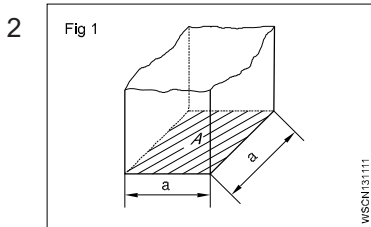
$$d^2 = \frac{3.46 \text{ cm}^2}{0.785}$$

$$d = \sqrt{\frac{3.46}{0.785}} \text{ cm}$$

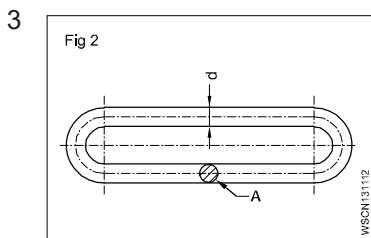
$$d = 2.1 \text{ cm (or) } 21 \text{ mm}$$



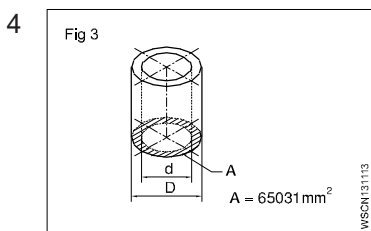
- 1 a  $\sqrt{2916} =$  \_\_\_\_\_  
 b  $\sqrt{45796} =$  \_\_\_\_\_  
 c  $\sqrt{8.2944} =$  \_\_\_\_\_  
 d  $\sqrt{63.845} =$  \_\_\_\_\_



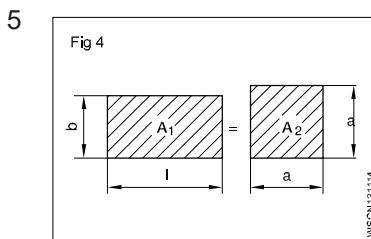
A = 2025 mm<sup>2</sup>  
 a = \_\_\_\_\_ mm



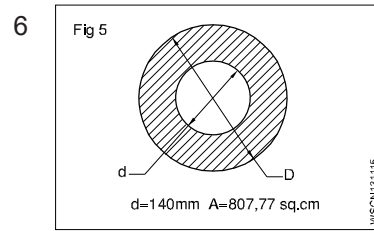
A = 176.715 mm<sup>2</sup>  
 d = \_\_\_\_\_ mm



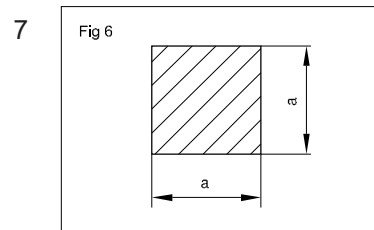
A = 65031 mm<sup>2</sup>  
 d = 140 mm  
 D = \_\_\_\_\_ mm



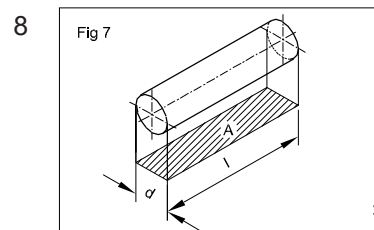
l = 58 cm  
 b = 45 cm  
 $A_1 = A_2$   
 a = \_\_\_\_\_ cm



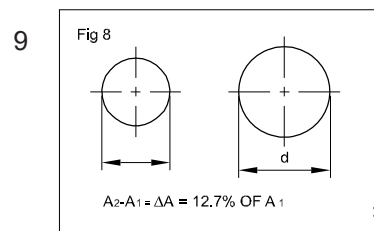
A = 807.77 cm<sup>2</sup>  
 d = 140 mm  
 D = \_\_\_\_\_ mm



a x a = 543169 mm<sup>2</sup>  
 a = \_\_\_\_\_ mm



d : l = 1:1.5  
 A = 73.5 mm<sup>2</sup>  
 d = \_\_\_\_\_ mm



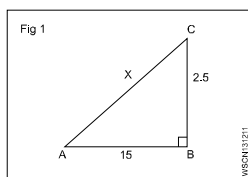
increase in area  
 A = 12.7%  
 A = 360 mm<sup>2</sup>  
 d = \_\_\_\_\_ mm  
 (d = diameter after the increase in area)

## Applications of pythagoras theorem and related problems Exercise 1.3.12

- 1 What is the side AC if AB = 15 cm, BC = 25 cm.

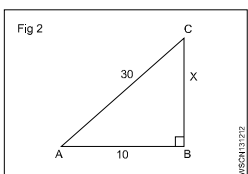
$$\begin{aligned} AC^2 &= AB^2 + BC^2 \\ &= 15^2 + 25^2 \\ &= 225 + 625 = 850 \end{aligned}$$

$$AC = \sqrt{850} = 29.155 \text{ cm}$$



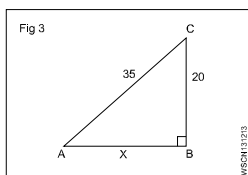
- 2 What is the side BC if AB = 10 cm, AC = 30 cm.

$$\begin{aligned} AC^2 &= AB^2 + BC^2 \\ 30^2 &= 10^2 + BC^2 \\ 900 &= 100 + BC^2 \\ BC^2 &= 900 - 100 = 800 \\ BC &= 28.284 \text{ cm} \end{aligned}$$



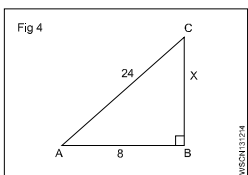
- 3 What is the side AB if BC = 20 cm, AC = 35 cm.

$$\begin{aligned} AC^2 &= AB^2 + BC^2 \\ 35^2 &= AB^2 + 20^2 \\ 1225 &= AB^2 + 400 \\ AB^2 &= 1225 - 400 = 825 \\ AB &= 28.72 \text{ cm} \end{aligned}$$



- 4 What is the value of side BC if AB = 8 cm, AC = 24 cm.

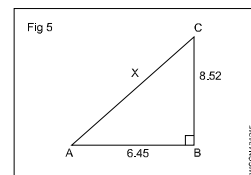
$$\begin{aligned} AC^2 &= AB^2 + BC^2 \\ 24^2 &= 8^2 + BC^2 \\ 576 &= 64 + BC^2 \\ BC^2 &= 576 - 64 = 512 \\ BC &= \sqrt{512} = 22.63 \text{ cm} \end{aligned}$$



- 5 What is the value side AC if AB = 6.45 cm, BC = 8.52 cm.

$$\begin{aligned} AC^2 &= AB^2 + BC^2 \\ AC^2 &= 6.45^2 + 8.52^2 \\ AC^2 &= 41.60 + 72.59 \\ &= 114.19 \end{aligned}$$

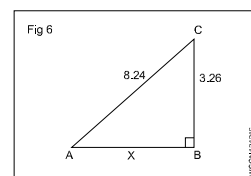
$$AC = \sqrt{114.19} = 10.69 \text{ cm}$$



- 6 What is the value of side AB if BC = 3.26 cm, AC = 8.24 cm.

$$\begin{aligned} AC^2 &= AB^2 + BC^2 \\ 8.24^2 &= AB^2 + 3.26^2 \\ 67.9 &= AB^2 + 10.63 \\ AB^2 &= 67.9 - 10.63 \\ &= 57.27 \end{aligned}$$

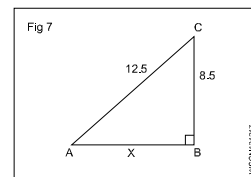
$$AB = \sqrt{57.27} = 7.57 \text{ cm}$$



- 7 What is the value of side AB if AC = 12.5 cm, BC = 8.5 cm.

$$\begin{aligned} AC^2 &= AB^2 + BC^2 \\ 12.5^2 &= AB^2 + 8.5^2 \\ 156.25 &= AB^2 + 72.25 \\ AB^2 &= 156.25 - 72.25 \\ &= 84 \end{aligned}$$

$$AB = \sqrt{84} = 9.17 \text{ cm}$$



## ASSIGNMENT

- 1 What is the value of side AB, if right angled triangle of side AC = 12.5 cm and BC = 7.5 cm.
- 2 What is the value of side AC, if right angled triangle of side AB = 6.5 cm and BC = 4.5 cm.
- 3 What is the value of side BC, if right angled triangle of side AC = 14.5 cm and AB = 10.5 cm.
- 4 What is the value of side AC, if right angled triangle of side AB = 7 cm and BC = 5 cm.
- 5 What is the value of side BC, if right angled triangle of side AC = 13.25 cm and AB = 8.75 cm.

**Ratio**

**Introduction**

It is the relation between two quantities of the same kind and is expressed as a fraction.

**Expression**

a, b two quantities of the same kind.  $\frac{a}{b}$  or a:b or a ÷ b or

a in b is the ratio.

Ratio is always reduced to the lowest terms.

Example

$$7:14 = \frac{7}{14} = \frac{1}{2} = 1:2$$

**Proportion**

It is the equality between the ratios, a : b is a ratio and c : d is another ratio. Both ratios are equal. Then

$$a : b :: c : d \text{ or } \frac{a}{b} = \frac{c}{d}$$

Example

$$250 : 2000 :: 1 : 8$$

**Proportion fundamentals**

If  $\frac{a}{b} = \frac{c}{d}$  then

- $ad = bc$

- $\frac{a}{c} = \frac{b}{d}$

- $\frac{b}{a} = \frac{d}{c}$

- $\frac{a+b}{b} = \frac{c+d}{c}$  and  $\frac{a+b}{a} = \frac{c+d}{d}$

- $\frac{a-b}{b} = \frac{c-d}{d}$

- $\frac{a+b}{b+d} = \frac{a}{c} = \frac{c}{d}$

$$3:4::6:8 \text{ or } \frac{3}{4} = \frac{6}{8}$$

- $3 \times 8 = 6 \times 4$

- $\frac{3}{6} = \frac{4}{8}$

- $\frac{4}{3} = \frac{8}{6}$

- $\frac{3+4}{4} = \frac{6+8}{8}$

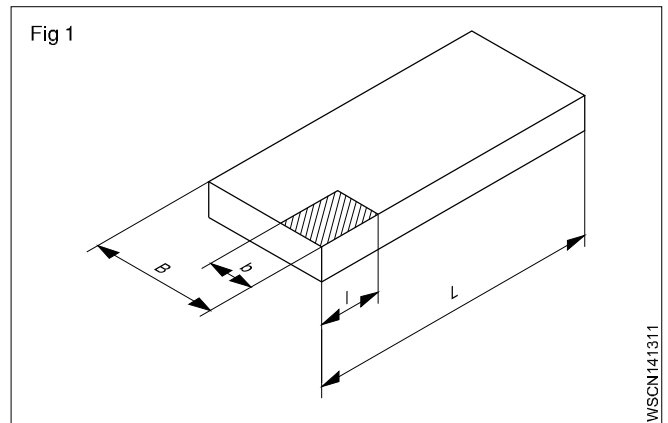
- $\frac{3-4}{4} = \frac{6-8}{8}$

- $\frac{3+6}{4+8} = \frac{3}{8}$

**Ratio - relation of two quantities of the same kind.**  
**Proportion - equality between two ratios.**

**Example**

- A steel plate of 800 x 1400 mm is to be drawn to a scale of 1:20. What will be the lengths in the Fig 1

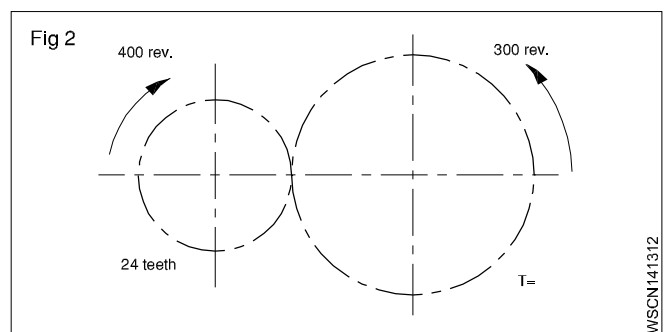


The reduction ratio is  $\frac{1}{20}$ .

B is reduced from 800 to  $800 \times \frac{1}{20} = 40$  mm.

L is reduced from 1400 to  $1400 \times \frac{1}{20} = 70$  mm.

- Find the number of teeth of the larger gear in the gear transmission shown in the Fig 2.



Speed ratio = 400 : 300

Teeth ratio = 24:T

$$\frac{400}{300} = \frac{T}{24}$$

$$\therefore T = \frac{24 \times 400}{300} = 32 \text{ Teeth}$$

Find the ratio of A:B:C

If A:B= 2:3 and B:C=4:5

$$A:B = 2:3$$

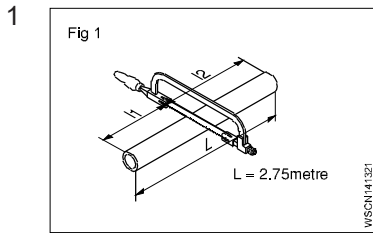
$$B:C = 4:5$$

$$A:B = 8 : 12 \text{ (Ratio 2:3 multiply by 4)}$$

$$B:C = 12:15 \text{ (Ratio 4:5 multiply by 3)}$$

$$\therefore A:B:C = 8:12:15$$

## ASSIGNMENT

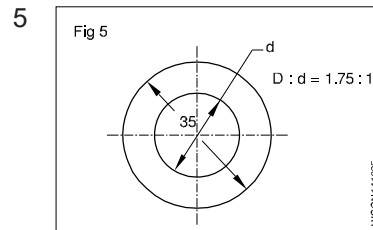


$$l_1 : l_2 = 2:3$$

$$L = 2.75 \text{ metres}$$

$$l_1 = \text{_____ metres}$$

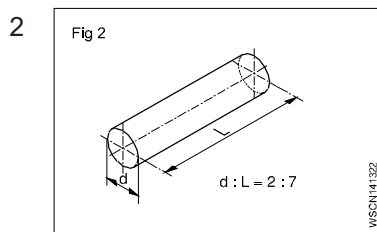
$$l_2 = \text{_____ metres}$$



$$D : d = 1.75 : 1$$

$$D = 35 \text{ mm}$$

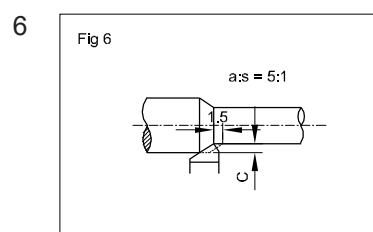
$$d = \text{_____ mm}$$



$$d : L \text{ of shaft} = 2:7$$

$$d = 40 \text{ mm}$$

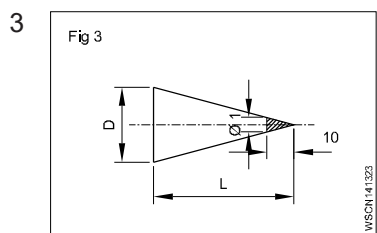
$$L = \text{_____ mm}$$



$$a : s = 5 : 1$$

$$s = 1.5 \text{ mm}$$

$$a = \text{_____ mm}$$



$$D : L = 1:10$$

$$L = 150 \text{ mm}$$

$$D = \text{_____ mm}$$

7 A:B=9:12

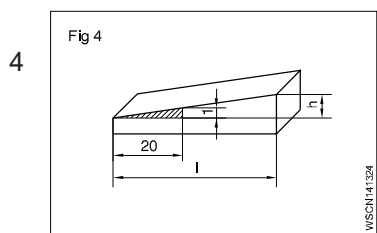
$$B:C=8:10$$

$$\text{Then } A:B:C = \text{_____}$$

8 A:B=5:6

$$B:C=3:4$$

$$\text{Then } A:B:C = \text{_____}$$



$$\frac{\Delta h}{l} = \frac{1}{20}$$

$$l = 140 \text{ mm}$$

$$\Delta h = \text{_____ mm}$$

9 A:55=9:11

$$A = \text{_____}$$

10 15:9.3=40:x

$$x = \text{_____}$$

**Proportion**

**Description**

It is the equality between the ratios, a:b is a ratio and c:d is another ratio. Both ratios are equal. Then

$$a : b :: c : d \quad \text{e.g. } 250 : 2000 :: 1 : 8$$

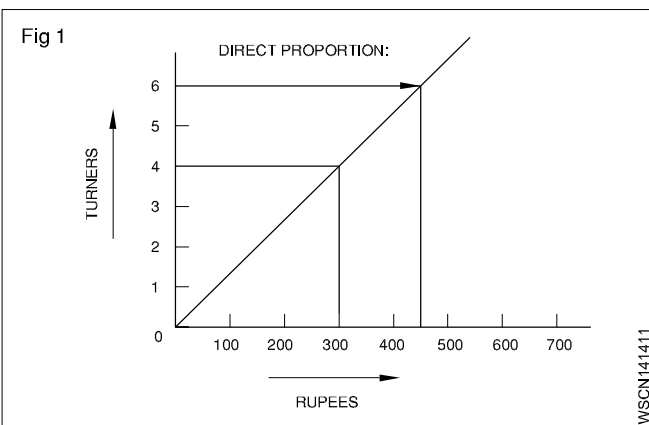
**Rule of three**

A three step calculation

- statement
- single
- multiple.

**Direct proportion**

The more in one the more in the other - An increase in one denomination produces an increase in the other. (Fig 1)



**Example**

4 turners earn 300 Rupees. How much will 6 Turners earn?

Statement

4 turners = 300 Rupees

Single

1 Turner = 75 Rupees

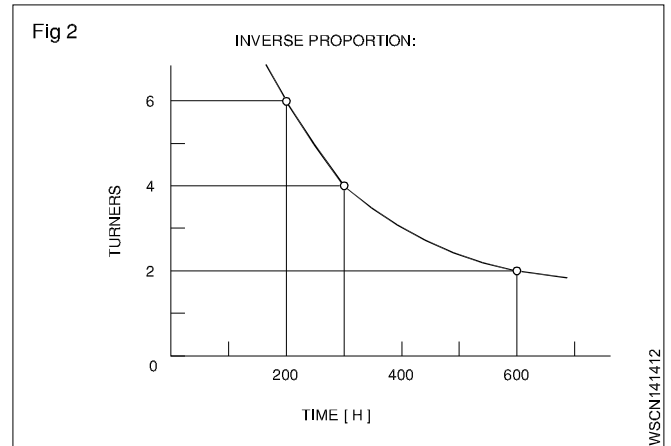
Multiple

6 Turners = 6 x 75 = 450 Rupees

Result - The more the more.

**Indirect or inverse proportion**

The more in one the lesser other - Increase in one quantity will produce a decrease in the other. (Fig 2)



**Example**

Four turners finish a job in 300 hours. How much time will 6 turners take to do the same job?

Solution procedure in three steps:

Statement

4 turners taken = 300 hours

The time will reduce if 6 turners to do the same job. Therefore this is inverse proportion.

$$\text{Multiple fraction } \frac{4 \text{ Turners}}{6 \text{ Turners}} \times 300 \text{ hours}$$

$$6 \text{ Turners} = 200 \text{ hours}$$

Result - The more the less.

**Problems involving both**

**Example**

Two turners need three days to produce 20 pieces. How long does it take for six turners to produce 30 such pieces?

Statement

2 turners, 20 piece = 3 days

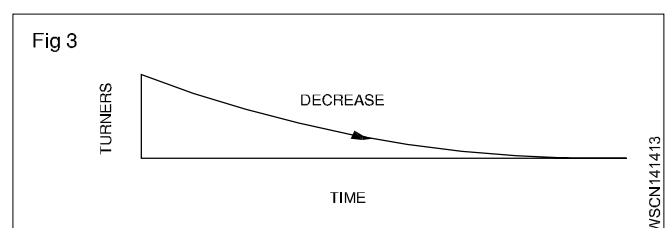
6 turners, 30 pieces = how many days.

First step (Fig 3)

Statement 2 turners for 20 pieces = 3 days

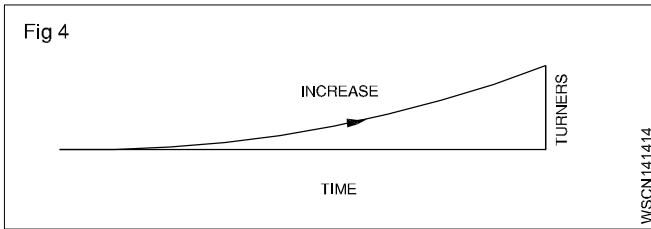
1 turners for 20 pieces = 3 x 2 = 6 days

$$\text{Multiple 6 turners for 20 pieces} = \frac{6}{6} = 1 \text{ day}$$



### Inverse proportion - The more the less.

Second step (Fig 4)



Statement 6 turners for 20 pieces = 1 day

Single 6 turners for 1 piece = days

Multiple 6 turners for 30 pieces =  $\frac{1}{20} \times 30 = 1.5$  days

### Direct proportion - The more the more.

**Solve the problem by first writing the statement and proceed to single and then to the multiple according to the type of proportion that is involved.**

#### Introduction

Proportional fundamentals, as applicable to motor vehicle calculations are discussed below.

#### Simple Proportion

- Proportion

This is an equality between two ratios

#### Examples

- If one vehicle fleet uses 30 litres of petrol per day how much petrol is used by 6. Vehicles operating under similar condition.

One vehicle uses petrol = 30 litres per day.

Then six vehicles will use = 6 Times as much

$$= 6 \times 30 = 180 \text{ litres/day.}$$

- If 4 vehicles of a fleet use 120 gallons of petrol per day how much petrol will be used by 12 vehicles operating under the same condition.

4 vehicles use 120 gallons per day

$$1 \text{ Vehicle will use } \frac{120}{4} = 30 \text{ gallons/day}$$

∴ 12 vehicles will use

**Both examples are called simple proportion because only two quantities were used and the day is common for both ratios.**

### Compound and Inverse proportions

- Compound proportions

#### Example

If 5 Fitter take 21 days to complete overhauling of 6 vehicles how long 7 Fitters will take to over haul 8 vehicles (Assume time of overhauling each vehicle is constant)

In this both direct and indirect proportions are used.

- 1 Fitter will over haul 1 vehicle in days (shorter time).
- Quantities (No. of days) are taken in last as that is the answer required in this case.

Ans: 7 Fitters will overhaul 8 vehicles in 20 days.

#### Inverse proportion

Some times proportions are taken inversely.

#### Examples

- If one water pump fills the fuel tank in 12 minutes, two pumps will take half the time taken.

**The time should not be doubled.**

- If two pumps take 30 minutes to fill up a tank how long will 6 similar pumps take this to fill this tank.

$$\text{Ans: Time taken by 6 pumps} = \frac{30 \times 2}{6} = 10 \text{ minutes}$$

#### Proportional parts in combustion equation

##### Introduction

Proportion of quantities form an important factor in the combustion process of a fuel. The following happens during the combustion process.

Fuel is a hydro carbon substance. The combustion air is supplied from atmosphere and contains oxygen and nitrogen. Now the following chemical changes take place during combustion of a fuel.

- Carbon burns with oxygen and forms Co and Co<sub>2</sub> (Carbon monoxide and there carbon dioxide.)
- Hydrogen burns with oxygen and becomes water (H<sub>2</sub>O)
- Sulphur burns with oxygen and becomes sulphur dioxide.
- Nitrogen is an inert gas and does not take part in combustion.

#### Method of finding proportional parts in one lb of a substance

To be found out now

- Proportion of oxygen and hydrogen in one lb/Kg of water.

- Proportion of hydrogen and carbon in one lb/kg of fuel.

### Examples

- The chemical formula for water is  $H_2O$ . This means 2 atoms of hydrogen and one atom of oxygen combined to make one molecule of water. If oxygen atom weighs 16 times as much as hydrogen find out the proportions in one kg of water.

### Solution

Parts by weight of water are as below

$$\text{Oxygen} = 16/2 = 8\text{kg}$$

$$\text{Hydrogen} = 1/1 = 1\text{kg}$$

$$\text{Total} = 8+1= 9\text{kg}$$

- A hydrocarbon fuel has formula  $C_6H_{14}$ . This shows one molecule of fuel contain 6 atoms of carbon and 14 atoms of hydrogen. If the carbon atom weighs 12 times as the hydrogen atom, find the proportionate parts of hydrogen and carbon in one kg of fuel.

### Solution

Parts of carbon by weight

$$= 6 \times 12 = 72$$

Parts of hydrogen by weight = 14.

$$\text{Total No. of parts} = 72 + 14 = 86.$$

$$\text{Weight of Carbon} = 72/86 = 0.8372 \text{ kg}$$

$$\text{Weight of Hydrogen} = 14/86 = 0.1628 \text{ kg}$$

### Ratio and Proportion

Proportion of air quantity required for combustion process

Mass of air required for complete combustion of fuel depends on the following factors and is called Air - fuel Ratio

- Carbon, Hydrogen, Sulphur are to burn with oxygen in the combustion process.

- It has been found that the following quantities of air (by wt) are required for this purpose to supply sufficient quantity of oxygen.

- For complete combustion of 1kg of carbon =  $2\frac{2}{3}$  Kgs of oxygen

- For complete combustion of 1 kg of hydrogen = 8kgs of oxygen

- For complete combustion of 1 kg of sulphur = 1 kg of oxygen

- Formula for calculation of mass of air for complete combustion.

Air contains 23% oxygen and 77% nitrogen

Mass of air = Mass of oxygen x for each constituent

$$\text{For Carbon} = 2\frac{2}{3} \times \frac{100}{23} = 11.6\text{kg.of air}$$

$$\text{For hydrogen} = 8 \times \frac{100}{23} = 34.8\text{kg.of air}$$

$$\text{For sulphur} = 1 \times \frac{100}{23} = 4.35 \text{ kg.of air}$$

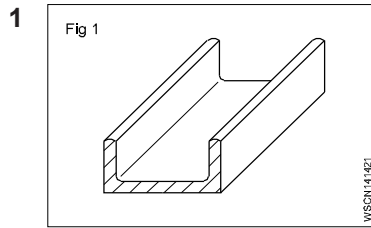
**Total** 50.75 Kg

Hence 50.75 kg of air is to be supplied to the engine for combustion of 1 kg of fuel.

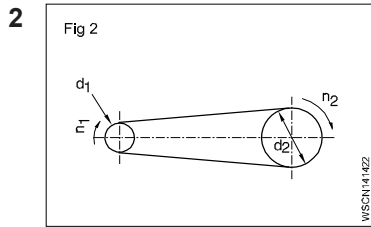
**As the combustion process is not even more quantity of air than 50.7 kg is to be supplied to the engine.**

**The calculations involved in the combustion equations is beyond the scope of ITI students as it involves chemistry and physics for computing the proportions of different elements.**

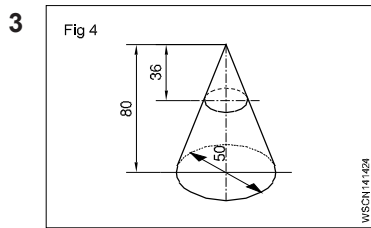
# ASSIGNMENT



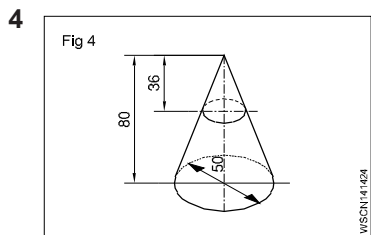
**Length = 6.1 metre**  
**Weight = 32 kgf**  
**Weight of 1 metre of the same rod = \_\_\_\_\_ kgf**



**$d_1 = 120 \text{ mm}$**   
 **$d_2 = 720 \text{ mm}$**   
 **$n_1 = 1200 \text{ rpm}$**   
 **$n_2 = \text{_____ rpm}$**



**$Z_1 = 42 \text{ T}$**   
 **$n_2 = 96 \text{ rpm}$**   
 **$n_1 = 224 \text{ rpm}$**   
 **$Z_2 = \text{_____ T}$**



**$D = 50 \text{ mm}$**   
 **$H = 80 \text{ mm}$**   
 **$h = 36 \text{ mm}$**   
 **$d = \text{_____ mm}$**

- 5 If a mechanic assembles 8 machines in 3 days. How long he will take to assemble 60 machines.
- 6 In an autoshop the grinding wheel makes 1000 rpm and the driven pulley is 200 mm dia. If the driving pulley is 150 mm dia. Find out the rpm of the driving pulley.
- 7 In a gearing of a vehicle the following facts are found.  
 A 180 mm dia of gear meshes with 60mm dia gear. If the bigger gear makes 60 rpm. What will be the rpm of smaller gear.
- 8 A vehicular job is completed by 5 mechanics in 4 days. If only 3 mechanics are available, in how many days the work can be completed.

- 9 In a gearing arrangement of a vehicle a gear having 26 teeth is meshing with a gear of 52 teeth. The dia of 52 teeth gear is 200mm. Find out the diameter of 26 teeth gear wheel.
- 10 If two water pumps take 45 minutes to fill up a tank how long will 4 similar pumps will take to this tank.
- 11 In a belt-pulley drive the driving pulley is of 12 cm diameter and rotates at 360 rpm. Find the rpm of driven pulley whose dia meter is 20 cm diameter.
- 12 To overhaul a gear box, 12 mechanics are needed to complete the work in 5 days. If only 7 mechanics are available, how many days they will be able to complete the overhauling work.

13 Express in simple ratios the following

- a  $45 \div 60$                       b  $40 \text{ paise} \div \text{Rs}4.00$
- c  $\frac{20\text{mm}}{4 \text{ metres}}$                       d  $4^\circ\text{C} \div 100^\circ\text{C}$

14 Air contains 24% oxygen and 78% nitrogen by mass (weight). Calculate the quantity of air (mass of air) required for complete combustion of unit mass fuel (The main constituents that take part in combustion process are carbon, hydrogen and sulphur)

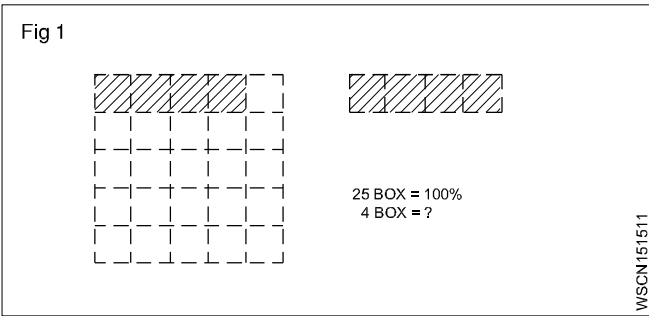
Note: Given the following data (Solve the problem)

- a 1 kg of carbon requires \_\_\_\_\_ kg of oxygen.
- b 1 kg of hydrogen requires 8 kg of oxygen.
- c 1 kg of sulphur requires 1 kg of oxygen.
- 15 A fuel is a hydro carbon substance of  $\text{C}_7\text{H}_{14}$ . This shows each molecule of fuel contains 7 atoms of carbon and 14 atoms of hydrogen. If carbon atomic weight is 12 times greater than hydrogen atom, find out the proportionate parts of hydrogen and carbon in one kg of fuel.
- 16 A vehicle worth Rs.20,000/- can be insured at a cost of Rs.150/-. How much wired it cost to insure a vehicle worth Rs.24000/- for one year and 3 month at the same rate. (Compound proportion)



Percentage

Percentage is a kind of fraction whose denominator is always 100. The symbol for percent is %, written after the number 16%.



Ex.  $\frac{16}{100} = 0.16$

In decimal form, it is 0.16. Percentage calculation also involves rule of three. The statement (the given data), for unit, and then to multiple which is for calculating the answer.

Example

The amount of total raw sheet metal to make a door was 3.6 metre<sup>2</sup> and wastage was 0.18 metre<sup>2</sup>. Calculate the % of wastage.

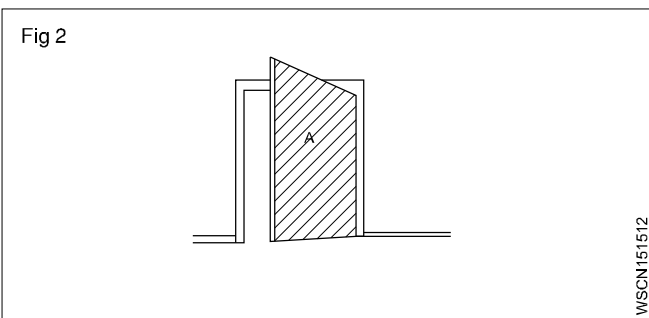
Solution procedure in three steps.

Statement:

Area of door (A) = 3.6 m<sup>2</sup> = 100 %.

Wastage = 0.18 m<sup>2</sup>

Single:  $\frac{100}{3.6} 1 \text{ m}^2$



Multiple: for 0.18 m<sup>2</sup> =  $\frac{100}{3.6} \times 0.18$ .

Wastage = 5%.

Conclusion

The three steps involved are,

- step one : describe the situation (availability)
- step two : decide for unit
- step three : proceed for the multiple.

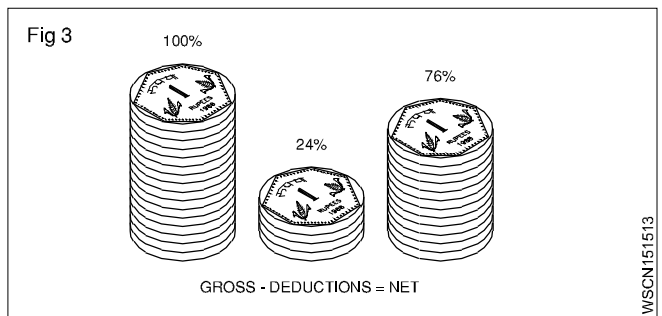
Analyse the given data and proceed to arrive at the answer through the unit.

Example

A fitter receives a take-home salary of 984.50 rupees.

If the deduction amounts to 24%, what is his total salary? (Fig 3)

Total pay 100%



Deduction 24%

Take home salary 76%

If the take home pay is Rs.76, his salary is 100.

For 1% it is  $\frac{1}{76}$

For Rs.984.50, it is  $\frac{1}{76} \times 984.50$ .

For 100% it is  $\frac{984.50}{76} \times 100 = 1295.39$

100% i.e. gross pay = Rs.1295.40.

Example 1

75 litres of oil is taken out from a oil barrel of 200 litres capacity. Find out the percentage taken in this.

Solution

% of oil taken = Oil taken out (litres) / Capacity of Barrel (litres) x 100

=  $\frac{75}{200} \times 100 = 37\frac{1}{2}\%$

Example 2

A spare part is sold with 15% Profit to a customer, to a price of Rs.15000/-. Find out the following (a) What is the purchase price (b) What is the profit.

Solution: CP = x ,

CP = cost price

SP = sale price

SP=CP+15%of CP

$15000 = x + \frac{15x}{100} = \frac{100x + 15x}{100}$

$$x = \frac{1500000}{115} = 13043.47$$

$$\text{Profit} = \text{SP} - \text{CP} = 15000 - 13043.47 = 1956.53$$

$$\text{Purchase price} = \text{Rs. } 13,043 / \text{Profit} = \text{Rs. } 1957$$

### Example 3

Out of 80000 cars, which were tested on road, only 16000 cars had no fault. What is the percentage in this acceptance.

$$= \frac{16000}{80000} \times 100 = \frac{100}{5} = 20\%$$

### Example 4

The price of a motor cycle dropped to 92% of original price and now sold at Rs. 18000/- What was the original price.

Solution

Present price of Motor cycle Rs. 18000

This is the value of 92% of original price

$$\text{Original Price} = 18000 \times \frac{100}{92} = \frac{1800000}{92}$$

$$= \text{Rs. } 19565$$

### Example 5

A Motor vehicle uses 100 litres of Petrol per day when travelling at 30 kmph. After top overhauling the consumption falls to 90 litres per day. Calculate percentage of saving.

Solution

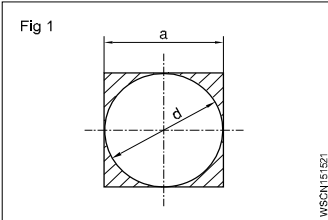
Percentage of saving = Decrease in consumption / Original consumption x 100

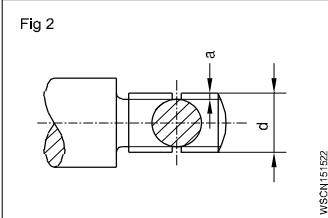
$$= (100 - 90) \frac{\text{litres}}{100} \times 100$$

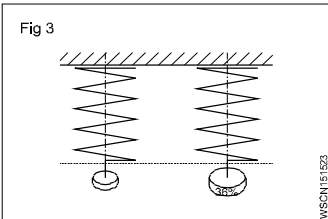
$$= \frac{10}{100} \times 100$$

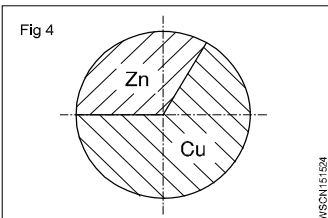
$$= 10\% \text{ Saving in fuel.}$$

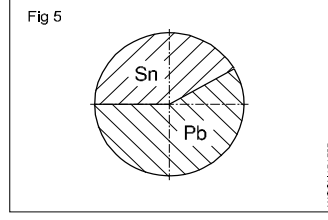
## ASSIGNMENT

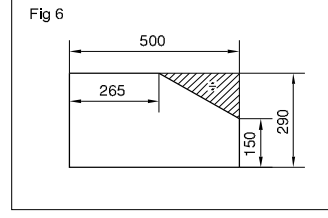
1   $a = 400\text{mm}$  (side of square)  
 $d = 400\text{ mm}$   
 Wastage = \_\_\_\_\_ %.

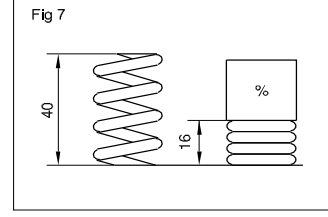
2   $d = 26\text{mm}$   
 'a' depth of u/cut = 2.4mm  
 reduction of area at cross-section = \_\_\_\_\_ %

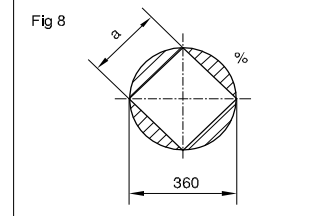
3  Percentage of increase = 36%  
 Value of increase = 611.2 N/mm<sup>2</sup>  
 Original tensile strength = \_\_\_\_\_ N/mm<sup>2</sup>.

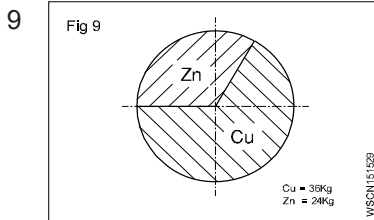
4  Copper in alloy = 27 kg  
 Zinc in alloy = 18 kg  
 % of Copper = \_\_\_\_\_ %  
 % of Zinc = \_\_\_\_\_ %.

5  Weight of alloy = 140 Kgf  
 Weight of Sn 40%  
 Pb = \_\_\_\_\_ Kgf  
 Sn = \_\_\_\_\_ Kgf.

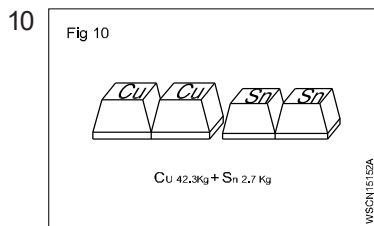
6  Shaded portion = \_\_\_\_\_ %.

7  Compression length = \_\_\_\_\_ %.

8   $d = 360\text{ mm}$   
 $a = 0.707 \times d$   
 Wastage = \_\_\_\_\_ %.



Cu = 36 Kg  
 Zn = 24 Kg  
 Cu = \_\_\_\_\_ %  
 Zn = \_\_\_\_\_ %



Cu = 42.3 Kg  
 Sn = 2.7 Kg  
 Cu \_\_\_\_\_ %  
 Sn = \_\_\_\_\_ %.

- 11 What is the selling price, If a trader buys a spare part for Rs.195/- This is 65% of selling price.
- 12 What is the purchase price if 25% profit is added to it, If a Motor cycle tyre is sold for Rs.300/-.
- 13 How many m<sup>3</sup> of elements of air present in 120 m<sup>3</sup> of air, If the composition of Air is 23% of Oxygen and 77% of Nitrogen.
- 14 How many kg of each of these elements are found. If an Engine bearing made of alloy of 40 kg consists of the following constituents.
- Copper (Cu) - 86%
  - Tin (Sn) - 10%
  - Zinc (Zn) - 4%
- 15 How much weight of these elements are found to exist. If a solder consists of 35% Tin and 65% Lead. In a solder of 40 kg.
- 16 Find out the following:
- Average consumption per journey.

- Average consumption per mile.
  - Using the average consumption express maximum consumption as a percentage of the average correct to two decimal places. If the total petrol consumption of car on 4 different journeys each of 200 miles are found to be as 6.65, 7.5, 6.85, 7.05 gallons respectively.
- 17 In a Transport workshop, the following expenditure was found to be occurring on the capital income.
- 40% income spent on tyres
  - 30% income spent on fuel and lubricants
  - 10% income spent on spare parts
- If the month end saving comes to Rs.2000/- what is the total income?
- 18 What is the final weight of the machined job if a casting weighs 80kg. During preliminary machining weight is reduced by 4% and final machining by 5%.
- 19 What is the weight of zinc, copper and tin, casting weight is 25kg. If a casting has 35% zinc, 40% copper and 25% tin.
- 20 What is the total weight of a solder, if solder consists of 35% tin 65% lead, and tin consists 14 grams.
- 21 What is the total annual income of the salesman, if a salesman gets a monthly pay of Rs.1000 and a commission of 2.5% on his sale. In one year sale amount is Rs.60,000.
- 22 What is the total income of a man, if he spends 15% of his income on agriculture, 21% on family, 24% on education of children and he saves Rs.360.
- 23 What is the percentage of his savings, if a person's monthly salary is Rs.450 and saves Rs.90 every months.

**Conversion of Fraction into Percentage**

1 Convert  $\frac{1}{2}$  into percentage.

$$\begin{aligned} \text{Solution: } \frac{1}{2} \times 100 \\ = 50\% \end{aligned}$$

2 Convert  $\frac{1}{11}$  into percentage

$$\begin{aligned} \text{Solution: } \frac{1}{11} \times 100 = \frac{100}{11} \\ = 9.01\% \end{aligned}$$

Convert the following fraction into percentage.

1  $\frac{1}{4}$

2  $\frac{1}{5}$

3  $\frac{2}{3}$

4  $\frac{3}{8}$

**Conversion of Percentage into Fraction**

1 Convert 24% into fraction.

$$\text{Solution: } \frac{24}{100} = \frac{6}{25}$$

2 Convert  $33\frac{1}{3}\%$  into fraction.

$$\begin{aligned} \text{Solution: } \frac{33\frac{1}{3}}{100} &= \frac{\frac{100}{3}}{100} = \frac{100}{3} \times \frac{1}{100} \\ &= \frac{1}{3} \end{aligned}$$

Convert the following percentage into fraction

1 15%

2  $87\frac{1}{2}\%$

3 80%

4 125%

**Conversion of Decimal Fraction into Percentage**

1 Convert 0.35 into percentage.

$$\begin{aligned} \text{Solution: } 0.35 \times 100 \\ = 35\% \end{aligned}$$

2 Convert 0.375 into percentage.

$$\begin{aligned} \text{Solution: } 0.375 \times 100 \\ = 37.5\% \end{aligned}$$

Convert the following Decimal Fraction into Percentage

1 0.2

2 0.004

3 0.875

4 0.052

**Conversion of Percentage into Decimal fraction**

1 Convert 30% into decimal fraction.

$$\text{Solution: } \frac{30}{100} = 0.3$$

2 Convert  $33\frac{1}{3}\%$  into decimal fraction.

$$\begin{aligned} \text{Solution: } \frac{33\frac{1}{3}}{100} &= \frac{\frac{100}{3}}{100} = \frac{100}{3} \times \frac{1}{100} \\ &= \frac{1}{3} = 0.333 \end{aligned}$$

Convert the following percentage into decimal fraction

1 15%

2 7%

3  $12\frac{1}{2}\%$

4 90%

**Introduction**

Algebra is a form of mathematics in which letters may be used in place of unknown. In this mathematics numbers are also used in addition to the letters and the value of number depends upon its place. For example in  $3x$  and  $x^3$ , the place of  $x$  is different. In  $3x=3$  is multiplied with  $x$ , whereas in  $x^3 - 3$  is an Index of  $x$ .

**Positive and negative numbers**

Positive numbers have + sign in front of them, and negative numbers have – sign in front of them. The same applies to letters also.

*Example*  $+x - y$

+8 or simply 8 positive number.

–8 negative number.

**Addition and subtraction**

Two positive numbers are added, by adding their absolute magnitude and prefix the plus sign.

To add two negative numbers, add their absolute magnitude and prefix the minus sign.

To add a positive and a negative number, obtain the difference of their absolute magnitudes and prefix the sign of the number having the greater magnitude.

$$+7 + 22 = +29$$

$$-8 - 34 = -42$$

$$-27 + 19 = -8$$

$$44 + (-18) = +26$$

$$37 + (-52) = -15$$

**Multiplication of positive and negative numbers**

The product of two numbers having like signs is positive and the product of two numbers with unlike signs is negative. Note that, where both the numbers are negative, their product is positive.

$$\text{Ex. } -20 \times -3 = 60$$

$$5 \times 8 = 40$$

$$4 \times -13 = -52$$

$$-5 \times 12 = -60$$

**Division**

The number that is divided is the dividend, the number by which we are dividing is the divisor and the answer is the quotient. If the signs of the dividend and the divisor are the same then the quotient will have a + sign. If they are unlike then the quotient will have a negative sign.

$$\frac{+28}{+4} = +7$$

$$\frac{+56}{-4} = -14$$

$$\frac{-72}{+9} = -8$$

$$\frac{-96}{-6} = +16$$

**When an expression contains addition, subtraction, multiplication and division, perform the multiplication and division operations first and then do the addition and subtraction.**

*Example*

$$12 \times 8 - 6 + 4 \times 12 = 96 - 6 + 48 = 138$$

$$102 \div 6 - 6 \times 2 + 3 = 17 - 12 + 3 = 8$$

**Parantheses and grouping symbols**

( ) Brackets

{ } Braces

$$7 + (6-2) = 7 + 4 = 11$$

$$6 \times (8-5) = 6 \times 3 = 18$$

**Parentheses**

These are symbols that indicate that certain addition and subtraction operations should precede multiplication and division. They indicate that the operations within them should be carried out completely before the remaining operations are performed. After completing the grouping, the symbols may be removed.

In an expression where grouping symbols immediately preceded or followed by a number but with the signs of operation omitted, it is understood, that multiplication should be performed.

Grouping symbols are used when subtraction and multiplication of negative numbers is done.

To remove grouping symbols which are preceded by negative signs, the signs of all terms inside the grouping symbols must be changed (from plus to minus and minus to plus).

Parentheses which are preceded by a plus sign may be removed without changing the signs of the terms within the parentheses.

When one set of grouping symbols is included within another set, remove the innermost set first.

When several terms connected by + or – signs contain a common quantity, this common quantity may be placed in front of a parentheses.

$$8 + 6(4-1) = 8 + 6 \times 3 = 26$$

$$(6+2)(9-5) = 8 \times 4 = 32$$

Plus 4 less negative 7 is written as  $4 - (-7)$ .

Plus 4 times negative 7 is written as  $4(-7)$ .

$$4 - (-7) = 4 + 7 = 11$$

$$8 - (7-4) = 8 - 3 = 5$$

$$3 + (-8) = 3 - 8 = -5$$

$$7 + (4 - 19) = 7 + (-15) = 7 - 15 = -8$$

$$3\{40 + (7 + 5)(8-2)\} = 3\{40 + 12 \times 6\} = 3 \times 112 = 336.$$

$8x + 12$  - quantity 4 may be factored out giving the expression  $8x + 12$  as  $4(2x + 3)$ .

The innermost set in a grouping symbols of an expression is to be simplified first.

## Algebraic symbols and simple equations

### Algebraic symbol

An unknown numerical value of a quantity is represented by a letter which is the algebraic symbol.

### Factor

A factor is any one of the numbers or letters or groups which when multiplied together give the expression. Factors of 12 are 4 and 3 or 6 and 2 or 12 and 1.

$8x + 12$  is the expression and this may be written as  $4(2x + 3)$ , 4 and  $(2x + 3)$  are the factors.

### Algebraic terms

If an expression contains two or more parts separated by either + or -, each part is known as the term.

$y - 5x$  is the expression.  $y$  and  $-5x$  are the terms.

The sign must precede the term.

### Coefficient

When an expression is formed into factors whose product is the expression, then each factor is the coefficient of the remaining factors.

$$48x = 4 \times 12 \times x$$

4 is the coefficient of  $12x$ .  $x$  is the coefficient of 48.

### Equation

It is a statement of equality between numbers or numbers and algebraic symbols.

$$12 = 6 \times 2, 13 + 5 = 18.$$

$$2x + 9 = 5, y - 7 = 4y + 5.$$

### Simple equation

Equations involving algebraic symbols to the first power are simple equations.

$$2x + 4 = 10, 4x + 12 = 14.$$

### Addition and subtraction

Quantities with algebraic symbols are added or subtracted by considering those terms involving same symbols and powers.

$$10x + 14 - 7y^2 - 11a + 2x - 4 - 3y^2 - 4a + 8$$

$$= 10x + 2x - 7y^2 - 3y^2 - 11a - 4a + 14 - 4 + 8$$

$$= 12x - 10y^2 - 15a + 18$$

$$2x = 10, 2x + 6 = 10 + 6$$

$$y + 12 = 20, y + 12 - 8 = 20 - 8$$

$$x + 10 = 12,$$

$$x + 10 - 10 = 12 - 10$$

$$3x = 6, 2 \times 3x = 2 \times 6, 6x = 12$$

$$5y = 20, \frac{5y}{5} = \frac{20}{5}$$

The same number may be added or subtracted to both members of an equation without changing its equality.

Each member of an equation may be multiplied or divided by the same number or symbol without changing its equality.

The equality of an equation is not altered when the numbers or symbols are added or subtracted from both sides. Multiplication and division by the same numbers or symbols on both sides also will not affect the equality.

### Transposition of the terms of the equations

= equals to

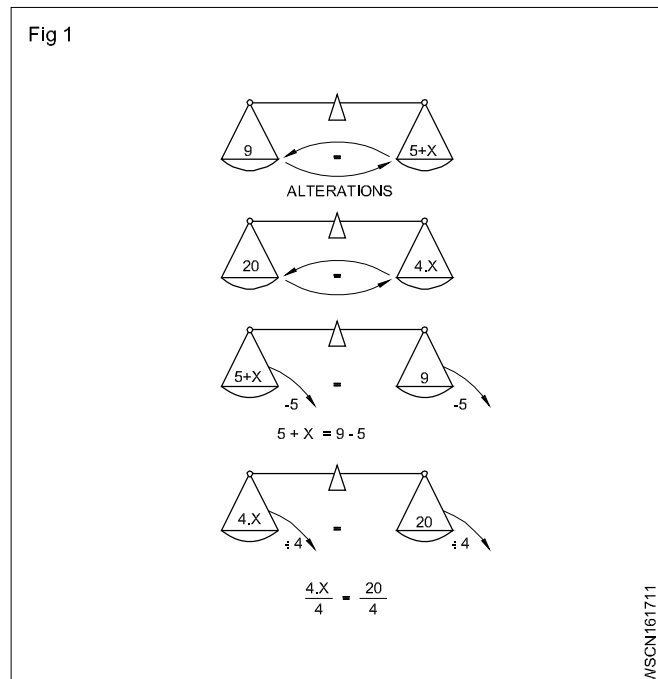
+ plus

- minus

x multiply

÷ divided by

### Concept of equality (Fig 1)



An equation can be compared to a pair of scales which always remain in equilibrium. The two sides of the equation can fully be transposed.  $9 = 5 + x$  may also be written as  $5 + x = 9$ .

We must always perform the same operation on both sides of the equation to keep the equilibrium. Add or subtract the same amount from both sides.  $5 + x = 9$  By adding 3 on both sides, the equation becomes  $5 + x + 3 = 9 + 3$  or  $x + 8 = 12$ .

$5 + x = 9$  Subtract 5 from both sides then  $5 + x - 5 = 9 - 5$ .  
 $x = 4$ .

5 is transposed from left side to the right side by changing its sign from + to -.

$\frac{x}{4} = 20$ . Multiply both sides by 4. Then  $\frac{x}{4} \times 4 = 20 \times 4$ .  
 $x = 80$ ,  
 $5x = 25$ .

Divide both sides by 5 then  $\frac{5x}{5} = \frac{25}{5}$   
 $x = 5$ .

When transposing numbers or letter symbols from one side to the other side multiplication becomes division and the division becomes multiplication.

**The equality of an equation remains unchanged when both sides of the equation are treated in the same way. When transposing from one side to the other side,**

**a plus quantity becomes minus quantity.**

**a minus quantity becomes a plus quantity**

**a multiplication becomes a division**

**a division becomes a multiplication.**

**To solve simple equations isolate the unknown quantity which is to be found on the left side of the equation.**

#### Example

- Solve for x if  $4x = 3(35 - x)$   
 $4x = 105 - 3x$  (brackets removed)  
 $4x + 3x = 105$  (By transposing  $-3x$  on the right side to the left side)  
 $7x = 105$   
 $x = 15$  (dividing both sides by 7)

## Addition, subtraction, multiplication and division of algebra Exercise 1.6.18

### Addition

#### Example 1

Add  $2x, 3x, 7x$

**Solution:** Since this is only addition, put '+' symbol & each bracket

$$= (+2x) + (+3x) + (+7x) = 12x$$

Add

$-3a, -2a, -5a$

$$= (-3a) + (-2a) + (-5a) = -10a$$

#### Example 2

Add  $10xy, -8x^2, -7xy, -7x^2$

$$= (10xy) + (-8x^2) + (-7xy) + (-7x^2)$$

$$= (10xy) + (-7xy) + (-8x^2) + (-7x^2)$$

$$= (3xy) + (-15x^2)$$

#### Example 3

Add  $\frac{a}{4}, \frac{a}{2}, -\frac{a}{8}$

$$\frac{a}{4}, \frac{a}{2}, -\frac{a}{8}$$

$$\left(\frac{a}{4}\right) + \left(\frac{a}{2}\right) + \left(-\frac{a}{8}\right)$$

$$\frac{2a + 4a - a}{8} = \frac{5a}{8}$$

### Subtraction

#### Example 1

Subtraction  $8m$  from  $2m$

**Solution :**  $(2m) - (8m)$

To be subtracted from $+8m$ after changed	$+ 2m$
the symbol	$- 8m$
after added	$- 6m$

#### Example 2

Subtraction  $(-5x + 3y)$  from  $(7x + 8y)$

**Solution:**  $(7x + 8y) - (-5x + 3y)$

$$+ 7x + 8y$$

$$+ 5x - 3y$$

$$+ 12x + 5y$$

(Multiply all the terms which should be subtracted with '-' symbol subsequently add or subtract the similar terms as stated in the steps)

### Solving of Simple Equations

Rules Related to signs in Algebra

#### 1 Multiplication Rules

(i)  $+$   $\times$   $+$   $=$   $+$

(ii)  $-$   $\times$   $-$   $=$   $+$

(iii)  $+$   $\times$   $-$   $=$   $-$

(iv)  $-$   $\times$   $+$   $=$   $-$

#### 2 Division Rules

(i)  $\frac{+}{+} = +$

(ii)  $\frac{-}{-} = +$

(iii)  $\frac{+}{-} = -$

(iv)  $\frac{-}{+} = -$

#### Examples

1)  $a + 4 = 7$

$$a = 7 - 4$$

$$a = 3$$

2)  $M - 5 = 3$

$$m = 3 + 5$$

$$m = 8$$

3)  $7P = 17$

$$P = \frac{17}{7}$$

4)  $\frac{x}{6} = 9$

$$x = 9 \times 6$$

$$x = 54$$



$$\begin{aligned}
 5) \quad 7x + 3 &= 15 + x \\
 7x - x &= 15 - 3 \\
 6x &= 12 \\
 x &= \frac{12}{6} = 2
 \end{aligned}$$

$$\begin{aligned}
 6) \quad \frac{5}{9}y &= 0 \\
 Y &= 0 \times \frac{9}{5} \\
 y &= 0
 \end{aligned}$$

$$\begin{aligned}
 7) \quad \frac{8}{5}M + 6 &= 8 \\
 \frac{8}{5}M &= 8 - 6 \\
 \frac{8}{5}M &= 2 \\
 M &= 2 \times \frac{5}{8} \\
 M &= \frac{10}{8} = \frac{5}{4}
 \end{aligned}$$

$$\begin{aligned}
 8) \quad \frac{x}{3} + \frac{x}{2} &= 30 \\
 \frac{2x + 3x}{6} &= 30 \\
 5x &= 30 \times 6 \\
 x &= \frac{30 \times 6}{5} = 36 \\
 x &= 36
 \end{aligned}$$

$$\begin{aligned}
 9) \quad \frac{x}{2} + \frac{x}{3} - \frac{5x}{12} &= \frac{x}{6} + 36 \\
 \frac{x}{2} + \frac{x}{3} - \frac{5x}{12} - \frac{x}{6} &= 36 \\
 \frac{6x + 4x - 5x - 2x}{12} &= 36 \\
 \frac{3x}{12} &= 36 \\
 x &= 36 \times \frac{12}{3} = 144
 \end{aligned}$$

$$\begin{aligned}
 10) \quad \frac{5}{8}a - \frac{a}{2} + \frac{15}{4} &= 0 \\
 \frac{5a - 4a + 30}{8} &= 0 \\
 \frac{a + 30}{8} &= 0 \\
 a + 30 &= 0 \times 8 \\
 a &= -30
 \end{aligned}$$

### Multiplication

While dealing with multiplication, first of all multiply the symbols, subsequently coefficient, afterwards letters.

#### Example 1

$$\begin{aligned}
 &\text{Multiply } (2x-5) \times (x-1) \\
 &(2x-5)(x-1) \\
 &= 2x(x-1) - 5(x-1) \\
 &= 2x^2 - 2x - 5x + 5 \\
 &= 2x^2 - 7x + 5
 \end{aligned}$$

#### Example 2

$$\begin{aligned}
 &\text{Multiply } (4x^2 + 3x - 12) \text{ by } (2x + 3) \\
 &(4x^2 + 3x - 12)(2x + 3) \\
 &= 2x(4x^2 + 3x - 12) + 3(4x^2 + 3x - 12) \\
 &= 8x^3 + 6x^2 - 24x + 12x^2 + 9x - 36 \\
 &= 8x^3 + 6x^2 + 12x^2 - 24x + 9x - 36 \\
 &= 8x^3 + 18x^2 - 15x - 36
 \end{aligned}$$

### Division

Division is nothing but reverse operation of multiplication.

#### Example 1

Division  $(x^2 + 11x + 30)$  by  $(x + 6)$

$$(x^2 + 11x + 30) \div (x + 6)$$

$$\begin{array}{r}
 \phantom{x^2 + 11x + 30} \overline{) x^2 + 11x + 30} \\
 \underline{x^2 + 6x} \phantom{0} \\
 5x + 30 \\
 \underline{5x + 30} \\
 0
 \end{array}$$

$$x^2 + 11x + 30 \div x + 6 = x + 5$$

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## Assignment

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### Addition

- 1 Add  $7y$ ,  $8y$ ,  $5y$ ,  $3y$
- 2 Add  $5x$ ,  $6x$ ,  $7y - 9y$ ,  $10x$
- 3 Add  $9a^2$ ,  $-7m$ ,  $5$ ,  $-14a^2$ ,  $15m$ ,  $-6$

4 Add  $\frac{5}{8}m$ ,  $\frac{3}{16}m$ ,  $-\frac{3}{4}m$

### Subtraction

- 1 Subtract  $7x$  from  $9x$
- 2 Subtract  $8a$  from  $3a$
- 3  $(-5 - 3b) - (3a + 5b)$
- 4 Subtract  $(5m - 6n)$  from  $(3m + 5n)$

### Multiplication

- 1 Multiply  $6a$  x  $(-2ab)$
- 2 Multiply  $3x$   $(4x - 2y + 5)$
- 3 Multiply  $(3x + 2)$   $(3x - 2)$

### Division

- 1  $25x \div 5$
- 2  $60ab \div 15a$
- 3  $14x - 7y \div 7$

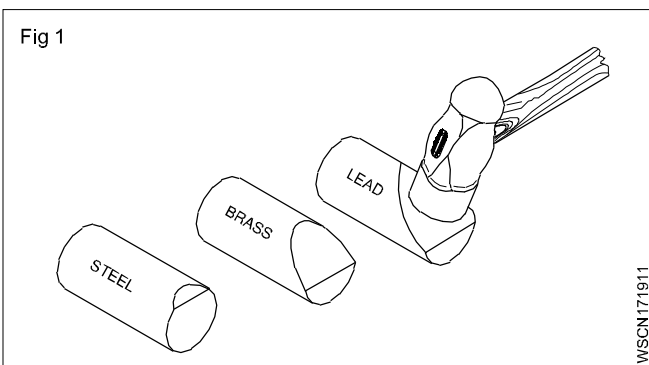
**Metal:**

Metal is a mineral used in all types of engineering works such as machineries, bridges, aero planes etc . so we must have basic knowledge about the metals.

Understanding the physical and mechanical properties of metals has become increasingly important for a machinist since he has to make various components to meet the designed service requirements against factors, such as the raise of temperature, tensile, compressive and impact loads etc. A knowledge of different properties of materials will help him to do his job successfully. If proper material/ metal is not used it may cause fracture or other forms of failures, and endanger the life of the component when it is put into function.

Fig 1 shows the way in which the metals get deformed when acted upon by the same load.

Note the difference in the amount of deformation.



**Physical properties of metals**

- Colour
- Weight/specific gravity
- Structure
- Conductivity
- Magnetic property
- Fusibility

**Colour**

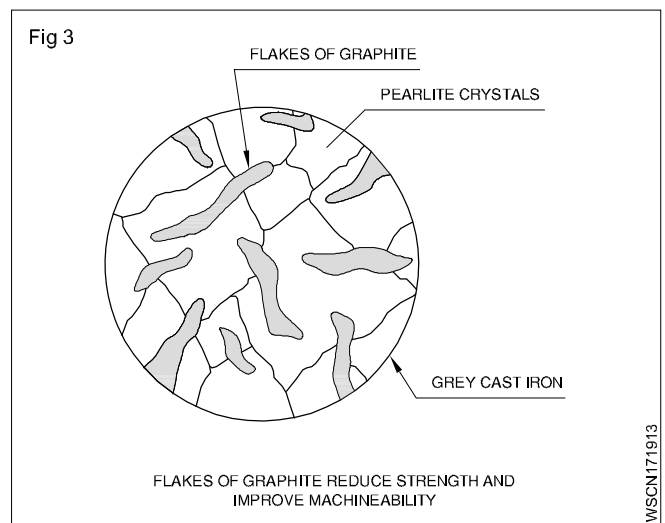
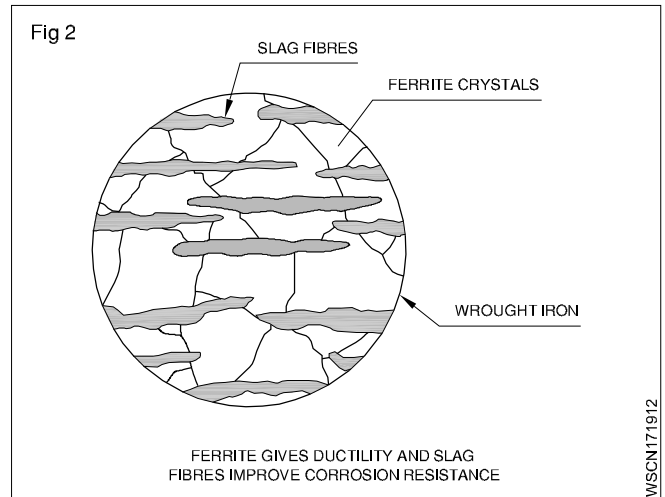
Different metals have different colours. For example, copper is distinctive red colour. Mild steel is blue/black sheen.

**Weight**

Metals may be distinguished, based on their weights for given volume. Metals like aluminium lighter weigh (Specific gravity 2.7) and metals like lead have a higher weight. (Specific gravity 11.34)

**Structure (Figs 2 and 3)**

Generally metals can also be differentiated by their internal structures while seeing the cross-section of the bar through a microscope. Metals like wrought iron and aluminium have a fibrous structure and metals like cast Iron and bronze have a granular structure.



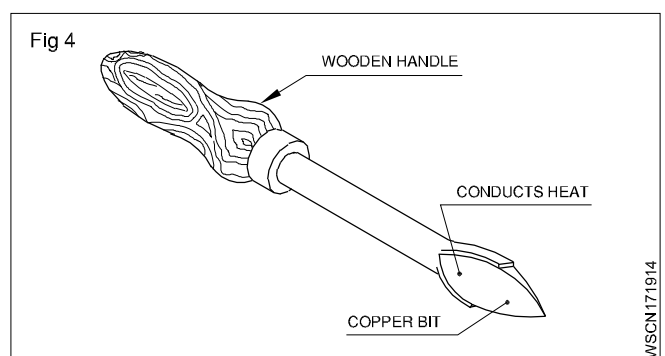
**Conductivity (Figs 4 and 5)**

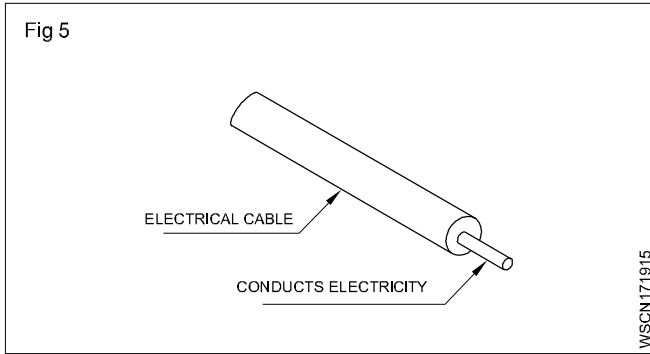
Thermal conductivity and electrical conductivity are the measures of ability of a material to conduct heat and electricity. Conductivity will vary from metal to metal. Copper and aluminium are good conductors of heat and electricity.

**Magnetic property**

A metal is said to possess a magnetic property if it is attracted by a magnet.

Almost all ferrous metals, except some types of stainless steel, can be attracted by a magnet, and all non-ferrous metals and their alloys are not attracted by a magnet.



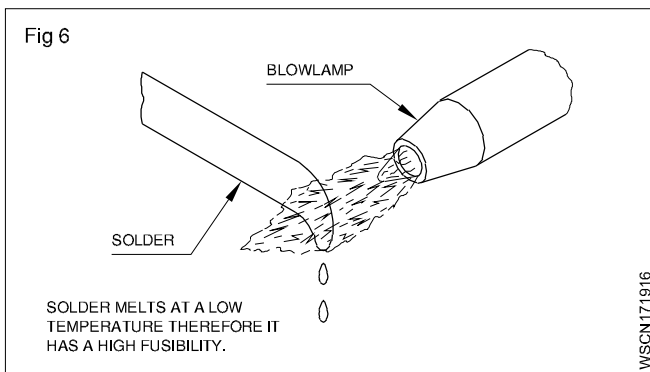


### Fusibility (Fig 6)

It is the property possessed by a metal by virtue of which it melts when heat is applied. Many materials are subject to transformation in the shape (i.e) from solid to liquid at different temperatures. Lead has a low melting temperature while steel melts at a high temperature.

Tin melts at 232°C.

Tungsten melts at 3370°C.



### Mechanical properties

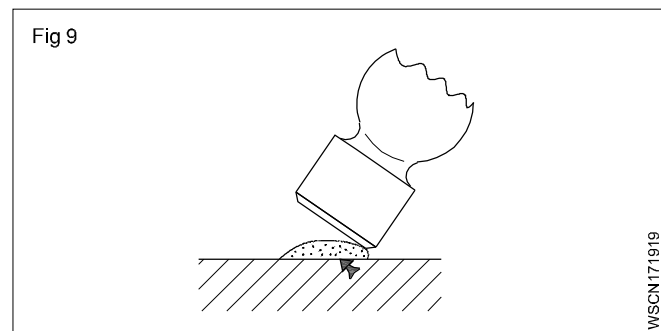
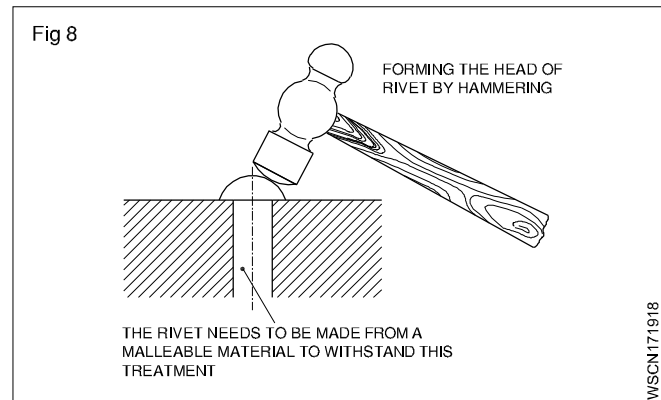
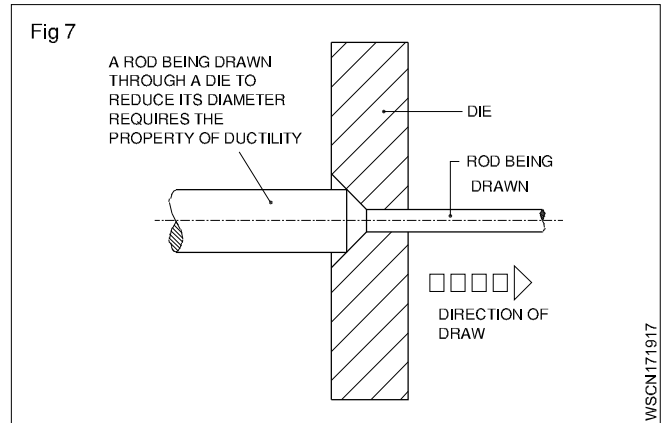
- Ductility
- Malleability
- Hardness
- Brittleness
- Toughness
- Tenacity
- Elasticity

### Ductility (Fig 7)

A metal is said to be ductile when it can be drawn out into wires under tension without rupture. Wire drawing depends upon the ductility of a metal. A ductile metal must be both strong and plastic. Copper and aluminium are good examples of ductile metals.

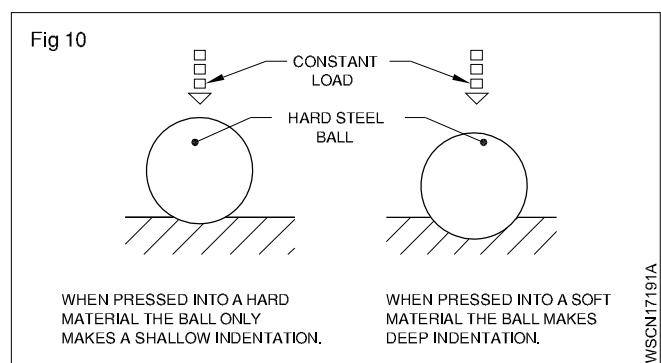
### Malleability (Figs 8 and 9)

Malleability is that property of a metal by which it can be extended in any direction by hammering, rolling etc. without causing rupture. Lead is an example of a malleable metal.



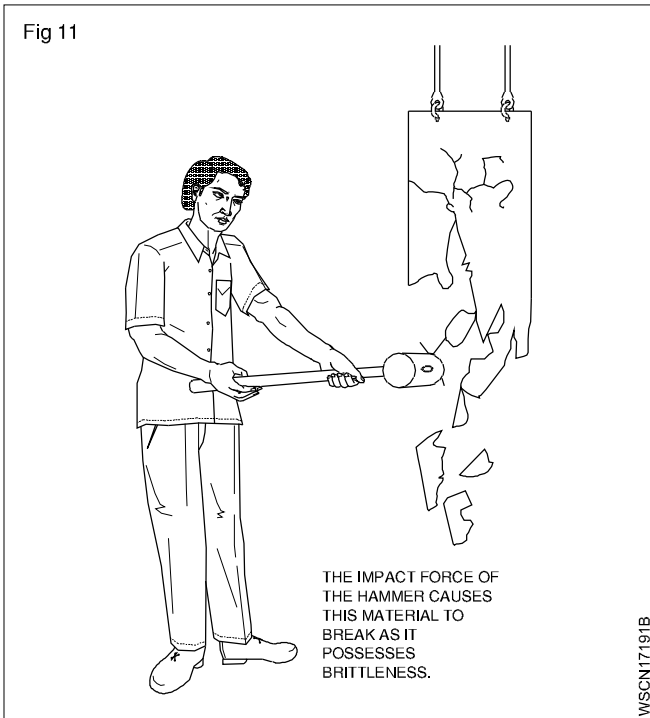
### Hardness (Fig 10)

Hardness is a measure of a metal's ability to withstand scratching, wear and abrasion, indentation by harder bodies. The hardness of a metal is tested by marking by a file etc.



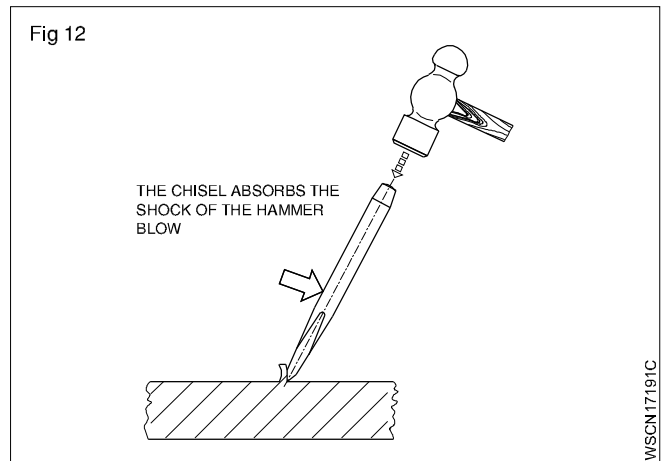
### Brittleness (Fig 11)

Brittleness is that property of a metal which permits no permanent distortion before breaking. Cast iron is an example of a brittle metal which will break rather than bend under shock or impact.



### Toughness (Fig 12)

Toughness is the property of a metal to withstand shock or impact. Toughness is the property opposite to brittleness. Wrought iron is an example of a tough metal.



### Tenacity

The tenacity of a metal is its ability to resist the effect of tensile forces without rupturing. Mild steel, Wrought Iron and copper are some examples of tenacious metals.

### Elasticity

Elasticity of a metal is its power of returning to its original shape after the applied force is released. Properly heat-treated spring is a good example for elasticity.

**Ferrous Metals**

Metals which contain iron as a major content are called ferrous metals. Ferrous metals of different properties are used for various purposes.

**Introduction of Iron, Cast Iron, wrought Iron and steel**

The ferrous metals and alloys used commonly are:

- Pig-iron
- Cast Iron
- Wrought Iron
- Steels and Alloy steels

Different processes are used to produce iron and steel.

**Pig-iron (Manufacturing process)**

Pig-iron is obtained by the chemical reduction of iron ore. This process of reduction of the iron ore to Pig-iron is known as SMELTING.

The main raw materials required for producing Pig-iron are:

- Iron ore
- Coke
- Flux

**Iron ore**

The chief iron ores used are:

- magnetite
- hematite
- limonite
- carbonite.

These ores contain iron in different proportions and are naturally available.

**Coke**

Coke is the fuel used to give the necessary heat to carry on the reducing action. The carbon from the coke in the form of carbon monoxide combines with the iron ore to reduce it to iron.

**Flux**

This is the mineral substance charged into a blast furnace to lower the melting point of the ore, and it combines with the non-metallic portion of the ore to form a molten slag.

Limestone is the most commonly used flux in the blast furnace.

**Properties and use of Pig-iron**

Pig-iron is, therefore, refined and remelted and used to produce other varieties of iron and steel.

**Cast Iron (Manufacturing process)**

The pig-iron which is tapped from the blast furnace is the crude form of raw material for the cupola, and should be further refined for making castings. This refining is carried out in the cupola furnace which is a small form of a blast furnace.

Generally cupolas are not worked continuously like blast furnaces but are run only as and when required.

**Cast Iron (Types)**

Cast iron is an alloy of iron, carbon and silicon. The carbon content ranges from 2 to 4%.

Types of cast iron

The following are the types of cast iron.

- Grey cast iron
- White cast iron
- Malleable cast iron
- Nodular cast iron

**Grey cast iron**

This is widely used for the casting of machinery parts and can be machined easily.

Machine base, tables, slideways are made of cast iron because it is dimensionally stable after a period of aging.

Because of its graphite content, cast iron provides an excellent bearing and sliding surface.

The melting point is lower than that of steel and as grey cast iron possesses good fluidity, intricate casting can be made.

Grey cast iron is widely used for machine tools because of its ability to reduce vibration and minimize tool chatter.

Grey cast iron, when not alloyed, is quite brittle and has relatively low tensile strength. Due to this reason it is not used for making components subjected to high stress or impact loads.

Grey cast iron is often alloyed with nickel, chromium, vanadium or copper to make it tough.

Grey cast iron is weldable but the base metal needs preheating.

**White cast iron**

This is very hard and is very difficult to machine, and for this reason, it is used in components which should be abrasion-resistant.

White cast iron is produced by lowering the silicon content and by rapid cooling. When cooled in this manner, it is called chilled cast iron.

White cast iron cannot be welded.

## Malleable cast iron

Malleable cast iron has increased ductility, tensile strength and toughness when compared with grey cast iron.

Malleable cast iron is produced from white cast iron by a prolonged heat-treatment process lasting for about 30 hours.

## Nodular cast iron

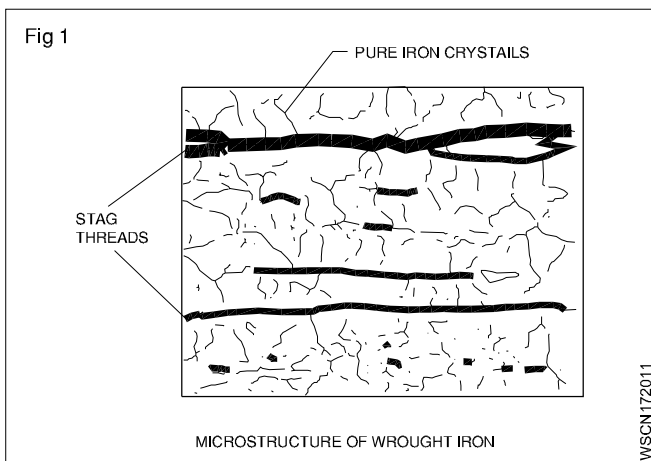
This is very similar to malleable cast iron. But this is produced without any heat treatment. Nodular cast iron is also known as: **Nodular Iron - Ductile Iron - Spheroidal Graphite Iron**

This has good machinability, castability, resistance to wear, low melting point and hardness.

Malleable and nodular castings are used for machine parts where there is a higher tensile stress and moderate impact loading. These castings are less expensive and are an alternative to steel castings.

## Wrought Iron (Manufacturing process) (Fig 1)

Wrought iron is the purest form of iron. The analysis of Wrought iron shows as much as 99.9% of iron. (Fig 1) When heated, wrought iron does not melt, but only becomes pasty and in this form it can be forged to any shape.



Modern methods used to produce wrought iron in large quantities are the

- puddling process
- aston or Byers process

## Steel

This is pure iron. Carbon content is more. Due to excessive carbon it is harder and tougher. Carbon content is from 0.15 to 1.5%. Besides there are other impurities like sulphur, phosphorous etc. Are there which cannot be separated. This is hardened and tempered by heating it to a definite temperature and cooling it in oil or water.

The following methods are adopted for making different types of steel:

- 1 Cementation process
- 2 Crucible process
- 3 Bassemer process
- 4 Open hearth process
- 5 Electro thermo process
- 6 High frequency process.

## 11.13 Main types of steel

Mainly steel is the following two types:

- 1 Plain steel
- 2 Alloy steel

**1 Plain steel.** In this carbon and iron are mixed. According to the percentage of carbon, plain steel is the following types:

- A Low carbon steel
- B Medium carbon steel
- C High carbon steel

**A Low carbon steel:** It is also called mild steel. In this, the percentage of carbon is from 0.15% to 0.25%. Due to less quantity of carbon, it is sufficiently soft and tolerates the strain. It can be put in different shapes through forging and rolling. This is not very hard or strong. This cannot be hardened or tempered by ordinary methods. Nuts, bolts, rivets, sheets, wires, T-iron and angle iron etc. are made out of it.

**B Medium carbon steel:** The carbon content is from 0.25% to 0.5%. Due to excess of carbon, it is harder and tougher than mild steel. The tenacity is more. This is used to be hardened or tempered. Various things are made by forging and rolling. This is used for making high tensile tubes, wires, agricultural implements, connecting rods, cam shafts, spanners, pulleys etc.

**C High carbon steel:** It has carbon content from 0.5% to 1.5%. It is very hard and wears least. This can be hardened by heat treatment. This can neither be cast nor rolled. This is very hard and tough. It acquires permanent magnetic properties. This is used for making pointed tools, springs, pumps, files, cutlery, cold chisels, press die etc.

## 2 Alloy Steel

When the steel is mixed with other metals like vanadium, manganese, tungsten etc. It is called an alloy steel. Alloy steel has properties of its ingredients.

### Types of Alloy Steel

**Alloy steel is mainly of two types:**

- A Low alloy steel
- B High alloy steel

**A Low Alloy steel:** Besides carbon, other metals are in lesser quantity. Its tensile strength is more. The welding can work on it. This can also be hardened and tempered. It is used in manufacturing various parts of an aeroplane and cam shaft etc.

**B High Alloy Steel:** Besides carbon, it has a high percentage of the metals higher than low alloy steel. This is the following types:

**a High Speed Steel:** It is also called high tungsten alloy steel because it has more quantity of tungsten. According to the quantity of tungsten it is classified in three types:

- 1 Tungsten 22%, Chromium 4%, Vanadium 1%
- 2 Tungsten 18%, Chromium 4%, Vanadium 1%
- 3 Tungsten 14%, Chromium 4%, Vanadium 1%

Cutting tools are made out of it because it is very hard but becomes soft at low critical temperature. This temperature is raised out of cutting process of tool, then the cutting tool becomes useless and is unfit for work. But due to high percentage of tungsten it keeps working upto high temperature. It is used for cutting tools, drilling, cutter, reamers, hacksaw blades etc.

**b Nickel Steel:** In this 0.3% carbon and 0.25 to 0.35% nickel is present. Due to nickel its tensile strength, elastic limit and hardness is increased. It does not catch rust. Its cutting resistance increases 6 times more than plain carbon and steel due to 0.35% nickel present in it. This is used for making rivets, pipes, axle shafting, parts of buses and aeroplanes. If 5% of cobalt is mixed with 30-35% nickel, it becomes invar steel. It is mainly used for making precious instruments.

**c Vanadium Steel:** It contains 1.5% carbon, 12.5% tungsten, 4.5% chromium, 5% vanadium and 5% cobalt. Its elastic limit, tensile strength and ductility is more. It has strength to bear sharp jerks. It is mainly used to manufacture of tools.

**d Manganese Steel:** It is also called special high alloy steel. It contains 1.6 to 1.9% of manganese

and 0.4 to 0.5% carbon. It is hard and less wear. It is not affected by magnet. It is used in grinders and rail points etc.

**e Stainless Steel:** Along with iron it contains 0.2 to 0.6% carbon, 12 to 18% chromium, 8% nickel and 2% molybdenum. It is used for making knives, scissors, utensils, parts of aeroplane, wires, pipes and gears etc.

**Properties of stainless steel:**

- 1 Higher corrosion resistance
- 2 Higher cryogenic toughness
- 3 Higher work hardening rate
- 4 Higher hot strength
- 5 Higher ductility
- 6 Higher strength and hardness
- 7 More attractive appearance
- 8 Lower maintenance

**f Silicon Steel:** It contains 14% of silicon. Its uses are multifarious according to the percentage of silicon. 0.5% to 1% silicon, 0.7 to 0.95% manganese mixture is used for construction work. 2.5 to 4% silicon content mixture is used for manufacturing electric motors, generators, laminations of transformers. In chemical industries 14% silicon content mixture is used.

**g Cobalt Steel:** High carbon steel contains 5 to 35% cobalt. Toughness and tenacity is high. It has magnetic property therefore used to make permanent magnets.



**Ferrous and Non ferrous alloys****Alloying metals and ferrous alloys**

An alloy is formed by mixing two or more metals together by melting.

For ferrous metals and alloys, iron is the main constituent metal. Depending on the type and percentage of the alloying metal added, the property of the alloy steel will vary.

**Metals commonly used for making alloy steels****Nickel (Ni)**

This is a hard metal and is resistant to many types of corrosion rust.

It is used in industrial applications like nickel, cadmium batteries, boiler tubes, valves of internal combustion engines, engine spark plugs etc. The melting point of nickel is 1450°C. Nickel can be magnetised. In the manufacture of permanent magnets a special nickel steel alloy is used. Nickel is also used for electroplating. Invar steel contains about 36% nickel. It is tough and corrosion resistant. Precision instruments are made of Invar steel because it has the least coefficient of expansion.

Nickel-steel alloys are available containing nickel from 2% to 50%.

**Chromium (Cr)**

Chromium, when added to steel, improves the corrosion resistance, toughness and hardenability of steel. Chromium steels are available which may contain chromium up to 30%.

Chromium, nickel, tungsten and molybdenum are alloyed for making automobile components and cutting tools.

Chromium is also used for electroplating components. Cylinder liners are chrome-plated inside so as to have wear resistance properties. Stainless steel contains about 13% chromium. Chromium-nickel steel is used for bearings. Chrome-vanadium steel is used for making hand tools like spanners and wrenches.

**Manganese (Mn)**

Addition of manganese to steel increases hardness and strength but decreases the cooling rate.

Manganese steel can be used to harden the outer surface for providing a wear resisting surface with a tough core. Manganese steel containing about 14% manganese is used for making agricultural equipment like ploughs and blades.

**Silicon (Si)**

Addition of silicon for alloying with steel improves resistance to high temperature oxidation.

This also improves elasticity, and resistance against corrosion. Silicon alloyed steels are used in manufacturing springs and certain types of steel, due to its resistance to

corrosion. Cast iron contains silicon about 2.5%. It helps in the formation of free graphite which promotes the machine-ability of cast iron.

**Tungsten (W)**

The melting temperature of tungsten is 3380°C. This can be drawn into thin wires.

Due to this reason it is used to make filaments of electric lamps.

Tungsten is used as an alloying metal for the production of high speed cutting tools. High speed steel is an alloy of 18% tungsten, 4% chromium and 1% vanadium.

Stellite is an alloy of 30% chromium, 20% tungsten, 1 to 4% carbon and the balance cobalt.

**Vanadium (Va)**

This improves the toughness of steel. Vanadium steel is used in the manufacture of gears, tools etc. Vanadium helps in providing a fine grain structure in tool steels.

Chrome-vanadium steel contains 0.5% to 1.5% chromium, 0.15% to 0.3% vanadium, 0.13% to 1.10% carbon.

This alloy has high tensile strength, elastic limit and ductility. It is used in the manufacture of springs, gears, shafts and drop forged components.

Vanadium high speed steel contains 0.70% carbon and about 10% vanadium. This is considered as a superior high speed steel.

**Cobalt (Co)**

The melting point of cobalt is 1495°C. This can retain magnetic properties and wear-resistance at very high temperatures. Cobalt is used in the manufacture of magnets, ball bearings, cutting tools etc. Cobalt high speed steel (sometimes known as super H.S.S.) contains about 5 to 8% cobalt. This has better hardness and wear resistance properties than the 18% tungsten H.S.S.

**Molybdenum (Mo)**

The melting point of molybdenum is 2620°C. This gives high resistance against softening when heated. Molybdenum high speed steel contains 6% of molybdenum, 6% tungsten, 4% chromium and 2% vanadium. This high speed steel is very tough and has good cutting ability.

**Cadmium (cd)**

The melting point of cadmium is 320°C. This is used for coating steel components.

**Alloying Metals and Non Ferrous Alloys****Non-ferrous Metals And Alloys****Copper and its alloys**

Metals without iron are called non-ferrous metals. Eg. Copper, Aluminium, Zinc, Lead and Tin.

## Copper

This is extracted from its ores 'MALACHITE' which contains about 55% copper and 'PYRITES' which contains about 32% copper.

### Properties

Reddish in colour. Copper is easily distinguishable because of its colour.

The structure when fractured is granular, but when forged or rolled it is fibrous.

It is very malleable and ductile and can be made into sheets or wires.

It is a good conductor of electricity. Copper is extensively used as electrical cables and parts of electrical apparatus which conduct electric current.

Copper is a good conductor of heat and also highly resistant to corrosion. For this reason it is used for boiler fire boxes, water heating apparatus, water pipes and vessels in brewery and chemical plants. Also used for making soldering iron.

The melting temperature of copper is 1083° C.

The tensile strength of copper can be increased by hammering or rolling.

### Copper Alloys

#### Brass

It is an alloy of copper and zinc. For certain types of brass small quantities of tin or lead are added. The colour of brass depends on the percentage of the alloying elements. The colour is yellow or light yellow, or nearly white. It can be easily machined. Brass is also corrosion-resistant.

Brass is widely used for making motor car radiator core and water taps etc. It is also used in gas welding for hard soldering/brazing. The melting point of brass ranges from 880 to 930°C.

Brasses of different composition are made for various applications. The following table-1 gives the commonly used brass alloy compositions and their application.

#### Bronze

Bronze is basically an alloy of copper and tin. Sometimes zinc is also added for achieving certain special properties. Its colour ranges from red to yellow. The melting point of bronze is about 1005°C. It is harder than brass. It can be easily machined with sharp tools. The chip produced is granular. Special bronze alloys are used as brazing rods.

Bronze of different compositions are available for various applications.

#### Lead and its alloys

Lead is a very commonly used non-ferrous metal and has a variety of industrial applications.

Lead is produced from its ore 'GALENA'. Lead is a heavy metal that is silvery in colour when molten. It is soft and malleable and has good resistance to corrosion. It is a good insulator against nuclear radiation. Lead is resistant to many acids like sulphuric acid and hydrochloric acid.

It is used in car batteries, in the preparation of solders etc. It is also used in the preparation of paints.

### Lead Alloys

#### Babbit metal

Babbit metal is an alloy of lead, tin, copper and antimony. It is a soft, anti-friction alloy, often used as bearings.

An alloy of lead and tin is used as 'soft solder'.

### Zinc and its alloys

Zinc is a commonly used metal for coating on steel to prevent corrosion. Examples are steel buckets, galvanized roofing sheets, etc.

Zinc is obtained from the ore-calamine or blende.

Its melting point is 420° C.

It is brittle and softens on heating; it is also corrosion-resistant. It is due to this reason it is used for battery containers and is coated on roofing sheets etc.

Galvanized iron sheets are coated with zinc.

### Tin and tin alloys

#### Tin

Tin is produced from cassiterite or tinstone. It is silvery white in appearance, and the melting point is 231° C. It is soft and highly corrosion-resistant.

It is mainly used as a coating on steel sheets for the production of food containers. It is also used with other metals, to form alloys.

**Example:** Tin with copper to form bronze. Tin with lead to form solder. Tin with copper, lead and antimony to form Babbit metal.

### Aluminium

Aluminium is a non-ferrous metal which is extracted from 'BAUXITE'. Aluminium is white or whitish grey in colour. It has a melting point of 660° C. Aluminium has high electrical and thermal conductivity. It is soft and ductile, and has low tensile strength. Aluminium is very widely used in aircraft industry and fabrication work because of its lightness. Its application in the electrical industry is also on the increase. It is also very much in use in household heating appliances.

## Difference between iron & steel, alloy steel & carbon steel Exercise 1.7.22

### Difference between iron and steel:

S.No	Basic distinction	Iron	Steel
1	Formation	Pure substance	Made up of iron and carbon
2	Types	Cast iron, Wrought iron and steel	Carbon steel and alloy steel
3	Rusting	Quickly gets oxidised and result in rust	Have different elements that protect from rusting
4	Surface	Its surface is rusty	Its surface stays shiny
5	Usage	Used in buildings, tools and automobiles	Used in buildings, cars, railways and automobiles
6	Existence	Available in nature	Has to be formed

### Steel Plants in India

S.No	Name of the Steel plant	State
1	Tata Iron	Bihar
2	Indian Iron Steel	West Bengal
3	Visweshwaraiah Iron Steel	Karnataka
4	Bhilai Steel Plant	Madya Pradesh
5	Durgapur Steel Plant	West Bengal
6	Alloy Steel Plant (Durgapur)	West Bengal
7	Bokaro Steel Plant	Bihar
8	Rourkela Steel Plant	Orissa
9	Salem Steel Plant	Tamilnadu
10	Vishakapatnam Steel Plant	Andhra Pradesh

### Comparison of the Properties of Cast Iron, Mild Steel and steel

Property	Cast Iron	Mild Steel	Steel
Composition	Carbon contents from 2 to 4.5%	Carbon contents from 0.1 to 0.25%	Carbon contents from 0.5 to 1.7%
Strength	– High compressive strength – Poor tensile strength – Poor shearing strength	– Moderate compressive strength – Moderate tensile strength – High shearing strength	– High compressive strength – High tensile strength – High shearing strength
Malleability	Poor	High	High
Ductility	Poor	High	High
Hardness	Moderately hard and can be hardened by heating to hardening temperature and quenching	Mild	Hard
Toughness	Possesses poor toughness	Very tough	Toughness varies with carbon content
Brittleness	Brittle	Malleable	Malleable
Forgeability	Cannot be forged	Can be forged	Can be forged
Weldability	Cannot be welded with difficulty	Can be welded very easily	Can be welded
Casting	Can be easily cast	Can be cast but not easily	Can be cast
Elasticity	Poor	High	High

<b>Ferrous metals</b>	<b>Non Ferrous metals</b>
1 Iron content is more	1 Iron content is missing
2 The melting point is high	2 The melting point is low.
3 This is of brown and black colour	3 This is of different colours
4 This catches rust	4 This doesn't catch rust.
5 This can be magnetised	5 This cannot be magnetised
6 This is brittle in cold state.	6 This becomes brittle in hot state.

#### **Difference between cast Iron and steel**

<b>Cast Iron</b>	<b>Steel</b>
1 Carbon content is high	Carbon content is less
2 Carbon is in free state	Carbon is mixed
3 Melting point is low	Melting point is high
4 It cannot be magnetised	It can be magnetised
5 Because it is brittle, it cannot be forged	It can be forged
6 It rusts with difficulty	It rusts quickly
7 It cannot be welded	It can be welded

#### **Difference between metals and non-metals**

<b>Metals</b>	<b>Non Metals</b>
Shiny	dull
Usually good conductors of heat and electricity	Usually poor conductors of heat and electricity
Most are ductile	not ductile
Opaque (opposite of 'transparent')	Transparent when as a thin sheet
Most are malleable	Usually brittle when solid
Form alkaline oxides	Form acidic oxides
Sonorous (make a bell-like sound when struck)	not sonorous
Usually have 1-3 valency electrons	Usually have 4-8 valency electrons
Most corrode easily	
Usually high melting points (usually solid at room temperature except for mercury)	

## Properties and uses of rubber, timber and insulating materials Exercise 1.7.23

### Properties and uses of rubber

#### Rubber

Rubber is an elastic material. It can be classified into

- Natural rubber
- Hard rubber
- Synthetic rubber

#### Natural rubber

It is obtained from the secretion of plants. It softens on heating, becomes sticky at 30°C and hardens at about 5°C.

Sulphur is added to rubber and the mixture is heated. This process is called vulcanising. By this process, stronger, harder and more rigid rubber is obtained. Further, it becomes less sensitive to changes of temperature and does not dissolve in organic solvents. Its oxidation is also minimised by increasing its weathering properties.

By adding carbon black, oil wax, etc, the deformation properties are minimised. Rubber is moisture-repellent and possesses good electrical properties. The main disadvantages of the rubber are as given under.

- Low resistance to petroleum oils.
- Cannot be exposed to sunlight.

- Cannot be used for high-voltage insulation.
- Low operating temperature (as it becomes brittle and develops cracks at a temperature of 60°C)
- Sulphur in rubber reacts with copper. Hence, copper wires are to be tinned.

#### Hard rubber

By increasing the sulphur content and prolonged vulcanization, a rigid rubber product called hard rubber or ebonite is obtained. It possesses good electrical and mechanical properties.

#### Uses

It is used for battery containers, panel boards, bushing, ebonite tubes, etc.

#### Synthetic rubber

This is similar to natural rubber and is obtained from thermoplastic vinyl high polymers. Some of the important synthetic rubbers are:

- Nitrite butadiene rubber
- Butyl rubber
- Hypalon rubber
- Neoprene rubber
- Silicon rubber

Sl.No.	Name	Properties	Uses
1	Nitrite butadiene rubber	Good resilience, wear resistance, flexibility at low temperature, resistance to ageing, oxidation, low tensile strength, high thermal conductivity, low hygroscopicity	Automobile tyre inner tubes.
2	Butyl	It is attacked by petroleum oils, gases and alcoholic solvents. It has thermal and oxidation stability and high resistance to ozone.	Used as insulation in hot and wet conditions, used as tapes in repair work.
3	Hypalon rubber	Resistance to deterioration when exposed to sunlight and temperature (up to 150°C).	Used in jacketing of electric wires and cables
4	Neoprene rubber	Better resistance to ageing, oxidation and gas diffusion, better thermal conductivity and flame resistance, poor mechanical properties.	Used for wire insulation and cable sheathing.
5	Silicon	High operating temperature (200°C) flexibility, moisture and corrosion resistance, resistance to oxidation, ozone, arcing, good insulating properties and thermal conductivity. It is a good insulator.	Insulation for power cables and control wires of blast furnace coke ovens, steel mills and nuclear power stations high frequency generators, boiler, airport lighting cranes.

## Properties and uses of timber

### General properties

Timber should have the following properties

- Straight fibres.
- Silky lustre when planed.
- Uniform colour.
- Regular annual rings.
- Heaviness.
- Firm adhesion of fiber and compact modular rays.
- Sweet smell.
- It should be free from loose or dead knots and shakes.
- The surface should not clog the teeth of the saw on cutting but should remain bright.

### Classification

- Timbers are classified as
  - a Softwood
  - b hardwood

### Softwood timber

- Usually all trees with needle leaves of softwood and those with broad leaves are of hard-wood.
- The wood contains resins and turpentine.
- The wood has a fragrant smell.
- Fibres are straight.
- Texture is soft and regular.
- Tough for resisting tensile stresses.
- Weak across the fibres.
- Annual rings are distinct, having one side soft, porous and light coloured. The other side is dense and dark.
- The general colour of the wood is pale tinted or light such as pine spruce, fir, ash, kail, deodar etc.

### Properties of hardwood

- The wood generally contains a large percentage of acid.
- It is brightly coloured.
- Annual rings are not distinct.
- It is difficult and hard to work with.
- It resists shearing stress.
- Fibre are overlapped.
- The general colour is dark brown such as oak, walnut, teak, mahogany, sishim, babul, sal etc.

## Uses

### Soft timber

- Because of its cheapness it is used for low grade furniture, doors and windows for cheap types of houses.
- Used as fuel.
- Some timbers are used for baskets and mat making.
- The bark is used as garment in some places.

### Hard timber

- Used for high quality furniture such as chairs, tables, sofas, dewans, beds, etc.
- Used for door, window frames for high quality houses as they can take good polish and painting finish.
- Used for manufacturing katha.

### Wood as an electrical insulator

Wood is impregnated with oil or other substance, for use as insulator.

#### Example

It is used in electrical machine windings, as slot wedges.

### Insulating materials

#### Description

These are the materials which offer very high resistance to the flow of current and make current flow very negligible or nil. These materials have very high resistance - usually of many megohms (1 Megohm =  $10^6$  ohms) per centimetre cubed. The insulators should also possess high dielectric strength. This means that the insulating material should not break down or puncture even on application of a high voltage (or high electrical pressure) to a given thickness.

#### Properties of insulators

The main requirements of a good insulating material are:

- High specific resistance (many megohms/cm cube) to reduce the leakage currents to a negligible value.
- Good dielectric strength i.e. high value of breakdown voltage (expressed in kilovolts per mm).
- Good mechanical strength, in tension or compression (It must resist the stresses set up during erection and under working conditions.)
- Little deterioration with rise in temperature (The insulating properties should not change much with the rise in temperature i.e. when electrical machines are loaded.)
- Non-absorption of moisture, when exposed to damp atmospheric condition. (The insulating properties, specially specific resistance and dielectric strength decrease considerably with the absorption of even a slight amount of moisture.)

## Products and insulators

Insulators	Uses in electric field
1 Mica	In elements or winding (Slot insulation)
2 Rubber	Insulation in wires
3 Dry cotton	Winding
4 Varnish	Winding
5 Asbestos	In the bottom of irons and kettles, etc.
6 Gutta parcha	Submarine cables
7 Porcelain	Overhead lines insulators
8 Glass	-do-
9 Wood dry	Cross arms in overhead lines
10 Platic	Wires insulation or switches body
11 Ebonite	Bobbin of transformer
12 Fibre	Bobbin making and winding insulation
13 Empire cloth	Winding insulation
14 Leathroid paper	-do-
15 Millimax paper	-do-
16 P.V.C.	Wire insulation
17 Bakelite	Switch etc. making, for insulation
18 Shellac	-do-
19 Slate	Making panel board
20 Paraffin Wax	Sealing

m - mass of a body

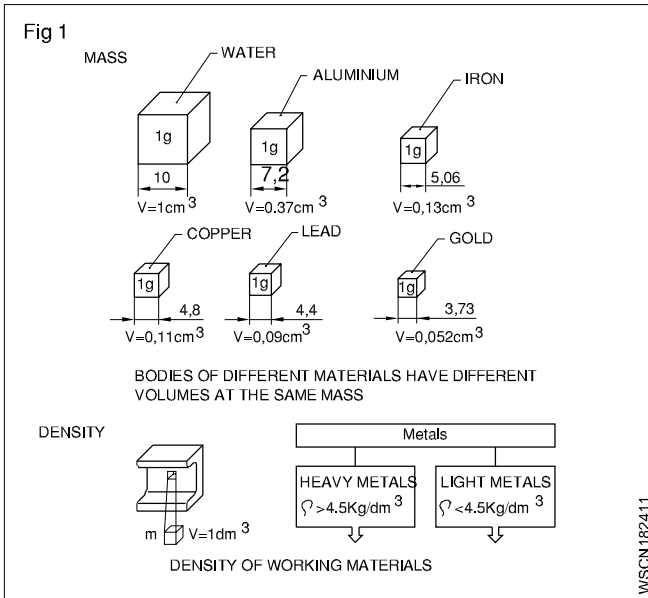
g - acceleration due to gravity in  $\text{metre/sec}^2 = 9.81 \text{ m/sec}^2$

V - volume of the body

$\rho$  - density (pronounced as 'rho')

W or FG - weight or weight force

**Mass (Fig 1)**



Mass of a body is the quantity of matter contained in a body. The unit of mass in F.P.S system is pound (lb), in C.G.S. system gram (gr) and in M.K.S and S.I systems kilogram (kg). 1ton which is 1000 kg is also used sometimes. The conversion factor is 1000. Three decimal places are shifted during conversion. E.g. 1 ton=1000 kg 1g = 1000 mg

**Density**

Density is the mass of a body per unit volume. Hence its unit will be  $\text{gr/cm}^3$  or  $\text{kg/dm}^3$  or  $\text{ton/m}^3$ .

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{m}{v} = \rho$$

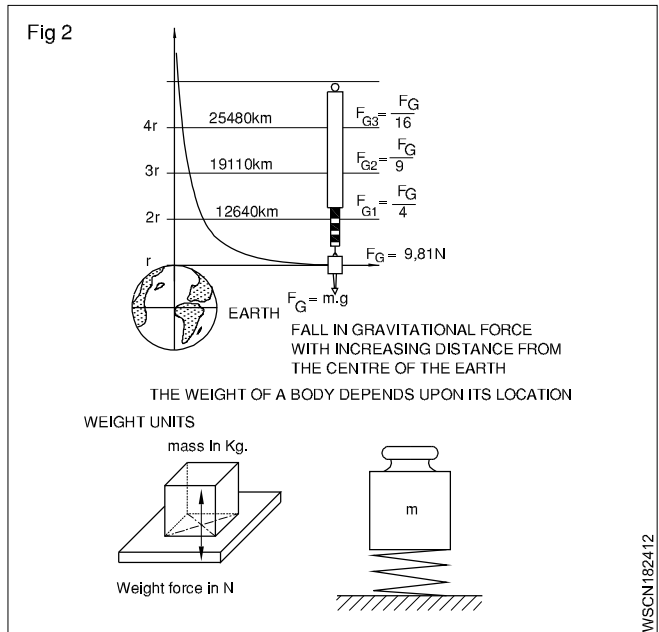
**Weight (Fig 2)**

Weight is the force with which a body is attracted by the earth towards its centre. It is the product of the mass of the body and the acceleration due to gravity. The weight of a body depends upon its location.

$$\text{weight} = W \text{ or } FG = \text{mass} \times \text{gravitational force} = m \times g$$

System	Absolute unit	Derived unit	Conversion
F.P.S. system	1 poundal	1 Lbwt	32.2 poundals (1 lb x 1 ft/sec <sup>2</sup> = 1 pound)
C.G.S. system	1 dyne	1 Gr.wt	981 dynes
M.K.S.	Newton	1 kg.wt	1 Newton =
S.I.system	Newton	Newton	1 kg x 1 m/sec <sup>2</sup>

**1 kg.wt = 9.81 Newton (approximately 10N)**      **1 Newton = 10<sup>5</sup> dynes.**





# Difference between mass & weight, density & specific gravity Exercise 1.8.25

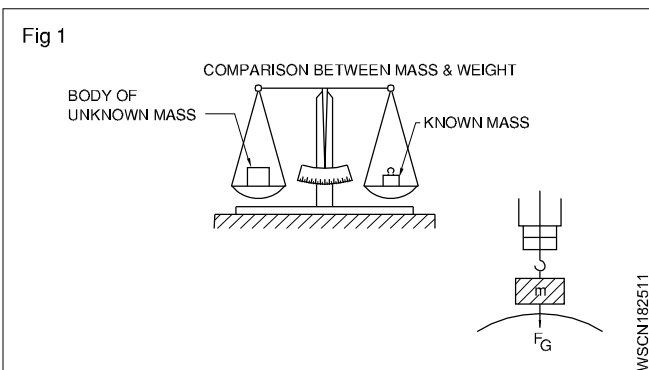
## Difference between mass and weight

S. No	Mass	Weight
1	Mass is the quantity of matter in a body (ie) measurement of matter in a body	Weight is measure of amount of force acting on mass due to acceleration due to gravity
2	It does not depend on the position or space	It depends on the position, location and space
3	Mass of an object will not be zero	Weight of an object will be zero if gravity is absent
4	It is measured using by physical balance	It is measured using by spring balance
5	It is a scalar quantity	It is a vector quantity
6	When immersed in water mass does not change	When immersed in water weight will change
7	The unit is in grams and kilogram	The unit is in kilogram weight, a unit of force

**Mass and weight are different quantities.**  
**Mass of a body is equal to volume x density.**  
**Weight force is equal to mass x acceleration due to gravity.**

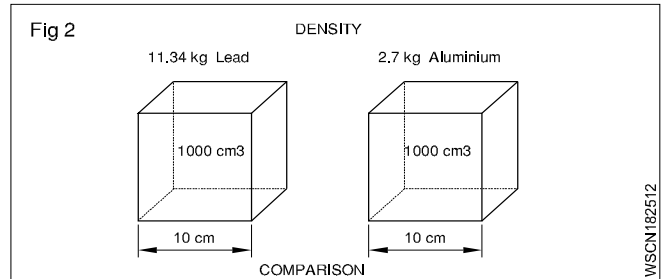
## Weight , Density and Specific gravity

It is now seen that the mass of a substance is measured by its weight only without any reference to volume. But if equal weights of lead & aluminium, are compared the volume of lead is much smaller than volume of aluminium. So we can now say that lead is more dense than aluminium, i.e In other words the density of lead is greater than aluminium. (Fig 1)



The relation of mass and volume is called density.

The density expresses the mass of volume E.g. 1 dm<sup>3</sup> of water has the mass of 1kg - thus the density of 1kg/dm<sup>3</sup>



## Unit

The density is measured as below

MKS/SI= Kg/m<sup>3</sup>, CGS - 1 gm/cm<sup>3</sup> FPS-lbs/c ft

	Solids	gm/cc <sup>3</sup>	Liquids	gm/cc <sup>3</sup>
1	Aluminum	2.7	Water	1.00
2	Lead	11.34	Petrol	0.71
3	Cast iron	6.8 to 7.8	Oxygen	1.43
4	Steel	7.75 to 8.05	Diesel Oil	0.83

The specific gravity of a substance is also called its relative density.

Formula

$$\text{Specific gravity (or) Relative density} = \frac{\text{Density of the substance}}{\text{Density of the water at } 4^{\circ}\text{C}}$$

$$= \frac{\text{Mass of any volume of a substance}}{\text{Mass of an equal volume of water at } 4^{\circ}\text{C}}$$

## Comparison Between Density And Specific Gravity (Relative Density)

Density	Relative density or Specific gravity
Mass per unit volume of a substance is called its density Its unit is gm per cu cm; lbs per cu.ft and kg/cubic meter	The density of substance to density of water at 4°C is its relative density It has no unit of measurement simply expressed in a number
$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$	Relative density $= \frac{\text{Density of the substance}}{\text{Density of water at } 4^{\circ}\text{C}}$

	Solids	Sp.gy	Liquids	Sp.gy
1	Aluminium	2.72	Petrol	0.71
2	Lead	11.34	Battery acid	1.2 to 1.23
3	Cast iron	6.8 to 7.8	Water	1.00
4	Steel	7.82	Diesel Oil	0.83

From the above table, we can calculate the weight of any given volume of a substance (say Diesel oil) in any units provided we know the specific gravity of the substance. Also vice-versa for volume of density is known.

## Related problems with assignment of mass, weight & density Exercise 1.8.26

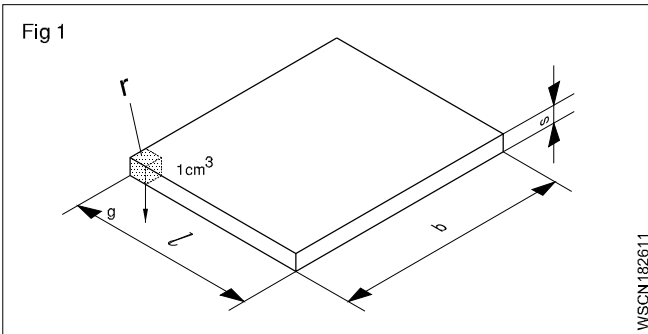
- 1 Calculate the mass in kg of a rectangular steel plate of dimensions 220 x 330 x 15 mm (Fig 1) (density of steel = 7.82 gm/cm<sup>3</sup>)

Mass = Volume x density

$$= 22 \times 33 \times 1.5 \text{ cm}^3 \times 7.82 \text{ gm/cm}^3$$

$$= 1089 \text{ cm}^3 \times 7.82 \text{ gm/cm}^3$$

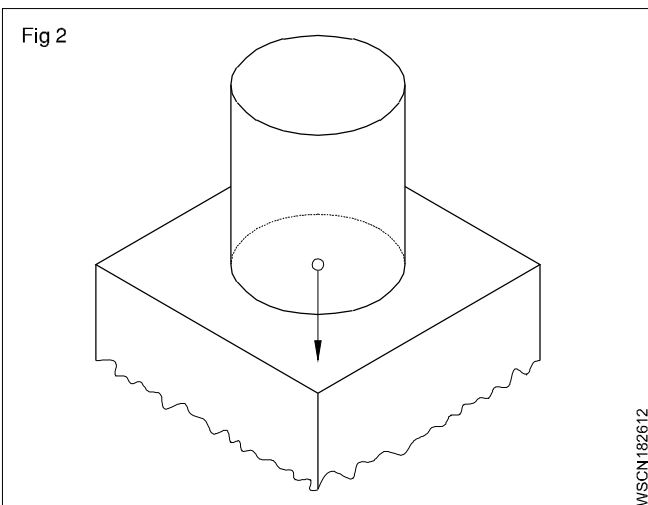
$$\text{mass} = 8.516 \text{ kg}$$



- 2 A storage container holds 250 litres of water. What weight in N will this amount of water exert on the surface on which it is standing?(Fig 2)

(1 litre of water = 1 kg of water)

Density of water 1 gm/cm<sup>3</sup> or 1 kg/dm<sup>3</sup>



**Acceleration due to gravity is taken as 10 metre/sec<sup>2</sup> (approximation).**

Capacity = 250 litres = 250 dm<sup>3</sup> in volume.

Mass of water = volume x density of water

$$= 250 \text{ dm}^3 \times 1 \text{ kg/dm}^3 = 250 \text{ kg}$$

Weight extended = mass x acceleration due to gravity

$$= 250 \text{ kg} \times 10 \text{ metre/sec}^2$$

$$= 2500 \text{ kg.metre/sec}^2 = 2500 \text{ N} (\because 1 \text{ kg.m/sec}^2 = 1 \text{ N})$$

- 3 A force of 15 dynes acting on a mass of 'm' produces an acceleration of 2.5 cm/sec<sup>2</sup>. Find the mass.

$$1 \text{ Gr. wt.} = 981 \text{ dynes}$$

$$\therefore 15 \text{ dynes} = \frac{15}{981} \text{ Gr.wt}$$

Force = m x acceleration produced by the force

$$\therefore \text{Gr.wt} = \text{mass} \times 2.5 \text{ cm/sec}^2$$

$$\therefore \text{gr.cm/sec}^2 = \text{mass} \times 2.5 \text{ cm/sec}^2$$

$$\therefore \text{mass} = \frac{15}{981 \times 2.5} \text{ grams} = \frac{\text{gm.cm/sec}^2}{\text{cm/sec}^2}$$

$$\text{mass} = 0.00612 \text{ gram}$$

- 4 A force of 2 N acts on a mass of 10 kg. Find the acceleration produced by the force on the mass.

$$\text{Force} = 2 \text{ N} (\because 1 \text{ N} = 1 \text{ kg.m/sec}^2)$$

Force = mass x acceleration

$$\therefore 2 \text{ kg.metre/sec}^2 = 10 \text{ kg} \times \text{acceleration produced}$$

$$\therefore 2 \times 1 \text{ kg.metre/sec}^2 = 10 \text{ kg} \times \text{acceleration produced}$$

$$\therefore \text{acceleration produced} = \frac{2}{10} \text{ metre/sec}^2$$

$$= 0.2 \text{ metre/sec}^2$$

- 5 Calculate the weight of a body having a mass of 1 kg if the acceleration due to gravity is 9.81 metres/sec<sup>2</sup>

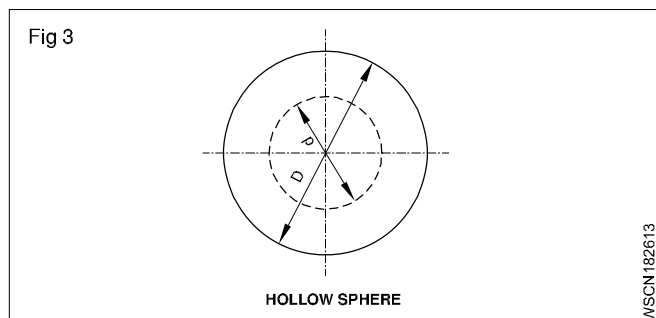
$$\text{Weight force} = \text{mass} \times \text{acceleration due to gravity} \\ = 1 \text{ kg} \times 9.81 \text{ metres/sec}^2$$

$$(1 \text{ kg.metre/sec}^2 = 1 \text{ N})$$

$$\therefore 9.81 \text{ kg metre/sec}^2 = 9.81 \text{ N}$$

**In the examples solved the value of 'g' is taken as 10 metre/sec<sup>2</sup>, unless specifically mentioned otherwise.**

- The outside and inside diametres of a hollow sphere are 150 & 70mm respectively. Calculate its mass if the density of material is 7.5 gm/cm<sup>3</sup>. (Fig 3)



Mass = Volume x Density

$$= \text{Volume} \times 7.5 \text{ gm/cm}^3$$

$$D = 150 \text{ mm} = 15 \text{ cm} \quad R = 7.5 \text{ cm}$$

$$d = 70\text{mm} = 7 \text{ cm} \quad r = 3.5 \text{ cm}$$

$$\text{Volume} = \frac{4}{3} \pi (R^3 - r^3) \text{unit}^3$$

$$= \frac{4}{3} \pi (7.5^3 - 3.5^3)$$

$$= 1587.5 \text{ cm}^3$$

$$\text{Mass} = 1587.5 \text{ cm}^3 \times 7.5 \text{ gm/cm}^3$$

$$= 11906.6 \text{ gm} = 11.9\text{kg} \quad \text{say } 12\text{kg}$$

6 A car has a mass of 800 kg. Find out its weight force (Take 9.81 m/sec<sup>2</sup>)

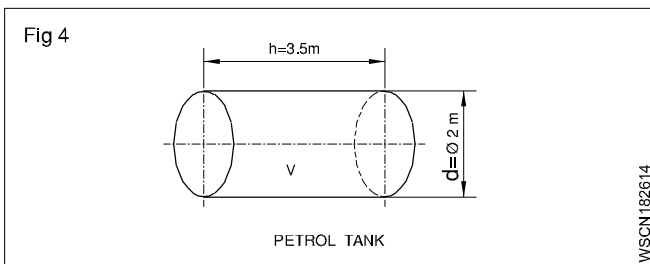
$$(\because 1\text{N} = 1\text{kg.m/sec}^2)$$

The Wt. force of a car = Mass of car x gravitational acceleration

$$= 800 \times 9.81 \text{ N}$$

$$= 7848 \text{ Newtons}$$

7 A cylindrical tank 2m dia x 3.5 m deep is filled with petrol. Find the weight of petrol in Tonnes, Assume density of petrol 720 Kg/m<sup>3</sup>. (Fig 4)



Volume of Tank

$$v = \pi r^2 h \text{ (or) } \frac{\pi d^2}{4} \times h \text{ unit}^3 = \frac{\pi \times 2^2}{4} \times 3.5 \text{ m}^3$$

$$3.14 \times 3.5 \text{ m}^3 = 10.99 \text{ m}^3$$

$$\text{Since } 1 \text{ m}^3 = 1000 \text{ litres}$$

$$\text{Volume of Tank} = 10.99 \times 1000 \text{ litres}$$

$$\text{Density of petrol} = 720 \text{ Kg/m}^3$$

$$\begin{aligned} \text{Weight of Petrol in Kg} &= 10.99 \times 1000 \text{ litres} \times 720 \text{ Kg} \\ &= 720 \times 10990 \text{ Kg} \end{aligned}$$

Weight of Petrol in Tonnes

$$\text{(Metric Units)} = \frac{720 \times 10990}{1000}$$

$$\text{Weight of Petrol} = 7912.8 \text{ Tonnes}$$

8 If the battery acid specific gravity is 1.3, and this is being filled up into a cylindrical tank. Find out its density.

$$\text{(Density of water} = 1000 \text{ gm/cm}^3)$$

Specific gravity or Relative density

$$= \frac{\text{Density of the substance}}{\text{Density of water at } 4^\circ\text{C}}$$

Now, density of battery acid

$$= \text{Specific gravity} \times \text{Density of water}$$

$$= 1.3 \times 1000 \text{ gm/cm}^3$$

$$= 1300 \text{ gm/cm}^3$$

### Determination of specific gravity of a substance

The specific gravity of a substance may be determined by

- 1 Arche medies principle
- 2 Hydrometer

### Archemedes Principle

Archemedes principle states that when a body is fully or partially immersed in a liquid, the amount of liquid displaced by the body is equal to the loss of weight of the body in the liquid.

Weight of a body in a liquid = total weight of the body

- weight of the liquid displaced by the body

This quantity if it is zero then the body will float. It is negative the body will rise up till the weight of liquid displaced by the immersed portion of the body is equal and equal to the weight of the body. If it is positive the body will sink. Specific gravity of solids in soluble in water

$$= \frac{\text{weight of solid in air}}{\text{loss of weight of solid in water}}$$

specific gravity of solids soluble in water

$$= \frac{\text{weight of solid in air} \times \text{specific gravity of the liquid}}{\text{loss of weight of solid in which the solid is in solution}}$$

specific gravity of a liquid

$$= \frac{\text{loss weight of a solid in water}}{\text{loss of weight of the same solid in liquid}}$$

**The solid chosen should be such that it is insoluble in both water and the liquid whose specific gravity is to be determined.**

### Example

1 An iron piece weighs 160 kgf in air and 133 kgf when it is fully immersed in water. Determine the volume and specific gravity of the iron piece.

$$\text{Weight of the solid in air} = 160 \text{ kgf}$$

$$\text{Weight of the solid in water} = 133 \text{ kgf}$$

$$\therefore \text{Loss of weight in water} = 27 \text{ kgf}$$

By Archemedies principle the loss of weight of a solid in water = volume of water displaced.

$$\therefore \text{Volume of water displaced} = 27 \text{ cm}^3$$

∴ Volume of the solid = 27 cm<sup>3</sup>

$$\text{Density of the iron piece} = \frac{\text{mass of iron}}{\text{volume of the piece}}$$

$$= \frac{160}{160-133} = \frac{160}{27} = 5.93$$

$$\text{Specific gravity} = \frac{\text{Density of iron}}{\text{Density of water}} = \frac{5.93}{1} = 5.93$$

Specific gravity of iron piece = 5.93

- 2 A metal piece weighs 6.5 kgf in air and 3.5 kgf in water. Find its weight when it is fully immersed in a liquid whose specific gravity is 0.8 and also the S.G of the metal.

Weight of metal piece in air = 6.5 kgf

Weight of metal piece in water = 3.5 kgf

∴ Loss of weight in water = 3.00 kgf (6.5 - 3.5)

∴ Specific gravity of metal

$$\text{Loss of weight} = \frac{\text{weight of substance in air}}{\text{weight of substance in water}} = \frac{6.5 \text{ kgf}}{3 \text{ kgf}} = 2.166$$

By applying the principle of Archimedes the above results are derived.

By using a hydrometer also, the specific gravity of a liquid is determined. The most common type of hydrometer is the Nicholson's hydrometer which is a variable weight but constant immersion type.

Specific gravity of a liquid

weight of hydrometer + weight required to sink the =

hydrometer in the liquid to a fixed mark

weight of hydrometer + weight required to sink the hydrometer

in water up to the same mark.

Let the weight of the metal piece in the liquid = W

∴ loss of weight of the metal in the liquid = 6.5 kgf - W

$$\text{Specific gravity of the liquid} = \frac{\text{loss of weight in liquid}}{\text{loss of weight of water}}$$

$$\therefore 0.8 = \frac{6.5 \text{ kgf} - w}{3 \text{ kgf}}$$

$$\therefore w = 6.5 \text{ kgf} - 3 \text{ kgf} \times 0.8 = 4.1 \text{ kgf}$$

∴ loss of weight of the metal in the liquid = 4.1 kgf.

- 3 A solid of wax weighs 21 kgf in air. A metal piece weighing 19 kgf in water is tied with the wax solid and both are immersed in water and the weight was found to be 17 kgf. Find the specific gravity of wax.

Weight of wax in air = 21 kgf

Weight of metal and wax in water = 17 kgf

Weight of metal piece only in water = 19 kgf

∴ weight of wax in water = (17 - 19) kgf

= - 2 kgf

∴ loss of weight of wax in

water

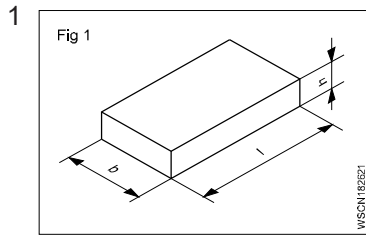
= (21 - (-2)) kgf

= 23 kgf

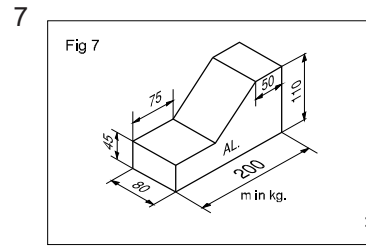
$$\text{specific gravity of wax} = \frac{21 \text{ kgf}}{23 \text{ kgf}} = 0.913$$

Sl.No	Metal	Density gm/cc
1	Aluminium	2.7
2	Cast Iron	6.8 - 7.8
3	Copper	8.92
4	Gold	19.32
5	Iron	7.86
6	Lead	11.34
7	Nickel	8.912
8	Silver	0.5
9	Steel	7.75 - 8.05
10	Tin	7.31
11	Zinc	7.14
12	Diamond	3.51
13	Bismuth	9.78
14	Brass	8.47
15	Phosphrous Bronze	8.7 - 8.9
16	Ice	0.93
17	Air	0.0013
18	Mercury	13.56
19	Petrol	0.71
20	Diesel	0.83
21	Kerosene	0.78 - 0.81
22	Water	1.0

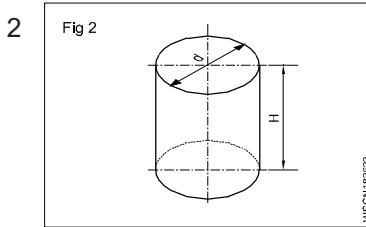
# ASSIGNMENT



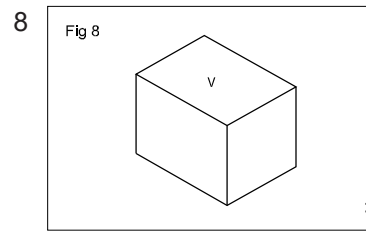
$l = 1800 \text{ mm}$   
 $b = 65 \text{ mm}$   
 $h = 12 \text{ mm}$   
 $\rho = 7.85 \text{ g/cm}^3$   
 $m = \underline{\hspace{2cm}} \text{ kg}$



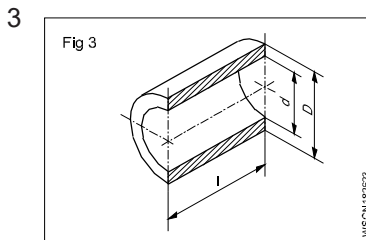
$L = 200 \text{ mm}$   
 $l_1 = 75 \text{ mm}$   
 $l_2 = 50 \text{ mm}$   
 $B = 80 \text{ mm}$   
 $H = 110 \text{ mm}$   
 $h = 45 \text{ mm}$   
 $\rho = 2.7 \text{ g/cm}^3$   
 $m = \underline{\hspace{2cm}} \text{ kg}$



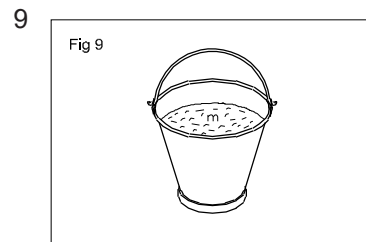
Capacity = 36 litres  
 $d = 32 \text{ cm}$   
 $H = \underline{\hspace{2cm}} \text{ cm}$



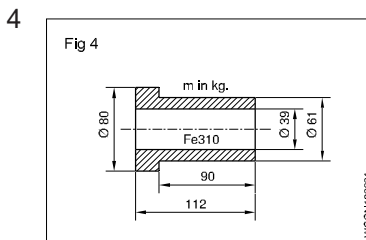
$V = 320 \text{ cm}^3$   
 $\rho = 8.9 \text{ g/cm}^3$   
 $g = 9.80665 \text{ metre/sec}^2$   
 $m = \underline{\hspace{2cm}} \text{ kg}$   
 $FG = \underline{\hspace{2cm}} \text{ N}$



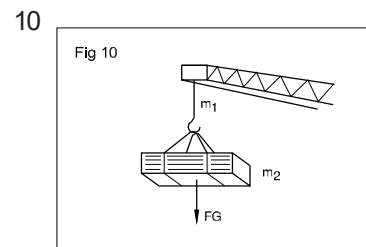
$D = 74 \text{ mm}$   
 $d = 68 \text{ mm}$   
 $l = 115 \text{ mm}$   
 $\rho = 8.6 \text{ g/cm}^3$   
 $m = \underline{\hspace{2cm}} \text{ gms}$



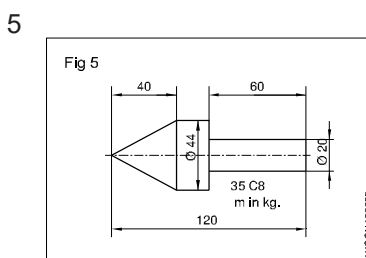
Capacity = 35 litres  
 $g = 10 \text{ metres/sec}^2$   
 $FG = \underline{\hspace{2cm}} \text{ N}$



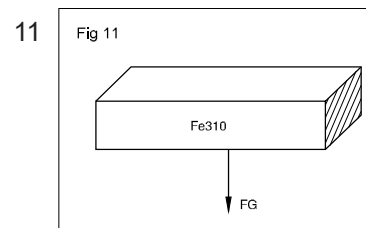
$D_1 = 80 \text{ mm}$   
 $D_2 = 61 \text{ mm}$   
 $d = 39 \text{ mm}$   
 $L = 112 \text{ mm}$   
 $l = 90 \text{ mm}$   
 $\rho = 7.85 \text{ g/cm}^3$   
 $m = \underline{\hspace{2cm}} \text{ kg}$



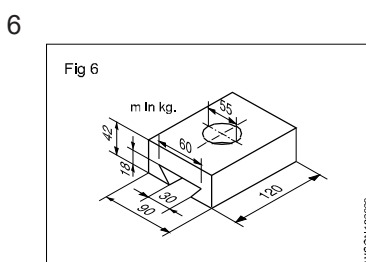
$(m_1)$  mass of chain = 150 kg  
 Total FG = 8 KN  
 Load =  $\underline{\hspace{2cm}} \text{ N}$   
 mass  $m_2 = \underline{\hspace{2cm}} \text{ kg}$



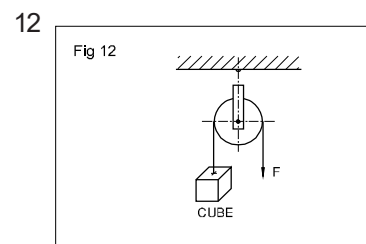
$D = 44 \text{ mm}$   
 $d = 20 \text{ mm}$   
 $L = 120 \text{ mm}$   
 $l_1 = 60 \text{ mm}$   
 $l_2 = 40 \text{ mm}$   
 $\rho = 7.85 \text{ g/cm}^3$   
 $m = \underline{\hspace{2cm}} \text{ kg}$



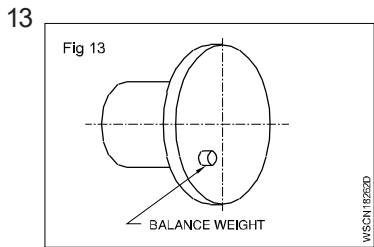
$W (FG) = 22.5 \text{ N}$   
 $V (\text{volume}) = \underline{\hspace{2cm}}$



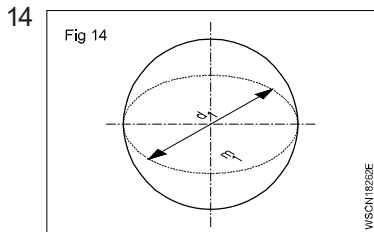
$L = 120 \text{ mm}$   
 $B = 90 \text{ mm}$   
 $b_1 = 60 \text{ mm}$   
 $b_2 = 30 \text{ mm}$   
 $d = 55 \text{ mm}$   
 $H = 42 \text{ mm}$   
 $h = 18 \text{ mm}$   
 $\rho = 7.85 \text{ g/cm}^3$   
 $m = \underline{\hspace{2cm}} \text{ kg}$



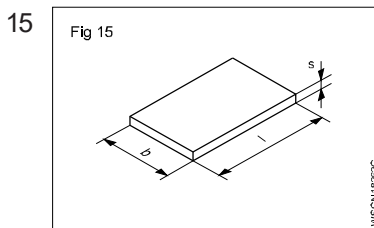
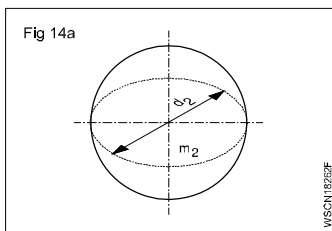
$F = 250 \text{ d N}$   
 side of cube =  $\underline{\hspace{2cm}} \text{ mm}$   
 (cubical counter weight balances 'F')



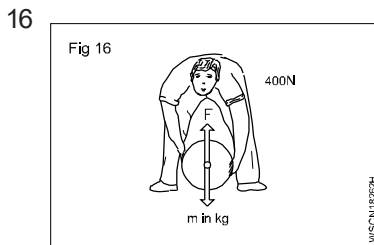
unbalanced load in the set up = 16 cN  
 $\phi$  of balancing weight = 20 mm  
 l of balancing weight = \_\_\_\_\_ mm



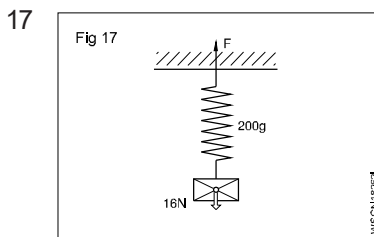
$d_1 = 40$  mm  
 $m_1 = 9 \times 10^{-2}$  kg  
 $r_1 = r_2$   
 $d_2 = 60$  mm  
 $FG_2 =$  \_\_\_\_\_ N



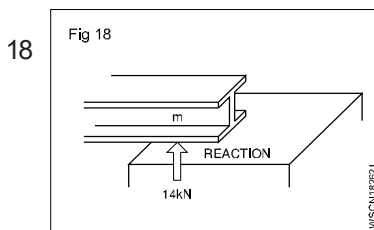
$l \times b = 1$  m<sup>2</sup>  
 $FG = 7.85 \times 10^{-2}$  kN  
 $s =$  \_\_\_\_\_ mm



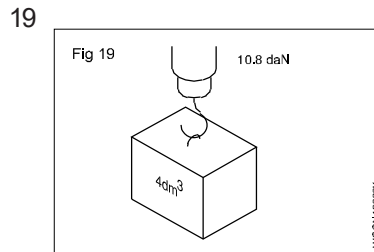
$F = 400$  N  
 $m =$  \_\_\_\_\_ kg



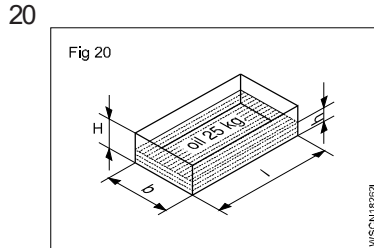
$m_1 = 200$  gms  
 $FG = 16$  N  
 $F =$  \_\_\_\_\_ dN



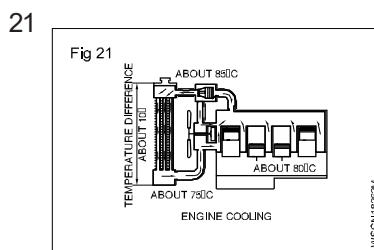
$R = 14$  kN  
 $m =$  \_\_\_\_\_ kg



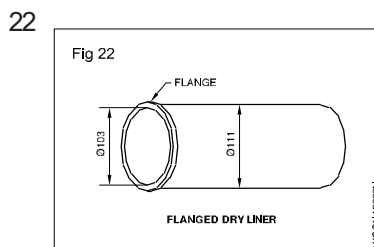
$V = 4$  dm<sup>3</sup>  
 $FG = 10.8$  daN  
 $\rho =$  \_\_\_\_\_ gm/cm<sup>3</sup>



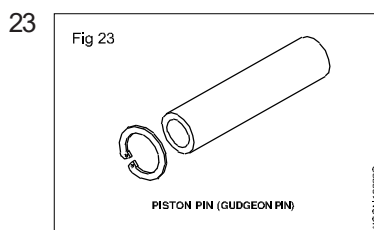
$l = 500$  mm  
 $b = 300$  mm  
 $H = 250$  mm  
 $\rho$  of oil = 0.9 gm/cm<sup>3</sup>  
 $m = 2.5$  kg  
 $h =$  \_\_\_\_\_ mm



Engine cooling  
 Datagiven  
 Water in Radiator = 10 litres  
 Find  
 Mass of water = \_\_\_\_\_ kg  
 (Assume 1 litre = dm<sup>3</sup> in volume)  
 Density of water = 1 kg/dm<sup>3</sup>

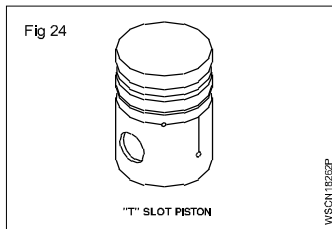


Cylinder Liner Dimension  
 Datagiven  
 $OD = 111$  mm  
 $ID = 103$  mm  
 Length = 240 mm  
 Material = C.I  
 Density of C.I = 7.259 gm/cm<sup>3</sup>  
 Find its mass \_\_\_\_\_ in kg



Gudgeon Pin (Solid)  
 Datagiven  
 Dia = 200 mm  
 Length = 70 mm  
 Material = M.S  
 Density = 7.85 gm/cm<sup>3</sup>  
 Find out its

24



Data given

Dia = 80 mm

Length = 100 mm

Density of Aluminum = 2.7 g/cm<sup>3</sup>

Find its Mass \_\_\_\_\_ in kg

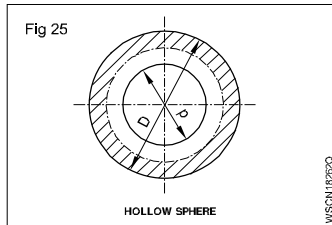
28 Conversion of vehicle weights

Take g = 10 m/sec<sup>2</sup>

Weight force      Mass

- a 480 Newton \_\_\_\_\_
- b 14800 N \_\_\_\_\_
- c 2000 N \_\_\_\_\_
- d 7000 N \_\_\_\_\_

25



Hollow sphere (Cast Brass)

Data given

O.D = 150 mm

I.D = 120 mm

Density of Brass = 6.89 gm/cc

Use Vol =  $\frac{4}{3} \pi (R^3 - r^3)$

Find

Mass of Hollow sphere = \_\_\_\_\_ kg

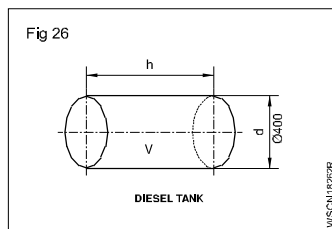
29 Conversion of mass of vehicle

Take g = 9.81 m/sec<sup>2</sup>

Mass of Vehicle      Its weight

- a 1200 kg \_\_\_\_\_ N
- b 800 kg \_\_\_\_\_ N
- c 700 kg \_\_\_\_\_ N
- d 900 kg \_\_\_\_\_ N

26



Diesel Tank

Data given

Diameter = 400 mm

Depth of filling (h) = 600 mm

Spongy of oil = 0.8

Density of water = 1000 kg/m<sup>3</sup>

Find

Mass of oil in Tank = \_\_\_\_\_ in kg

30 Fill up the blanks

Comparison of Metals & Liquids

	Material	Sp.gy	Density
a	Lead	11.34	_____
b	Copper	8.92	_____
c	Cast Iron	7.20	_____
d	Petrol	0.71	_____
e	Diesel	0.83	_____
f	Sulphuric Acid	1.84	_____

27 Definition

Define the following term

- a Mass
- b Weight
- c Density
- d Specific gravity

31 Fill in the blanks with correct statement in a & b

- a The density of water - 1000 kg/m<sup>3</sup> specific gravity of nitric acid = 1.2. The density of nitric acid = \_\_\_\_\_
- b      Material      Density      Specific gravity
- i      Water      1000 kg/m<sup>3</sup>      \_\_\_\_\_
- ii      Aluminium      2.7 g/cm<sup>3</sup>      \_\_\_\_\_
- iii      Iron      8 g/cc      \_\_\_\_\_
- iv      Copper      8.7 g/cc      \_\_\_\_\_
- c Mass of a body = Volume x \_\_\_\_\_
- d Weight force = Mass x \_\_\_\_\_
- e Give abbreviation for
- i Mega newton \_\_\_\_\_
- ii Kilo newton per square metre \_\_\_\_\_
- f 1 litre of water = \_\_\_\_\_ kg.

# Rest, motion, speed, velocity, difference between speed & velocity, acceleration & retardation

## Exercise 1.9.27

### Body at rest

When a body does not change its position, with respect to its surroundings, it is said to be at rest.

### Body at motion

When a body changes its position, with respect to its surroundings, it is said to be in motion. The motion may be linear if the body moves in a straight line or it may be circular when it moves in a curved path.

### Terms relating to motion

#### Displacement

When a body is in motion from one place to another, the displacement is the distance from the starting position to the final position.

#### Speed

It is the rate of change of displacement of a body in motion. It has got no direction and it is a scalar quantity.

$$\text{Speed} = \text{distance travelled per unit time} \quad \frac{s}{t} = \frac{\text{(Distance)}}{\text{Time}}$$

Unit = m/s, km/Hr, mile/Hr.

#### Velocity

It is the rate of change of displacement of a body in motion in a given direction. It is a vector quantity and can be represented both in magnitude and direction by a straight line. Velocity may be linear or angular. The unit of linear velocity is metre/sec,

$$\text{Velocity} = \frac{S}{t} = \frac{\text{Displacement}}{\text{Time}}$$

Unit = m/s, km/Hr, mile/Hr.

Difference between speed & velocity

Speed	Velocity
The rate of change place of an object is its speed.	The speed in a definite direction is called velocity.
In the speed, direction is not indicated. Only the magnitude is expressed.	Both the magnitude and direction are expressed.
Speed = $\frac{\text{Distance covered}}{\text{Time}}$	Velocity = $\frac{\text{Distance in definite direction}}{\text{Time}}$

#### Acceleration

Rate of change of velocity is known as acceleration or it is the change of velocity in unit time. Its unit is metre/sec<sup>2</sup>. It is a vector quantity.

$$a = \frac{\text{change in velocity}}{\text{Time}} \text{ m/sec}^2$$

unit = m/s<sup>2</sup> (metre per square second)

u = Initial velocity in metre per second(m/sec)

v = Final velocity in metre per second(m/sec)

s = Distance in metre (m)

t = Time in second (sec)

a = Acceleration m/sec<sup>2</sup>(positive value)

R = Retardation m/sec<sup>2</sup>(negative value of acceleration)

### Equations of motion

Then  $v = u + at$

$$s = ut + \frac{1}{2} at^2 \text{ and } v^2 - u^2 = 2as$$

$$v^2 = u^2 + 2as$$

### Retardation

When the body has its initial velocity lesser than its final velocity it is said to be in acceleration. When the final velocity is lesser than the initial velocity the body is said to be in retardation. Then the three equation of motion will be

$$v = u - at$$

$$s = ut - at^2$$

$$u^2 - v^2 = 2as$$

### Average speed

V<sub>m</sub> - Average speed in metre/min, (metre/sec)

n - Revolutions per minute or number of strokes per minute

s - Distance travelled, length of stroke.

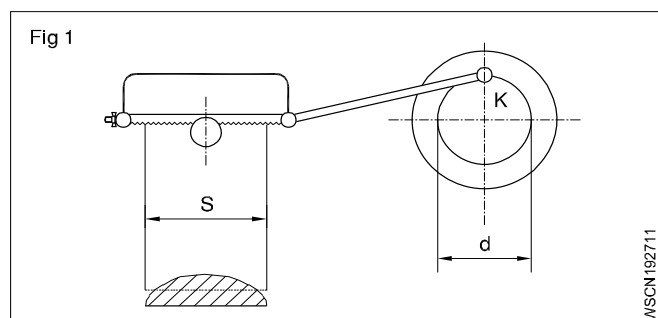
### Stroke speed (Fig 1)

For one revolution of the point k, of the crank pin the distance the power saw blade moves = 2 x s

Therefore 'n' revolutions in a minute the distance = 2 x s x n. Since the stroke of the blade will be given in metre to determine the average speed

$$V_m = 2 \times s \times n$$

### Piston speed (Fig 2)



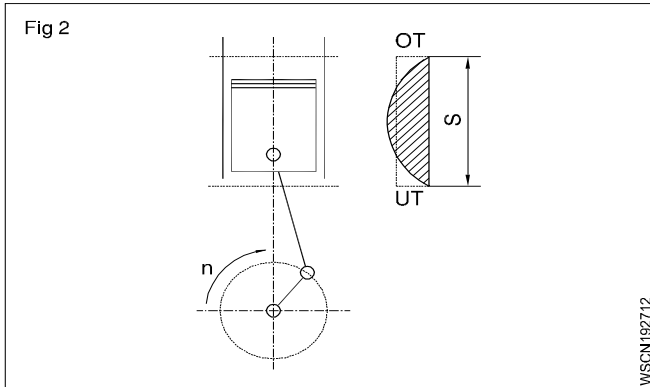
As the piston moves backward and forward, its speed constantly changes between the upper and lower dead centres. Hence in this case also the average speed  $V_m =$



$2 \times s \times n$ . Since  $s$  is expressed in mm and  $n$  in number of revolutions/per minute and since  $V_m$  is given in metre/sec, we have

$$V_m = 2 \times s \times \frac{n}{1000} \text{ metre/min.}$$

$$= \frac{2 \times s \times n}{1000 \times 60} \text{ m/sec}$$



**If  $s$  is given in metres then**

$$V_m = 2 \times s \times \frac{n}{60} = s \times \frac{n}{30} \text{ metre/sec.}$$

**$2 \times s$  denotes a double stroke.**

**In case of the reciprocating motion the average speed is taken into account for calculations.**

**$V_m = 2 \times s \times n$  metre/min if  $s$  is given in metres**

**Example (Fig 3)**

An extrusion press has a crank radius of 20 cm and an rpm of 30/min. Calculate the average speed in metre/min, metre/sec.

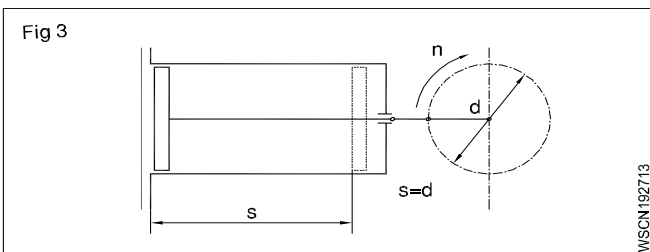
$s =$  The diameter = 40 cm.

One crank revolution makes the piston to travel in  $2s=80$ cm

$$V_m = 2 \times 400 \times \frac{30}{1000} \text{ metre/min.}$$

$$= 24 \text{ metre/min} = 0.4 \text{ metre/sec}$$

**NEWTON'S LAWS OF MOTION**



**Equations of motions under gravity**

**Upward**

$$V = u - gt$$

$$s = ut - \frac{1}{2}gt^2$$

$$u^2 - v^2 = 2gs$$

**Downward**

$$v = u + gt$$

$$s = ut + \frac{1}{2}gt^2$$

$$v^2 - u^2 = 2gs$$

**Motion under gravity**

A body falling from a height, from rest, has its velocity goes on increasing and it will be maximum when it hits the ground. Therefore a body falling freely under gravity has a uniform acceleration. When the motion is upward, the body is subjected to a gravitational retardation. The acceleration due to gravity is denoted with 'g'.

**Momentum**

It is the quantity of motion possessed by a body and is equal to the product of its mass, and the velocity with which it is moving. Unit of momentum will be kg metre/sec.

Momentum = mass x velocity

**Newton's laws**

**First law**

Every body continues to be in a state of rest or of uniform motion in a straight line unless it is compelled to change that state of rest or of uniform motion by some external force acting upon it.

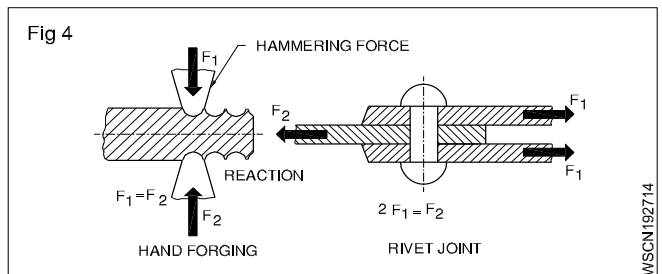
**Second law**

The rate of change of momentum of a moving body is directly proportional to the external force acting upon it and takes place in the direction of the force.

**Third law**

To every action there is always an equal and opposite reaction.

In the rivet joint equal forces act on the strap and they opposite force  $F_2$ . (Fig 4)



**Law of conservation of momentum**

When two moving bodies have an intentional or unintentional impact, then sum of the momentum of the bodies before impact = sum of the momentum after impact, or the change in momentum after the impact is zero.

- $m_1$  - mass of one body and
- $v_1$  - velocity with which it moves
- $m_2$  - mass of second body
- $v_2$  - velocity with which it moves

Momentum =  $m \times v =$  mass of the body x its velocity  
 Rate of change of momentum = force acting on the body

$$m \left( \frac{V - u}{t} \right) = F$$

force = mass x acceleration

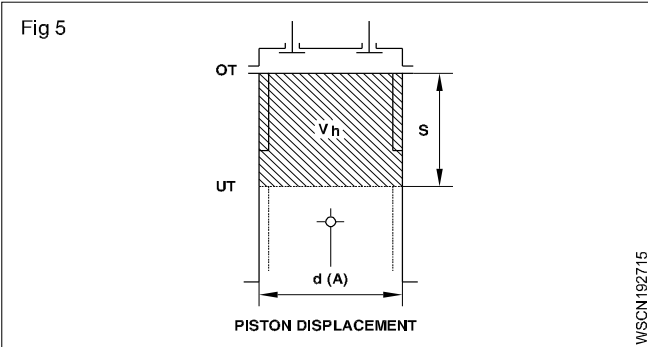
Momentum of two bodies before impact = momentum after impact

$$m_1 \times v_1 + m_2 \times v_2 = (m_1 + m_2)V$$

**Terms - Some Examples in vehicles**

**Displacement**

The piston displacement is the space between 2 dead centres (TDC and BDC) where in the piston moves in the cylinder. (Fig 5)



**Speed**

This is reckoned in 2 ways in a vehicle

- Vehicle speed in kmh/mph
- Engine speed in rpm

**Velocity**

A motor vehicle, normally changes its speed and direction on road. Hence used in velocity calculation.

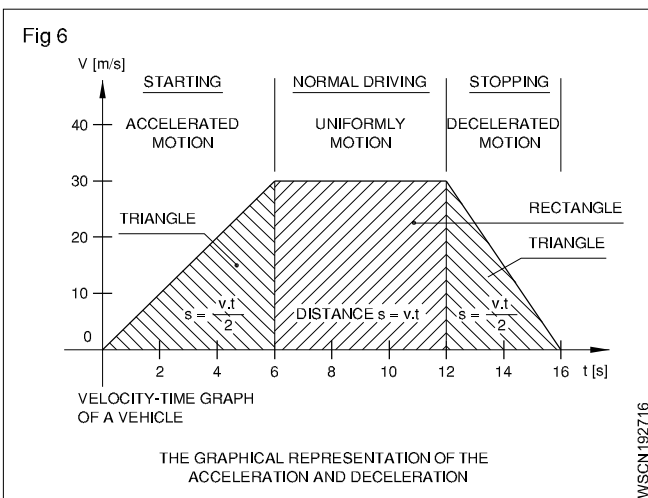
**Acceleration (Fig 6)**

When the speed of the vehicle is increased on road, it is said to be accelerated.

**Deceleration (Fig 6)**

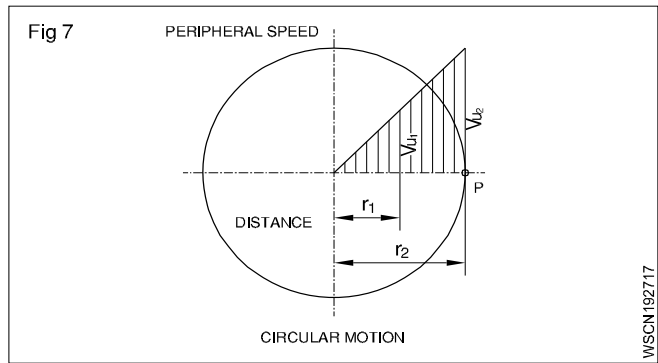
Deceleration or Retardation (this is further explained)

During the application of brakes of a vehicle the speed of the vehicle is decreased. Then it is said to be decelerated or retarded.



**Circular or Angular motion (Fig 7)**

When a body rotates about an axis, it is said to have angular motion or circular motion.



**Example**

In circular motion bodies (like shafts, axles, gear-wheels, pulleys, flywheels, grinding wheels) turn with constant speed around its axis.

The angular of circular motion is also called Angular velocity or Peripheral speed.

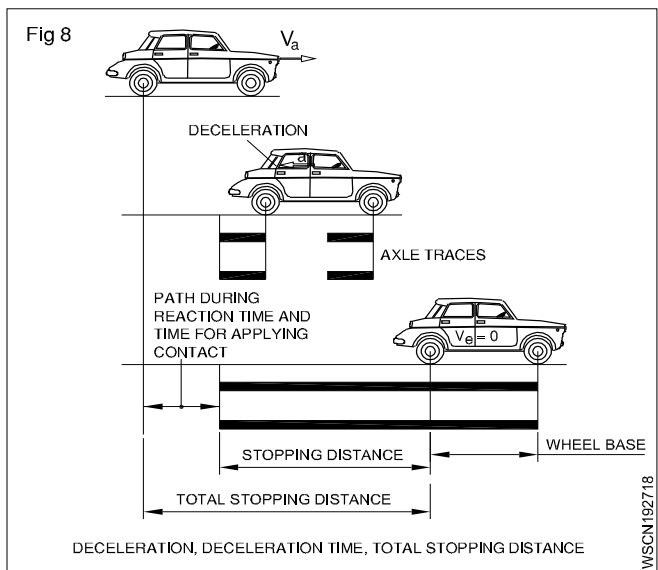
Expressed in Metre/sec or Radians per second.

**Bodies at rest and in motion**

**Terms related to brake system**

Every vehicle has a brake system. When brakes are applied on a moving vehicle (with certain velocity) its velocity is reduced and vehicle is decelerated and it stops at a certain distance. So the definition of the terms related to Brake application are set forth below.

**Deceleration (a) (Fig 8)**



This is the decrease in velocity within a certain time. e.g A car travelling at 90 kmph stops after 10 Sec.

$$\begin{aligned} \text{The deceleration} &= 90 \times \frac{1000}{3600} \times 1/10 \\ &= 25 \text{ m/s}/10 \text{ sec} \\ &= 2.5 \text{ m/sec}^2 \end{aligned}$$

**Deceleration time**

The time 10 seconds is called the above time to stop the vehicle.

## Stopping distance

During the deceleration time the car travels a distance called i.e Stopping distance 'd'.

But the total stopping distance is reckoned as equal to normal stopping distance and distance travelled by the car during reaction time of the driver.

The reaction time is explained as below

During the application of brakes, the driver takes sometime to recognise the danger and then to apply the brakes. The time (thus elapsed) is called reaction time. During this time the vehicle travels some more distance before coming to a stop. So the total stopping distance actually varies due to the reaction time of the driver and it is longer than the normal stopping distance. The reaction time varies between driver to driver.

### Example

A car is travelling with a speed of 72 kmph and its aceleration (a) = 5 m/sec<sup>2</sup>. The reaction time of driver to apply brakes is 1.5 seconds. calculate the total stopping distance.

### Solution

Velocity of car = 72 kmph

$$\left( 1 \text{ kmph} = \frac{1000 \text{ m}}{3600 \text{ sec}} = \frac{5}{18} \text{ m/sec} \right)$$

= 20 m/sec

aceleration = 5 m/sec<sup>2</sup>

$$\text{Normal stopping distance } S = \frac{V^2}{2a} \text{ (m)} = \frac{(20)^2}{2(5)} = 40$$

Total stopping distance

= 40 metre + Velocity x Reaction time

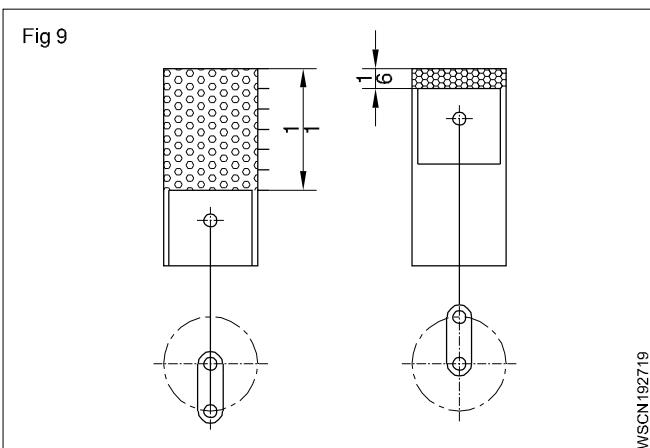
= 40 m + (20 x 1.5) m

= 70 metres.

## Newton's Law of Motion

Some Examples in vehicles

### First law (with examples) (Fig 9)



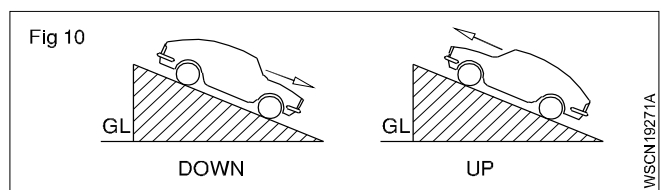
## Bodies at rest or in Uniform motion

The diesel engine piston remains at rest at TDC or BDC due to its inertia. Expansion of gas pressure or flywheel momentum moves the piston from TDC or BDC.

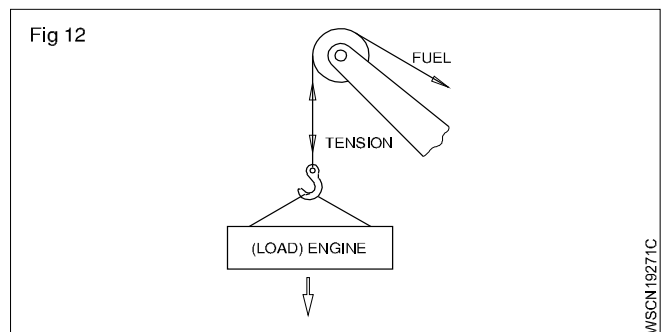
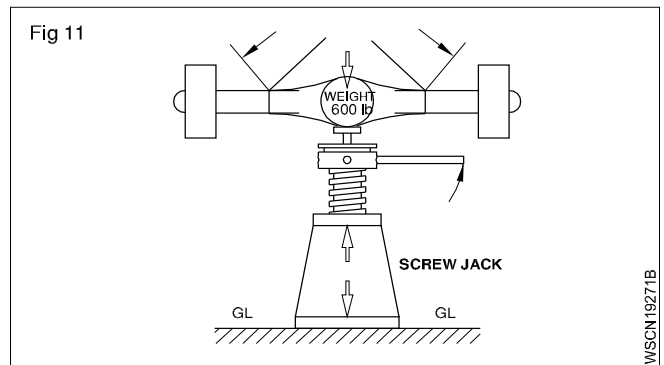
### Second law (with examples) (Fig 10)

The rate of change of momentum of a moving body (say Engine part or Vehicle) is directly proportional to external force acting take place in the direction of force.

- A connecting rod in motion is brought to rest at BDC.
- The direction of movement of a vehicle is altered by force of wind.
- When a vehicle travels in a down gradient its speed increases.
- The speed of vehicle is decreased when travelling up gradient.



### Third law (with examples) (Fig 11&12)



To every action there is always an equal and opposite reaction.

All upward force = All downward forces

- Jack is lifting a differential
- Crane rope is lifting an engine.

**Examples**

- A body travels a distance of 168 metres in a straight line in 21 secs. What velocity the body is travelling.

Velocity = distance travelled/time

$$= 168 \text{ metres}/21 \text{ secs}$$

$$= 8\text{m/sec}$$

- A train covers a distance of 150 kilometres, between two stations, in 2 1/2 hours. Determine the average velocity with which the train is moving.

Average velocity = Distance travelled/time taken

$$= 150 \text{ Km}/2 \frac{1}{2} \text{ hrs} = \frac{150}{\frac{5}{2}} = 150 \times \frac{2}{5} \text{ Km/hr}$$

$$= 60 \text{ Km/hr}$$

- A vehicle accelerates uniformly from a velocity of 8 km/hr to 24 km/hr in 4 secs. Determine the acceleration and the distance travelled by it during that time.

Initial velocity = 8 km/hr (u)

Final velocity = 24 km/hr (v)

time = 4 sec (t)

acceleration (a)

$$\therefore v = u + at$$

$$24 \text{ km/hr} = 8 \text{ km/hr} + a \times 4 \text{ sec}$$

$$(24\text{km/hr} - 8\text{km/hr} - 16\text{km/hr})$$

$$4a \text{ sec} = 16 \text{ km/hr} = 16000 \text{ metre}/3600 \text{ sec}$$

$$\text{acceleration (a)} = 16000 \text{ metre}/3600 \times 4 \text{ sec}^2$$

$$v-u = 4.44 \text{ m/sec a=}$$

$$\text{Acceleration (a)} = 1.1 \text{ metre}/\text{sec}^2$$

- A car moving with a velocity of 50 km/hr is brought to rest in 45 secs. Find out the retardation.

Initial velocity = 50 km/hr (1km= 1000 metres)

Final velocity = 0 km/hr (1 Hour=3600 seconds)

Time = 45 secs

$$v = u - at$$

$$50\text{km/hr} \times \frac{5}{18} \text{ m/sec} = 13.88 \text{ m/sec}$$

$$0 = u - at$$

$$a = \frac{v}{t} = \frac{13.88 \text{ m/sec}}{45 \text{ sec}} = 0.3\text{m}/\text{sec}^2$$

$$u = at$$

$$50000/3600 \text{ metre}/\text{sec} = a \times 45 \text{ sec}$$

$$\therefore \text{Retardation} = 50000/3600 \times 45 \text{ metre}/\text{sec}^2$$

$$= 0.30 \text{ metre}/\text{sec}^2$$

- A body falling freely under the action of gravity reaches the ground in one second. Determine the height from which the body fell. Take g = 9.81 metre/sec<sup>2</sup>.

Initial velocity = 0 metre/sec (U)

Acceleration due to gravity = 9.81 metre/sec<sup>2</sup>(g)

Time taken = 1 sec (t)

$$= ut + \frac{1}{2} gt^2 \quad 0 \times 1 \text{ sec} + \frac{1}{2} \times 9.81 \text{ m}/\text{sec}^2 \times 1^2 \text{ sec}$$

$$= 0 \times 1 \text{ sec} + \frac{1}{2} \times 9.81 \text{ metre}/\text{sec}^2 \times 1 \text{ sec}^2$$

$$1 \text{ Sec}^2 = 4.905 \text{ metres.} \quad s = 4.905 \text{ metres}$$

- A force of 30 N acts on a body at rest. The mass of the body is 50 kg. Determine the velocity of the body after 4 secs, the distance it covers during that period and the acceleration

$$F = m \times a$$

$$30 \text{ N} = 50 \text{ kg} \times a$$

$$3 \text{ kg} \times \text{metre}/\text{sec}^2 = 50 \text{ kg} \times a$$

$$\therefore \text{acceleration} = 3/50 \text{ metre}/\text{sec}^2$$

$$= 0.06 \text{ metre}/\text{sec}^2 \quad a = 0.06 \text{ m}/\text{sec}^2$$

$$v = u + at$$

$$= 0 + 0.06 \text{ metre}/\text{sec}^2 \times 4 \text{ sec} = 0.24 \text{ metre}/\text{sec}$$

$$s = ut + 1/2 at^2 = 0 + 1/2 \times 0.06 \text{ metre}/\text{sec}^2 \times 16 \text{ sec}^2$$

$$= 0.48 \text{ metre} \quad s = 0.48 \text{ metre}$$

- A stone is thrown vertically upwards with a velocity of 120 metre/sec. Determine (a) the maximum height to which it travels before starting to return to earth. (b) The total time taken by the stone to go up and come down. (c) The velocity with which it will strike the ground.

Initial velocity of throw = 120 metre/sec (u)

Final velocity = 0 metre/sec (v) (taken g = 10 m/sec<sup>2</sup>)

Retardation due to gravity = 10 metre/sec<sup>2</sup>

$$u^2 - v^2 = 2g.s$$

$$\therefore 120^2 \text{ metre}^2/\text{sec}^2 - 0 = 2 \times 10 \text{ metre}/\text{sec}^2 \times s$$

$$\therefore s = 120 \times 120/2 \times 10 \text{ metre}$$

$$= 720 \text{ metre}$$

when it comes down its velocity at start = 0 metre/sec.

The acceleration due to gravity = 10 metre/sec<sup>2</sup> and the distance travelled = 720 metre

$$\therefore v^2 - u^2 = 2as \quad v^2 - 0 = 2 \times 10 \text{ m}/\text{sec}^2 \times 720 \text{ m}$$

$$v^2 - 0 = 2 \times 10 \times 720 \text{ metre}^2/\text{sec}^2 \quad v = \sqrt{14400} \text{ m}^2/\text{sec}^2$$

$$\therefore v = 120 \text{ metre}/\text{sec}$$

Time taken to go up and reach a velocity of 0 metre/sec = u/g = 120 metre/sec/10 metre/sec<sup>2</sup> = 12 sec.

Time taken to start from rest and attain a velocity of 120 metre/sec = v/g = 12 sec.

$$\therefore \text{Total time taken} = 24 \text{ sec.}$$

- Calculate the Angular velocity in radian/second of an engine flywheel when it is rotating at 2800 rpm. (Fig 1 & 2)

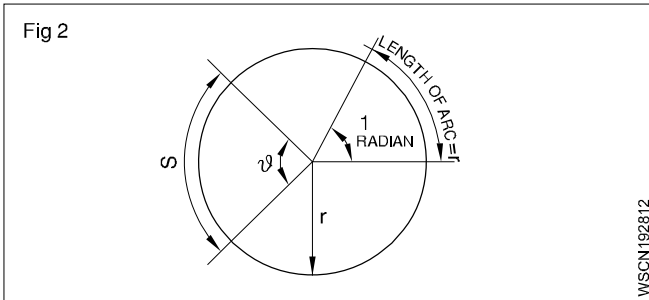
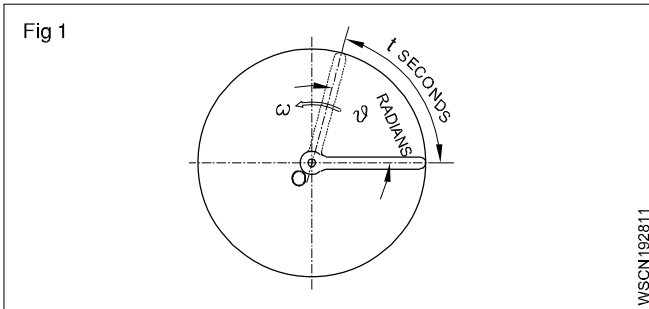
Angular velocity (W) = This is the rate of change of displacement or angle turned through per unit time.

Solution

Angular velocity of flywheel  $W = \frac{2\pi N}{60}$  rad/sec.  
[N = 2800 rpm]

$$= \frac{2\pi \times 2800}{60} \text{ radian/sec.}$$

$$= 293.3 \text{ radian/sec.}$$



- A motor car road wheel of dia 540 mm turns through an angle of  $120^\circ$ . Calculate the distance moved by a point on tyre thread of the wheel.

Solution

There are  $2\pi$  radians in one turn of wheel. i.e  $2\pi$  radians =  $360^\circ$

Since wheel turns  $120^\circ$  angle,  $120^\circ = 120 \times \frac{2\pi}{360}$   
= 2.094 radians

Distance moved by a point on tyre  $S = r\theta$

[where  $r = 270$  mm

$$\theta = 2.094 \text{ radian}]$$

$$S = 270 \times 2.094 \text{ mm}$$

$$= 565.38 \text{ mm}$$

Circumferential distance moved by the point = 565.38 mm

- The rear wheels of a car have diameter of 600 mm. The rear axle makes 250 rpm. Find out the peripheral speed of rear wheels in m/sec.

Solution

$$\text{Peripheral speed } V = \frac{\pi d N}{1000} \times \frac{1}{60} \text{ (m/s)}$$

$$= \frac{3.14 \times 600}{60} \times \frac{250}{1000} = 7.85 \text{ m/sec}$$

- Calculate the stopping distance of a car travelling with a speed of 72 km/h and being accelerated with a  $-5 \text{ m/sec}^2$ .

Solution

$V_a$  (initial speed of a car) = 72 kmph

$$\left(1 \text{ kmph} \times \frac{1000}{3600} \text{ m/sec}\right) = 72 \times \frac{5}{18} \text{ m/sec}$$

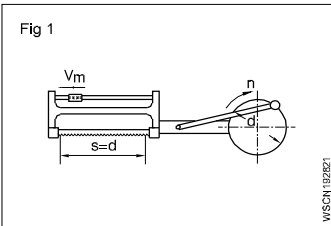
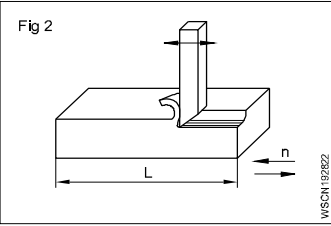
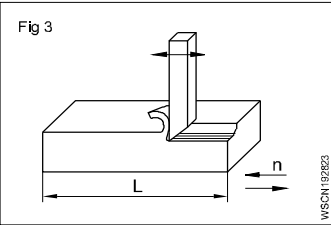
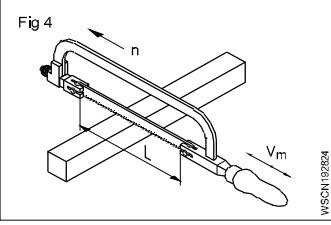
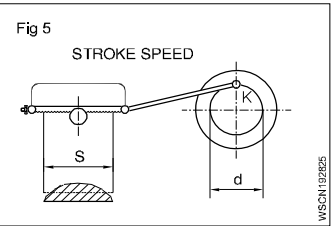
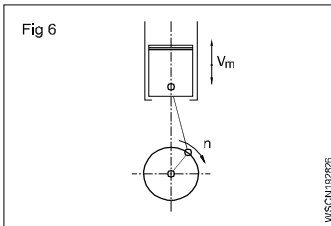
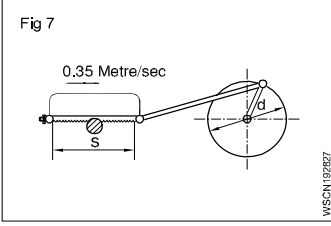
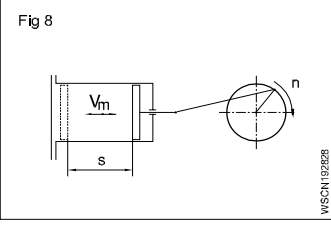
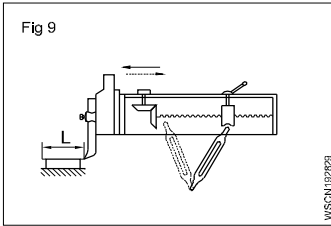
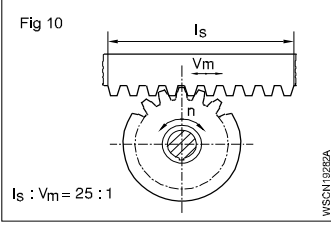
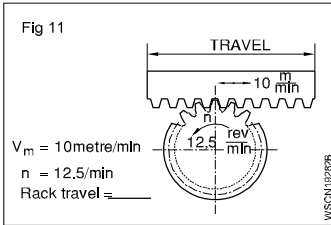
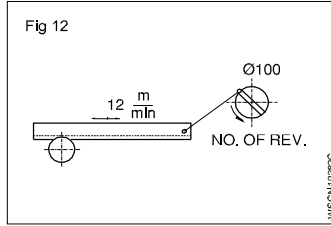
$$= 20 \text{ metres/sec}$$

$$\text{Stopping distance } S = \frac{V_a^2}{2a} \text{ (metre)}$$

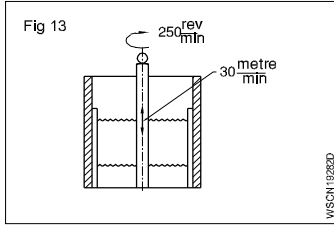
$$= \frac{20^2}{2 \times 5} = \frac{400}{10}$$

$$= 40 \text{ metre}$$

# ASSIGNMENT

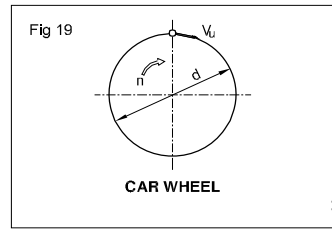
- 1   $S = 180 \text{ mm}$   
 $n = 65 \text{ (double stroke)}$   
 $V_m = \underline{\hspace{2cm}} \text{ metre/min}$   
 $V_m$  is average cutting speed)
- 2   $V = 16 \text{ metre/min}$   
 $s = 210 \text{ mm}$   
 $n = \underline{\hspace{2cm}}$
- 3  (V is the cutting speed)  
 $n = 22 \text{ strokes (Double stroke)/min}$   
 $V = 18 \text{ metre/min}$   
 $s = \underline{\hspace{2cm}} \text{ mm}$
- 4   $s = 240 \text{ mm}$   
 $n = 30 \text{ (working stroke)}$   
 $V = \underline{\hspace{2cm}} \text{ metre/min}$
- 5   $n = 50 \text{ cutting strokes}$   
 $V = 32 \text{ metre/min}$   
 $d = \underline{\hspace{2cm}} \text{ mm}$
- 6   $s = 64 \text{ mm}$   
 $n = 3600 \text{ rpm}$   
 $V_m = \underline{\hspace{2cm}} \text{ metre/sec}$   
 $V_m$  is the average piston speed)
- 7   $V_m = 0.35 \text{ metre/sec}$   
 $s = 200 \text{ mm}$   
 $n = \underline{\hspace{2cm}} \text{ rpm}$
- 8   $s = 650 \text{ mm}$   
 $V_m = 90 \text{ metre/min}$   
 $n = \underline{\hspace{2cm}} \text{ rpm}$
- 9  $V_{m1} = 5.2 \text{ metre/sec}$   
 Increased to  
 $V_{m2} = 6.3 \text{ metre/sec}$   
 Increase in  $n$  (rpm) =  $\underline{\hspace{2cm}} \%$
- 10   $s = 250 \text{ mm}$   
 $n = 45 \text{ (double strokes)}$   
 $V = \underline{\hspace{2cm}} \text{ metre/min}$
- 11   $Is : V_m = 25 : 1$   
 $n = \underline{\hspace{2cm}} \text{ (double strokes)}$   
 $Is = \text{rack travel}$   
 $V_x m = \text{stroke speed/min}$
- 12   $V_m = 10 \text{ metre/min.}$   
 $n = 12.5 / \text{min.}$   
 Rack travel =  $\underline{\hspace{2cm}}$
- 13   $\text{dia of crank} = 100 \text{ mm}$   
 Rack speed =  $12 \text{ metre/min}$   
 Crank disc 'n' =  $\underline{\hspace{2cm}} \text{ rpm}$

14



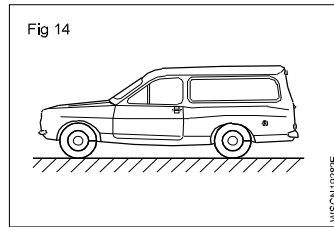
spindle 'n' = 250 rpm  
 Average stroke speed  
 = 30 metre/min  
 stroke length = \_\_\_\_\_ mm

20



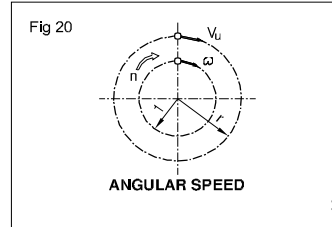
Car wheel  
 n = 720 rpm  
 Peripheral speed  
 = 18.84 m/sec  
 d = \_\_\_\_\_

15



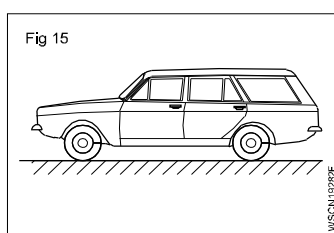
Car Speed = 90 km/hr  
 Time to stop = 10 sec  
 Deceleration  
 = \_\_\_\_\_ metre/  
 sec<sup>2</sup>

21



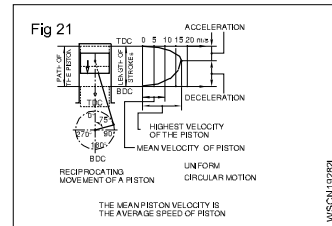
Angular speed  
 n = 2000 rpm  
 Angular velocity  
 = \_\_\_\_\_ radians/sec  
 Use  
 W = 2πN/60 rad/sec

16



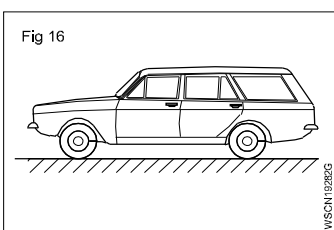
Car speed = 80 km/hr  
 Distance stopped = 60 metre  
 Deceleration of car  
 = \_\_\_\_\_ metre/sec<sup>2</sup>

22



Piston Velocity/Speed  
 S = 74 mm  
 n = 4500 rpm  
 Mean velocity  
 = \_\_\_\_\_ m/sec  
 Maximum velocity  
 5 = \_\_\_\_\_ m/sec  
 (Average Speed of  
 Piston)

17



Deceleration = 4.5 m/  
 sec<sup>2</sup>  
 Stopping distance = 50 metres  
 Velocity of car  
 = \_\_\_\_\_ km/hr

23 Total Stopping Distance =  $\frac{V^2}{2a}$  + velocity × reaction time

(Use = V<sup>2</sup>/2a)

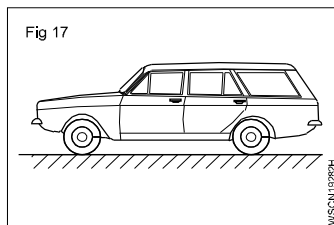
V = Vehicle speed = 80 km/hr

Deceleration = 5m/sec<sup>2</sup>

Reaction Time of driver = 2 seconds

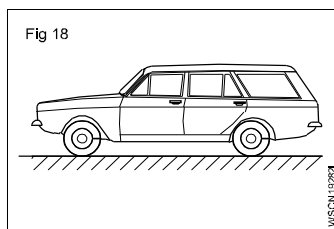
Total Stopping Distance = \_\_\_\_\_ meter

18



Distance travelled by  
 car = 600 km  
 Time = 8 hrs 20 min  
 Average velocity  
 = \_\_\_\_\_ km/hr

19



Average velocity  
 = 56.3 km/hr  
 Distance travelled  
 = 464.475 km  
 Travelling time  
 = \_\_\_\_\_ hrs

# Units of work, power and energy, horse power of engines and mechanical efficiency

## Exercise 1.10.29

F - force or weight force in N

s - distance the body on which force acts is moved in metres

t - time in seconds

v - speed in metre/sec

w - work done by the force in joules

P - Power in Watts

$P_{out}$  - Power output

$P_{in}$  - Power input

### Force

A Force is that which changes or tends to change the state of rest or motion of a body.

Force = Mass x Acceleration

$$F = Ma$$

### Unit

$$F = M \times a$$

$$= \text{kg} \times \text{m}/\text{sec}^2$$

$$= 1 \text{ Newton (SI unit)}$$

**(Newton: If 1 kg of mass accelerates at the rate of 1m/sec<sup>2</sup> then the force exerted on the mass is 1 newton)**

$$\text{FPS} = 1 \text{ pound} \times 1 \text{ Feet}/\text{second}^2$$

$$= 1 \text{ pound}$$

$$\text{CGS} = 1 \text{ gm} \times 1\text{cm}/\text{second}^2$$

$$= \text{Dyne}$$

$$\text{Mks} = 1 \text{ kg} \times 1\text{m}/\text{second}^2$$

$$= \text{Newton.}$$

$$1 \text{ Newton} = 10^5 \text{ dynes}$$

$$1\text{kg wt} = 9.81\text{N}$$

$$1 \text{ pound} = 4.448\text{N,}$$

$$\text{Newton} = 0.225 \text{ pound.}$$

### Work(Fig 1)

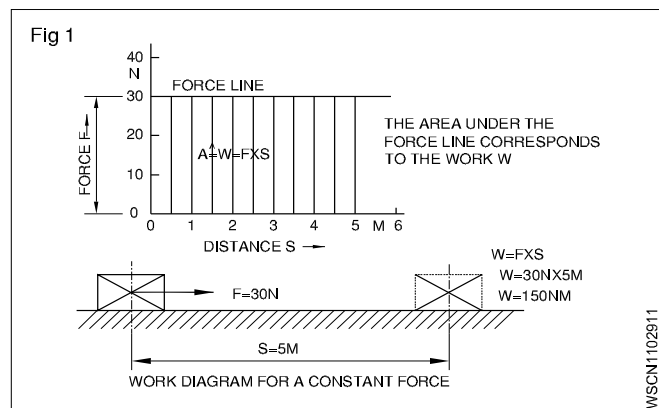
Work is said to be done by a force, when it moves, its point of application through a distance. Applied for 'F' moves a body through a distance's.

Work done 'W' = F x s.

The S.I. unit of work is 1 joule which is the work done by a force of moving the body through a distance of 1 metre.

Therefore joule = 1 N x 1 metre = 1 Nm

Also 1 joule = 1 Nm = 10<sup>5</sup> dynes x 100 cm = 10<sup>7</sup> dynes cm = 10<sup>7</sup> ergs.



### Absolute units (Fig 2)

In C.G.S. system unit of work = 1 erg = 1 dyne x 1 cm

In F.P.S system unit of work = 1 Foot poundal = 1 poundal x 1 foot

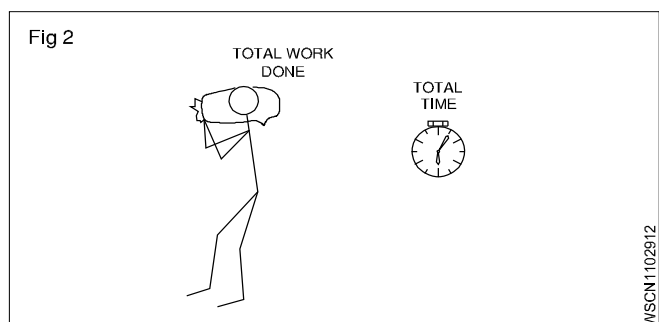
In M.K.S. system unit of work = 1 joule = 1 Newton x 1 metre

### Derived units

C.G.S. system 1 Gm Wt x 1 cm = 981 ergs.

F.P.S. system 1 ft LB = 981 foot poundal

M.K.S. system 1 kgf metre = 981 joule.



### Power(Fig 2)

It is the work done in unit time.

$$\text{Power } P = \frac{\text{total work done}}{\text{total time}}$$

$$P = \frac{\text{Nm}}{\text{sec}}$$

$$\text{The S.I units of power} = 1\text{Nm}/\text{sec} = \frac{1 \text{ joule}}{\text{sec}}$$

$$\text{which is} = 1 \text{ watt. power in watts} = \frac{w}{t} = \frac{F \cdot s}{t} = FXV$$

which is equal to 1 Watt. Power in watts = w/t = F.s/t = F x V

In M.K.S. system the unit is 1 kgf meter/sec. One horse power is = 75 kg metre/sec or 4500 kgf metre/min.

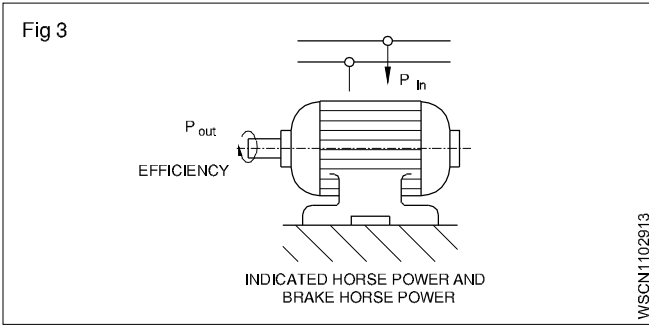


1HP (metric) = 735.5 Watts

1HP (British) = 746 Watts = 0.746 KW

1 KW = 1.34 HP

Power input is the power given to a machine to do work. Power output is what we get out of the machine. Power output is always less than power input due to friction in the machine. The ratio between power output to power input is efficiency of the machine and it is expressed percentage.(Fig 3)



$$\text{efficiency} = \frac{\text{power output}}{\text{power input}} \times 100\%$$

### Indicated Horse Power and Brake Horse Power

The power actually generated by the engine or generator is the indicated horse power which is indicated on the plate.

The Brake horse power is the power available to do useful work. B.H.P is always less than I.H.P. due to losses to overcome frictional resistance.

$$\therefore \text{mechanical efficiency} = \frac{\text{B.H.P}}{\text{I.H.P}} \times 100\%$$

Work done by a force = Magnitude of the force x distance moved by the body

Power = Total work done / total time taken

$$\text{efficiency} = \frac{\text{power output}}{\text{power input}} \times 100\%$$

### Energy

The energy of a body is its capacity to do work. It is equal to power x time. Hence the unit of energy is the same as the unit of work in all systems.

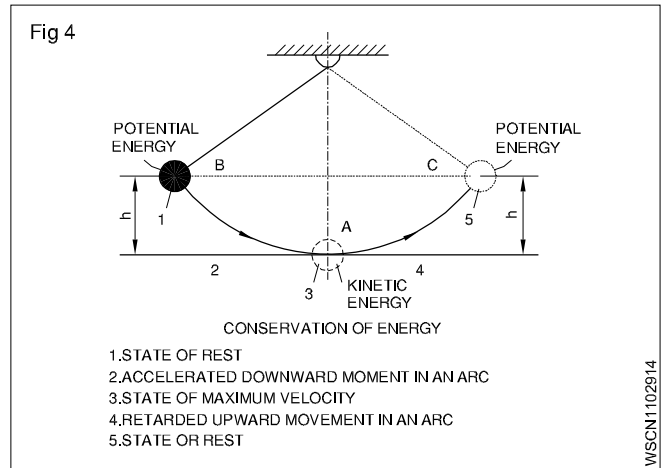
### Forms of energy

Mechanical energy, Electrical energy, Atomic energy, Heat energy, Light energy, Chemical energy, sound energy. Energy of one form can be transformed into energy of another form.

### Law of conservation of energy

- The energy can neither be created nor destroyed.
- Total energy possessed by a body remains the same.(Fig 4)

Depending upon the position of the body or body in motion, mechanical energy possessed by the body may be potential energy or kinetic energy respectively.



### Potential energy

Potential energy is the energy possessed by a body by virtue of its position (Fig 4). A body of mass 'm' kept at a height 'h' from a datum possesses a potential energy of mgh or Wh or Fh; where W or F are the Weight force. When the body is allowed to fall it will be able to do a useful work of Fh.

### Example

- Water stored in a Tank
- Coil Spring.

### Kinetic energy

It is the energy possessed by a body by virtue of its motion. If a body of mass 'm' starting from rest attains a velocity of 'v' after covering a distance of 's', by the action of an applied force 'F', then work done on the body=F x s But F= m x a. Therefore work done on the body = m x a x s.

But a x s =  $\frac{v^2}{2}$  because the body is starting from rest.

Therefore Work done on the body =  $\frac{1}{2}mv^2$ .

Since work done on the body = The energy possessed by the body

$$\text{Kinetic Energy} = \frac{1}{2}mv^2$$

Energy possessed by a body = work done on the body

Potential energy = mgh

$$\text{Kinetic energy} = \frac{1}{2}mv^2$$

If friction is neglected potential energy = Kinetic energy

### Example

- Rolling vehicle
- Rotating fly wheel
- Flowing water
- Falling weight

# Potential energy, kinetic energy and related problems with assignment

## Exercise 1.10.30

### Potential energy

Hammer head drops from height 'h'. m = 10 kg.

$$h = 1.4 \text{ m.}$$

$$u = 0 \frac{\text{metre}}{\text{sec}}$$

$$V^2 = 2 \text{ gs}$$

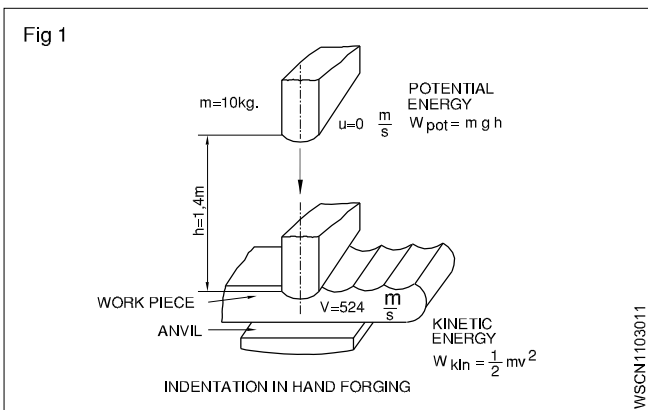
$$V^2 = 2 \times 9.81 \times 1.4$$

$$V^2 = 27.468$$

$$V^2 = 5.24 \text{ m/sec}$$

$$= 10 \text{ kg} \times 9.81 \text{ metre/sec}^2 \times 1.4 \text{ metre (Fig 5)}$$

$$= 137.3 \text{ N metre} \quad (\because 1\text{N} = 1\text{kg.m/sec}^2)$$

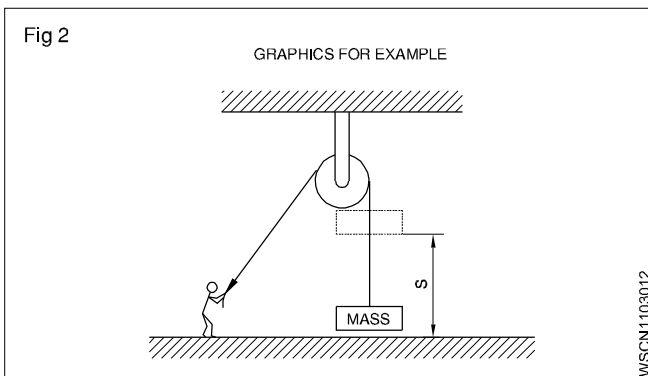


$$\text{K.E} = \frac{1}{2} \times 10 \text{ kg} \times 5.24^2 \frac{\text{metre}^2}{\text{sec}^2}$$

$$= 137.3 \text{ N metre.}$$

### Examples

- A pulley is used to lift a mass with a force of 900 N to a height of 10 metres in 2 minutes. Find the work done by the force and also the power. (Fig 6)



$$\text{Work done} = F \times s = 900\text{N} \times 10 \text{ metre}$$

$$= 9000 \text{ Nm} = 9000 \text{ joules.}$$

$$\text{Power} = \frac{W}{t} = \frac{9000 \text{ joules}}{120\text{sec}}$$

$$= \frac{75 \text{ joules}}{\text{sec}}$$

$$= 75 \text{ watts}$$

- Determine the horse power required to drive a lift in raising a load of 2000 kgf at a speed of 2 metre/sec, if the efficiency is 70%.

Useful workdone to raise the lift in 1 sec

$$\text{Force} = 2000 \text{ kgf}$$

$$\text{Work} = F \times d$$

$$\text{Power} = \frac{F \times d}{t} = \frac{2000 \times 2}{1} = 4000 \text{ w}$$

$$\text{Power output} = 4000 \text{ w}$$

$$\text{Power input} = \text{Power output}$$

$$= \frac{4000}{0.7} = 5714 \text{ w}$$

$$\eta = \frac{\text{Output}}{\text{Input}} \times 100\%$$

$$\text{HP} = \frac{5714}{746} = 7.659 \approx 7.6 \text{ HP}$$

$$\text{Power input} = 7.6 \text{ HP}$$

- A mass of 100 gm is allowed to fall from a height of 10 metres. Determine the amount of Kinetic energy gained by the body. (Take the value of g as 10 metre/sec<sup>2</sup>)

Since initial velocity is 0 and distance travelled is 10 metres. final velocity<sup>2</sup>

$$= V^2 = 2 \times g \times s = 2 \times 10 \times 10 \text{ metre}^2/\text{sec}^2$$

$$\therefore \text{K.E} = \frac{1}{2} mv^2 = \frac{1}{2} \times 100 \text{ gm} \times 200 \text{ metres}^2/\text{sec}^2$$

$$= 10000 \text{ gm metre}^2/\text{sec}^2$$

$$= 10 \times 10^7 \text{ ergs}$$

$$= 10 \text{ Joules.}$$

### K.E. developed by the vehicle at a constant speed

- A motor vehicle of one tonne is travelling at 60 km/hr. Calculate K.E of the vehicle at this speed.

$$\text{K.E of the vehicle} = \frac{1}{2} mv^2$$

Where m = one tonne or 1000 kg

$$v = 60 \text{ km/hr}$$

Solution

Changing v into meter/sec we get,

$$V = 60 \times \frac{1000}{60 \times 60} = \frac{50}{3} \text{ m/sec} \quad (\because 1 \text{ km} = 1000 \text{ m})$$
$$\quad (\because 1 \text{ hour} = 3600 \text{ sec})$$

$$\begin{aligned} \text{Now K.E. of vehicle} &= \frac{1}{2} \times 1000 \times \frac{50}{3} \times \frac{50}{3} \\ &= 1000 \times \frac{2500}{18} \\ &= \frac{2500000}{18} \text{ J} \\ &= \frac{2500000}{100 \times 18} \text{ KJ} \\ &= \frac{1250}{9} \text{ KJ} \\ &= 138.89 \text{ KJ} \end{aligned}$$

#### K.E. developed by a vehicle during acceleration

- A motor vehicle of 1200 Kg mass is being accelerated 36 km to 48 km/hr speed. Calculate the increase in K.E during its acceleration.

Solution

Mass of motor vehicle = 1200 kg

K.E. of the vehicle at 36 km/hr speed

$$= \frac{1}{2} \times 1200 \times 36^2 \text{ J} \quad \text{KE} = \frac{1}{2} mv^2 \text{ J}$$

$$v = 36 \text{ km/hr} = 36 \times \frac{1000}{60 \times 60} = 10 \text{ m/sec}$$

K.E of the vehicle at 48 km/hr speed

$$= \frac{1}{2} \times 1200 \times 48^2 \text{ J} \quad (\because 1 \text{ kg.m/sec}^2 = 1 \text{ N})$$

( $\because 1 \text{ Nm} = 1 \text{ J}$ )

$$v = 48 \text{ km/hr} = 48 \times \frac{1000}{60 \times 60} = \frac{40}{3} \text{ m/sec}$$

$$\text{KE} = \frac{1}{2} \times 1200 \times 10 \times 10 = 60000 \text{ J}$$

$$\text{KE} = \frac{1}{2} \times 1200 \times \frac{40}{3} \times \frac{40}{3} = 106666.67 \text{ J}$$

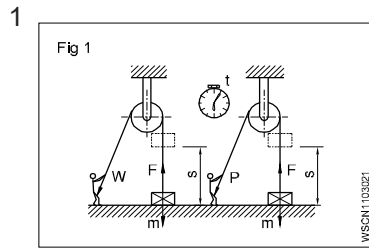
$$\begin{aligned} \text{Increase in K.E of the vehicle} &= 106666.67 \text{ J} - 60000 \text{ J} \\ &= 46666.67 \text{ J} \\ &= 46.666 \text{ KJ.} \end{aligned}$$

#### Workdone in vehicle operation

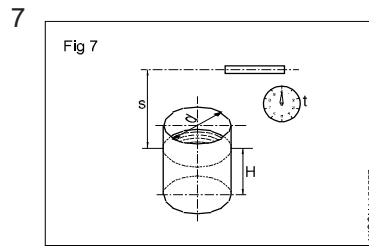
The Mechanical Work performed by the motor vehicle for its propulsion on road can generally be classified into two major categories of work done.

- Workdone by the IC engine in developing full power under all condition of speed and load.
- Workdone by the motor vehicle in performing different operations on road like hill climbing/acceleration/braking/ towing and reversing operation

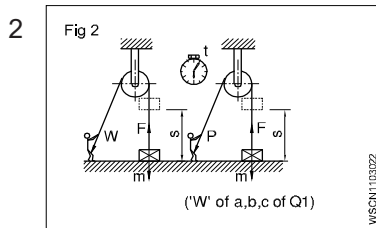
# ASSIGNMENT



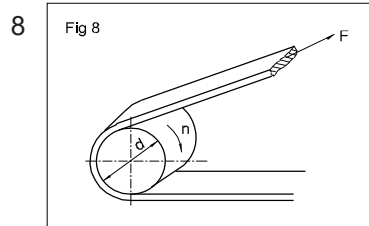
$m = 55 \text{ kg}$   
 a)  $s = 1.82 \text{ metres}$   
 $W = \text{_____ joules}$   
 b)  $s = 1.40 \text{ metres}$   
 $W = \text{_____ joules}$   
 c)  $s = 0.85 \text{ metres}$   
 $W = \text{Joules}$



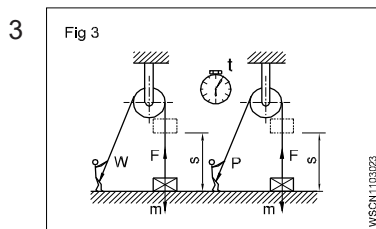
$d = 3 \text{ metre}$   
 $H = 2 \text{ metre}$   
 $t = 20 \text{ minutes}$   
 $s = 6 \text{ metres}$   
 $P = \text{_____ kW}$   
 Water filled in the tank. s is the pumping height



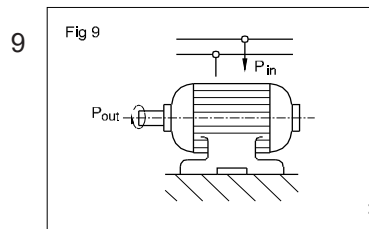
$t = 8 \text{ secs}$   
 a)  $P = \text{_____ Watts}$   
 b)  $P = \text{_____ Watts}$   
 c)  $P = \text{_____ Watts}$



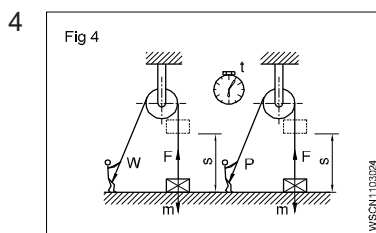
$d = 200 \text{ mm}$   
 $n = 750 \text{ rpm}$   
 $F = 700 \text{ N}$   
 $P = \text{_____ kW}$



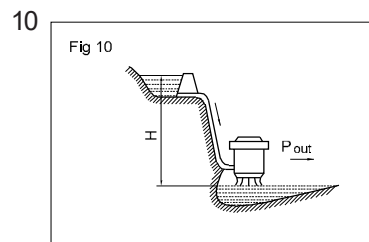
$W = 1312.5 \text{ Joules}$   
 $m = 350 \text{ kg}$   
 $s = \text{_____ metres}$



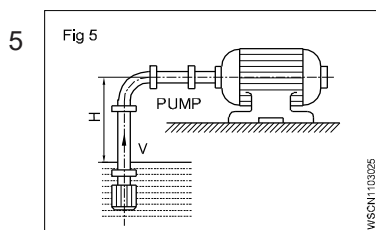
$P_{\text{input}} = 4 \text{ kW}$   
 $P_{\text{output}} = 3450 \text{ Joules/sec}$   
 $\eta = \text{_____ \%}$



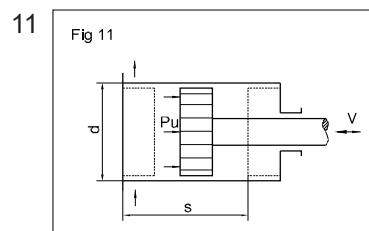
$m = 75 \text{ kg}$   
 $s = 100 \text{ metres}$   
 $t = 12 \text{ secs}$   
 $W = \text{_____ Nm}$   
 $P = \text{_____ Watts}$



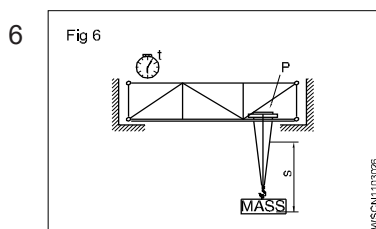
Volume of water  
 $'V' = 10 \text{ metre}^3$   
 $H = 18 \text{ metres}$   
 $t = 20 \text{ sec}$   
 $\eta = 70 \%$   
 $P_{\text{output}} = \text{_____ kW}$



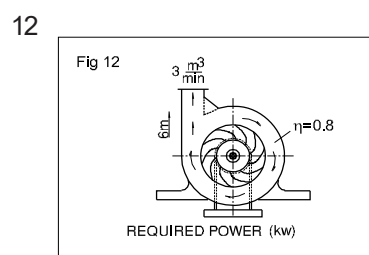
$V = 1 \text{ m}^3/\text{min}$   
 $H = 2 \text{ m}$   
 $\eta = 0.75$   
 Power input = \_\_\_\_\_ kW



$d = 225 \text{ mm}$   
 $s = 450 \text{ mm}$   
 Piston pressure  
 $'P' = 4.5 \text{ bar}$   
 $V = 2.5 \text{ metre/sec}$  (piston speed)  
 $\eta = 70 \%$   
 Power input = \_\_\_\_\_ kW



$P = 12 \text{ kw}$   
 $s = 4 \text{ metres}$   
 $t = 20 \text{ secs}$   
 $m = \text{_____ kg}$



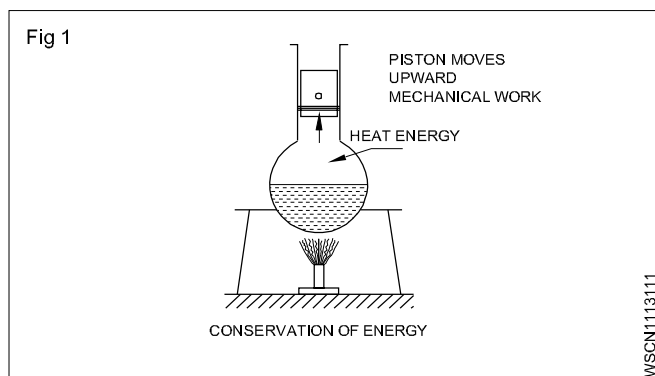
$'V'$  of water pumped  
 $= 3 \text{ metre}^3/\text{min}$   
 $H = 6 \text{ metre}$   
 $\eta = 0.8$   
 Power input = \_\_\_\_\_ kW

# Concept of heat and temperature, effects of heat, thermometer scale, celcius, fahrenheit, reamer, kelvin and difference between heat and temperature

## Exercise 1.11.31

### Heat

It is a form of energy. Heat energy can be transformed into other forms of energies. Heat flows from a hotter body to a colder body. (Fig 1)



### Units of heat

**Calorie:** It is the quantity of heat required to raise the temperature of 1 gram of water through 1°C.

**BTHU:** It is the quantity of heat required to raise 1 lb of water through 1°F. (British thermal unit).

**C.H.U;** It is the quantity of heat required to raise 1 lb of water through 1°C.

**Joule :** S.I. Unit (1 Calorie = 4.186 joule)

### Effects of heat

- Change in temperature
- Change in size
- Change in state
- Change in structure
- Change in Physical properties

### Specific heat

The quantity of heat required to raise the temperature of one gm of a substance through 1°C is called specific heat. It is denoted by the letter 's'.

Specific heat of water	= 1
Aluminium	= 0.22
Copper	= 0.1
Iron	= 0.12

### Thermal capacity:

It is the amount of heat required to raise the temperature of a substance through 1°C is called the thermal capacity of the substance.

Thermal capacity = ms calories.

**Calorific value:** The amount of heat released by the complete combustion of unit quantity of the fuel (Mass or volume) is known as calorific value of fuels.

### Water equivalent

It is the mass of water which will absorb the same amount of heat as the given substance for the same temperature rise. Water equivalent = Mass of the substance x specific heat of the substance.

Therefore water equivalent = ms

### Types of heat

- 1 Sensible heat and
- 2 Latent heat

#### 1 Sensible heat

Sensible heat is the heat absorbed or given off by a substance without changing its physical state. It is sensible and can be observed by the variation of temperature in the thermometers.

#### 2 Latent heat

The heat gained or given by the substance during a change of state (from solid to liquid to gas) is called latent heat or hidden heat. The heat absorbed or given off does not cause and temperature change in the substance.

Types, 1. Latent heat of fusion of solid

2. Latent heat of vaporisation of solid.

#### 1 Latent heat of fusion of solid

The amount of heat required per unit mass of a substance at melting point to convert it from the solid to the liquid state is called latent heat of fusion of solid. Its unit is cal/gram.

#### Latent heat of fusion of ice

The amount of heat required to convert per unit mass of the ice into water at 0°C temperature is called latent heat of fusion of ice.

Latent heat of fusion of ice(L) = 80 cal/gram

#### 2 Latent heat of vapourisation of liquid

The amount of heat required to vaporise a unit mass of liquid at its boiling point is called latent heat of vapourisation.

#### Latent heat of vaporisation of water or latent heat of steam

The amount of heat required to convert into steam of a unit mass of water at its boiling point (100°C) is called latent heat of vaporisation of water or latent heat of steam.

Latent heat of steam(L) = 540 cal/gram

## Temperature

It is the degree of hotness or coldness of a body. The temperature is measured by thermometers.

### Temperature Scales

Temperatures are calibrated between two fixed reference points namely the freezing point of water, and the boiling point of water. These two fixed points on different temperature scales are:

Scale	Freezing point	Boiling point
Centigrade (°C)	0°C	100°C
Fahrenheit (°F)	32°F	212°F
Kelvin (K)	273°K	373°K
Reaumur (°R)	0°R	80°R

**Heat is a form of energy. Temperature is the degree of hotness or coldness of a body. The relationship for conversion from one temperature scale to the others is**

$$\frac{^{\circ}\text{R}}{80} = \frac{^{\circ}\text{C}}{100} = \frac{^{\circ}\text{K} - 273}{100} = \frac{^{\circ}\text{F} - 32}{180}$$

### Boiling point

Any substance starts turning into a gas shows the temperature at which it boils this is known as the boiling point. The boiling point of water is 100°C.

### Melting point

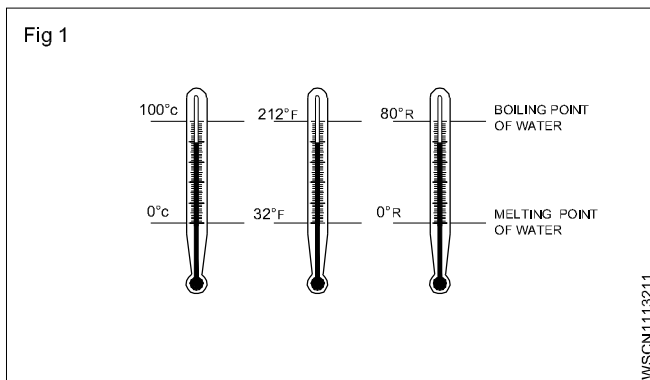
The temperature at which any solid melts into liquid or liquid freezing to solid is called the melting point of substance. The melting point of ice is 0°C.

### Difference between heat and temperature

Heat	Temperature
1 It is a form of energy.	This tells the state of heat.
2 Its unit is calorie.	Its unit is degree.
3 Heat is measured by calorimeter.	Temperature is measured by thermometer.
4 By adding quantity of heat of two substances their total heat can be calculated.	By adding two temperatures we cannot find the temperature of the mixture.
5 By heating a substance the quantity of heat is increased regardless of increase in temperature.	Two substances may read the same temperature though they might be having different amount of heat in them.

# Conversion between centigrade, fahrenheit, reamer, kelvin scale of temperature

## Exercise 1.11.32



1 Convert  $0^{\circ}\text{C}$  into  $^{\circ}\text{F}$

$$\frac{^{\circ}\text{F} - 32}{180} = \frac{^{\circ}\text{C}}{100}$$

$$^{\circ}\text{F} - 32 = \frac{^{\circ}\text{C}}{100} \times 180$$

$$^{\circ}\text{F} - 32 = \frac{0}{100} \times 180$$

$$\begin{aligned} ^{\circ}\text{F} &= 0 + 32 \\ &= 32^{\circ}\text{F} \end{aligned}$$

$$\mathbf{0^{\circ}\text{C} = 32^{\circ}\text{F}}$$

2 Convert  $-40^{\circ}\text{C}$  into  $^{\circ}\text{F}$

$$\frac{^{\circ}\text{F} - 32}{180} = \frac{^{\circ}\text{C}}{100}$$

$$^{\circ}\text{F} - 32 = \frac{^{\circ}\text{C}}{100} \times 180$$

$$^{\circ}\text{F} - 32 = \frac{-40}{100} \times 180$$

$$\text{F} - 32 = -72$$

$$\begin{aligned} ^{\circ}\text{F} &= -72 + 32 \\ &= -40^{\circ}\text{F} \end{aligned}$$

$$\mathbf{-40^{\circ}\text{C} = -40^{\circ}\text{F}}$$

3 Convert  $37^{\circ}\text{C}$  into k

$$\frac{^{\circ}\text{C}}{100} = \frac{^{\circ}\text{K} - 273}{100}$$

$$^{\circ}\text{K} - 273 = \text{C}$$

$$^{\circ}\text{K} = \text{C} + 273$$

$$^{\circ}\text{K} = 37 + 273$$

$$= 310 \text{ K}$$

$$\mathbf{37^{\circ}\text{C} = 310 \text{ K}}$$

4 Convert  $70^{\circ}\text{C}$  into Reaumer

$$\frac{^{\circ}\text{C}}{100} = \frac{^{\circ}\text{R}}{80}$$

$$^{\circ}\text{R} = \frac{\text{C}}{100} \times 80$$

$$^{\circ}\text{R} = \frac{70}{100} \times 80 = 56$$

$$\mathbf{70^{\circ}\text{C} = 56^{\circ}\text{R}}$$

5 Convert  $-25^{\circ}\text{F}$  into  $^{\circ}\text{C}$

$$\frac{^{\circ}\text{C}}{100} = \frac{^{\circ}\text{F} - 32}{180}$$

$$\frac{^{\circ}\text{C}}{100} = \frac{-25 - 32}{180}$$

$$^{\circ}\text{C} = \frac{-57}{180} \times 100$$

$$^{\circ}\text{C} = \frac{-285}{9} = -31.66$$

$$\mathbf{-25^{\circ}\text{F} = -31.7^{\circ}\text{C}}$$

6 Convert  $98.6^{\circ}\text{F}$  into  $^{\circ}\text{C}$

$$^{\circ}\text{C} = \frac{^{\circ}\text{F} - 32}{180} \times 100$$

$$^{\circ}\text{C} = \frac{98.6 - 32}{180} \times 100$$

$$= \frac{66.6}{180} \times 100$$

$$= \frac{6660}{180} = 37^{\circ}\text{C}$$

$$\mathbf{98.6^{\circ}\text{F} = 37^{\circ}\text{C}}$$

## ASSIGNMENT

Convert the following

1  $10.5^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

2  $40^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

3  $60^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

4  $80^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

5  $105^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

6  $-100^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

7  $77^{\circ}\text{F} = \underline{\hspace{1cm}}^{\circ}\text{C}$

8  $20^{\circ}\text{F} = \underline{\hspace{1cm}}^{\circ}\text{C}$

9  $428^{\circ}\text{F} = \underline{\hspace{1cm}}^{\circ}\text{C}$

10  $-210^{\circ}\text{F} = \underline{\hspace{1cm}}^{\circ}\text{C}$

11  $72^{\circ}\text{R} = \underline{\hspace{1cm}}^{\circ}\text{C}$

12  $143^{\circ}\text{C} = \underline{\hspace{1cm}}\text{K}$

13  $373^{\circ}\text{K} = \underline{\hspace{1cm}}^{\circ}\text{C}$

14  $746^{\circ}\text{K} = \underline{\hspace{1cm}}^{\circ}\text{F}$

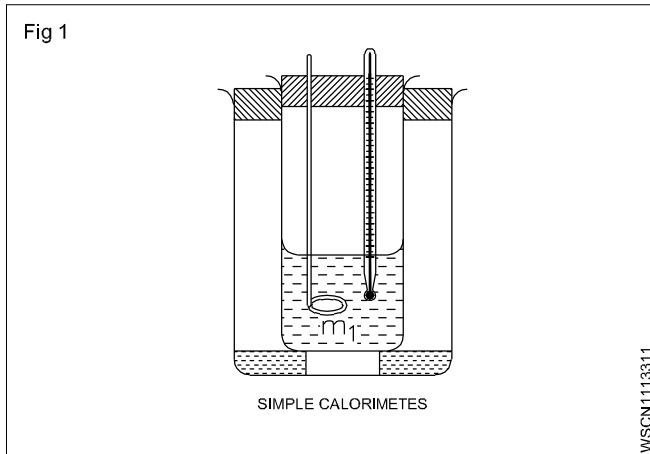
15 At what temperature will the reading of a fahrenheit thermometer be double of a centigrade one.

# Temperature measuring instruments, types of thermometer, pyrometer and transmission of heat

## Exercise 1.11.33

### Measuring heat energy

Energy can be released in chemical reactions as light, sound or electrical energy. But it is most often released as heat energy. This allows us to easily measure the amount of heat energy transferred.



The apparatus used to measure the amount of heat by mixer method is called calorimeter. It is nothing but cylindrical shaped vessel and a stirrer made out of mostly copper.

In a calorimeter when the hotter solid/liquid substance are mixed with the cooler solid/liquid substances, heat transfer takes place until both substances reach the same temperature. By the same time calorimeter also reaches the same temperature. By mixing rule,

$$\left[ \begin{array}{l} \text{Loss of heat} \\ \text{by solid/} \\ \text{liquid} \end{array} \right] = \left[ \begin{array}{l} \text{Heat absorbed by} \\ \text{solid / liquid} \\ \text{substance} \end{array} \right] + \left[ \begin{array}{l} \text{Heat absorbed} \\ \text{by calorimeter} \end{array} \right]$$

### Measurement

Temperature is generally measured in degrees Celsius. In this system the freezing point of water is defined as 0°C and the boiling point of water is defined as 100°C. The Kelvin temperature scale begins from absolute 0. i.e.—273°. The temperature intervals are the same.

$$\therefore 273\text{K} = 0^\circ\text{C}, 20^\circ\text{C} = 273\text{K} + 20^\circ\text{C} = 293\text{K}$$

### Instruments

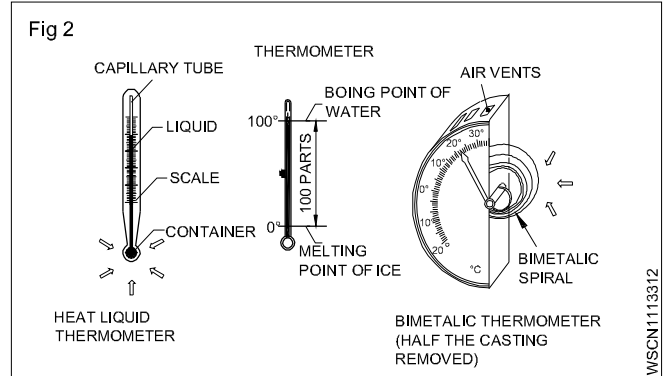
The instruments used to measure and read temperature takes into account changes in the properties of materials, electrical phenomena incandescence, radiation and melting.

### Thermometer

They are based on the principle that liquids and solids expand when they are subjected to heat. Mercury and alcohol expand uniformly. When heat is applied the volume of the liquid increases and the liquid rises in the capillary tube integral with the container. Mostly mercury is used in this type of thermometers because of its properties (Shiny

and will not adhere to the glass tubes and we can measure up to 300°C.

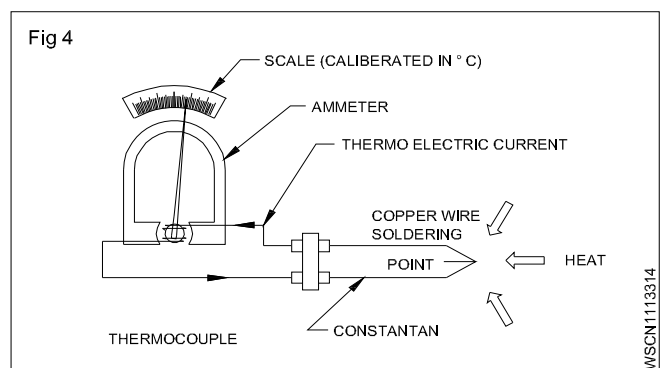
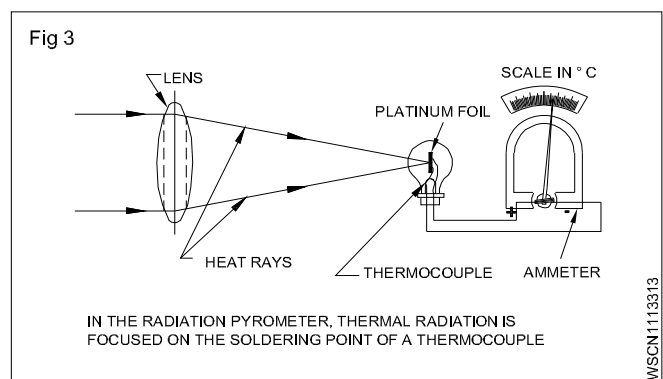
The bimetal thermometer consists of metals with different coefficient of expansion. The bimetal is twisted into a spiral which curls when the temperature rises.



### Pyrometer

Thermoelectric pyrometer is based on the principle that the soldering point between the wires of different metals, when heated a contact voltage is generated. The voltage depends upon the temperature difference between the hot measuring point and the cold end of the wire. Thermocouple elements are constructed of copper and Constant (up to 600°C) or of platinum and platinum-rhodium (up to 1600°C)

Radiation pyrometers are used to measure temperatures of red hot metals up to 3000°C. These concentrate thermal rays through an optical lens and focus them on to a thermo element. The scale of the ammeter is calibrated in degrees Celsius or Kelvin.





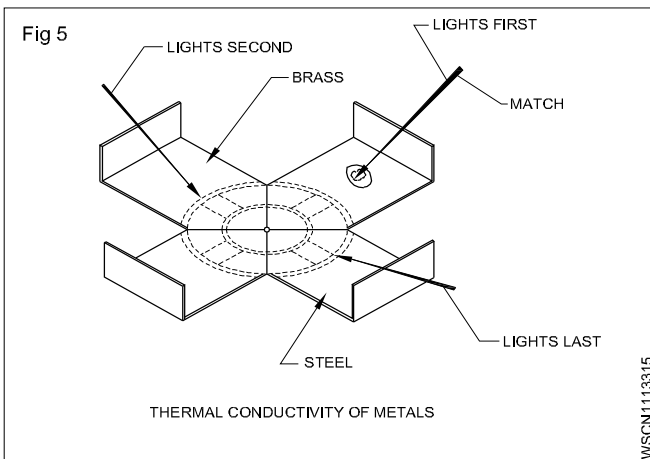
## Transmission of Heat

Heat is a form of energy and is capable of doing work. Heat flows from a hot body to a colder body or from a point of high temperature to a point of low temperature. The greater is the temperature difference the more rapidly will be the heat flow. Heat is transmitted in three ways.

- By Conduction
- By Convection
- By Radiation

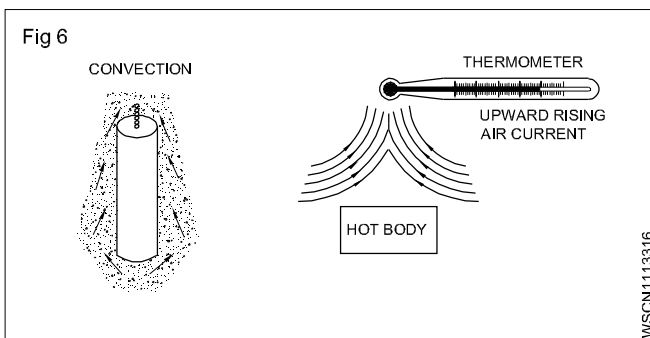
### Conduction

Conduction is the name given to the transmission of heat energy by contact. The heat source is in contact with the Conductor. (metal rod). The rod is in contact with a thermometer. Due to Conduction heat is transferred from the heated end to the free end. In general good electrical conductors are also good heat conductors and good electrical insulators are also good heat insulators. A good heat insulator does not necessarily withstand high temperature.



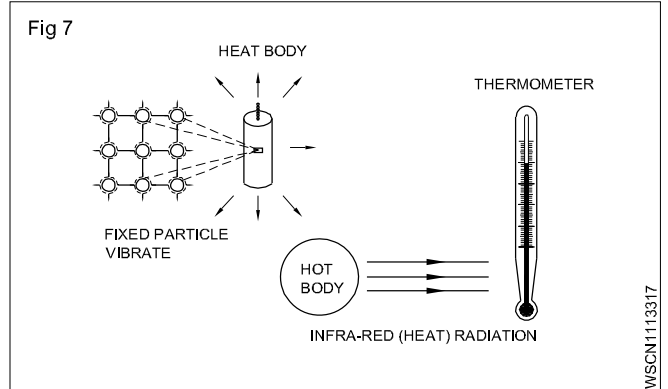
### Convection

Convection is the name given to the transmission of heat energy by the up-ward flow. When heated, the fluid (liquid/gas) becomes less dense and because of its mobility, is displaced upwards, by a similar but colder and more dense fluid. e.g., The domestic hot water system, The cooling system in motor cars.



## Radiation

Heat is radiated or transmitted from one object to the other in space without actually being in contact, by means of electro-magnetic waves. These waves are similar to light waves and radio waves. They can be refracted by lenses and reflected by mirrors. This radiation is called infrared. It requires no medium to carry the radiation. (e.g) The heat of the sun travels through the space.



**Transmission of heat takes place in three ways  
Conduction, Convection and Radiation.**

### Expansion due to heat

When a solid, liquid or gaseous substance is heated, it expands and volume is increased. Similarly when it is cooled, it contracts (shrinks) and volume is decreased.

E.g : small gaps are left in between the lines of railway track to allow for expansion during summer. If this is not done, the rails would expand and bend there by causing derailment of trains.

Except a few substances, all solids, liquids and gases expand. For the same amount of heat given, the expansion of liquids is greater than solid and expansion of gas is more than liquid.

Volume of water is reducing while heating from 0°C to 4°C. After that volume is increasing. The data at 4°C of water will be taken as reference point for any calculations relating with water.

# Co-efficient of linear expansion and related problems with assignment

## Exercise 1.11.34

### Expansion of solids

A solid substance shows the following types of expansion when heated.

- 1 Linear expansion
- 2 Superficial expansion and
- 3 Cubical expansion

#### 1 Linear expansion

When a solid is heated, its length increases. This is called linear expansion. It depends upon the material, original length and change in temperature.

#### Co-efficient of linear expansion

The co-efficient of linear expansion is the change in length per unit original length per degree rise in temperature. It is represented by  $\alpha$  (Alpha).

$$\text{Length of the solid at } t_1^{\circ}\text{C} = l_1$$

$$\text{Length of the solid at } t_2^{\circ}\text{C} = l_2$$

$$\text{Change in Temperature} = t_2 - t_1^{\circ}\text{C}$$

$$\text{Change in length} = l_2 - l_1$$

$$\alpha = \frac{l_2 - l_1}{l_1 \times (t_2 - t_1)}$$

$$\alpha = \frac{l_2 - l_1}{l_1 t} [t_2 - t_1 = t]$$

$$\left. \begin{array}{l} \text{Co - efficient of} \\ \text{linear expansion} \end{array} \right\} = \frac{\text{Change in length}}{\text{Original length} \times \text{change in temperature}}$$

$$\text{Increased length } l_2 - l_1 = \alpha l_1 t$$

$$\text{Final length } l_2 = l_1(1 + \alpha t)$$

#### 2. Superficial expansion

When a solid is heated, its area increases is called superficial expansion.

#### Co-efficient of superficial expansion

The increase in area per unit original area per degree rise in temperature is called co-efficient of superficial expansion. It is represented by  $\beta$  (Beta).

#### Co-efficient of superficial

$$\text{Expansion} = 2 \times \text{linear expansion}$$

$$\beta = 2\alpha$$

#### 3. Cubical expansion

When a solid is heated, its volume increases is called cubical expansion.

#### Co-efficient of cubical expansion

The increase in volume per unit original volume per degree rise in temperature. It is represented by  $\gamma$  (Gamma).

#### Co-efficient of cubical expansion

$$= 3 \times \text{linear expansion}$$

$$\gamma = 3\alpha$$

#### Examples

**Find the co-efficient of linear expansion. If an 8 metre long metal rod is heated from 30°C to 80°C. So that it may produce an elongation of 0.84 mm.**

$$\text{Initial length (l)} = 8\text{m}$$

$$\text{Increased length} = 0.84\text{ mm}$$

$$\text{Increased temperature(t)} = 80 - 30 = 50^{\circ}\text{C}$$

$$\left. \begin{array}{l} \text{Co - effiecient of linear} \\ \text{expansion}(\alpha) \end{array} \right\} = \frac{\text{Increased length}}{\text{Initial length} \times \text{Increased temp}}$$

$$= \frac{0.84}{8000 \times 50}$$

$$= \frac{0.84}{400000}$$

$$= 2.1 \times 10^{-6} /^{\circ}\text{C}$$

**If iron bridge is 100 metre long at 0°C. What will be the length of bridge if the temperature is 40°C and the co-efficient of linear expansion is  $12 \times 10^{-6}$  per degree.**

$$\text{Initial length of iron bridge} = 100\text{ m}$$

$$\text{Increased temperature} = 40 - 0 = 40^{\circ}\text{C}$$

$$\left. \begin{array}{l} \text{Co - effiecient of linear} \\ \text{expansion}(\alpha) \end{array} \right\} = \frac{\text{Increased length}}{\text{Initial length} \times \text{Increased temp}}$$

$$12 \times 10^{-6} = \frac{\text{Increased length}}{100 \times 40}$$

$$\text{Increased length} = \frac{12}{1000000} \times 100 \times 40$$

$$= 0.048\text{ m}$$

$$\text{Iron bridge at } 40^{\circ}\text{C} = 100 + 0.048 = 100.048\text{ m}$$

**The length of a metal rod is 100 cm at 30°C and 100.14 cm at 100°C. Calculate the co-efficient of linear expansion and the rod length in 0°C.**

$$\text{Initial length at } 30^{\circ}\text{C} = 100\text{ cm}$$

$$\text{Final length at } 100^{\circ}\text{C} = 100.14\text{ cm}$$

$$\text{Increased length} = 0.14\text{ cm}$$

$$\text{Increased temperature} = 100 - 30 = 70^{\circ}\text{C}$$

$$\left. \begin{array}{l} \text{Co-efficient of linear} \\ \text{expansion}(\alpha) \end{array} \right\} = \frac{\text{Increased length}}{\text{Initial length} \times \text{Increased temp}}$$

$$= \frac{0.14}{100 \times 70}$$

$$= \frac{14}{100 \times 70 \times 100}$$

$$= \frac{2}{100000}$$

$$= 2 \times 10^{-5}$$

To find the length at 0°C

$$l_1 = l_0 (1 + \alpha t)$$

$$100 = l_0 (1 + 2 \times 10^{-5} \times 30)$$

$$100 = l_0 (1 + 0.0006)$$

$$l_0 = \frac{100}{1 + 0.0006}$$

$$\text{Length at } 0^\circ\text{C} = 99.94 \text{ m}$$

**Find the change in length of metallic rod 100 cm long, when its temperature is increased from 25°C to 40°C and the co-efficient of linear expansion is  $10 \times 10^{-6} / ^\circ\text{C}$ .**

$$\begin{array}{ll} \text{Initial length} & = 100 \text{ cm} \\ \text{Increased temperature} & = 40 - 25 = 15^\circ\text{C} \\ \text{Co-efficient of linear} & = 10 \times 10^{-6}/^\circ\text{C} \\ \text{expansion } (\alpha) & \end{array}$$

$$\left. \begin{array}{l} \text{Co-efficient of linear} \\ \text{expansion}(\alpha) \end{array} \right\} = \frac{\text{Increased length}}{\text{Initial length} \times \text{Increased temp}}$$

$$10 \times 10^{-6} = \frac{\text{Increased length}}{100 \times 15}$$

$$\begin{aligned} \text{Increased length} &= 10 \times 10^{-6} \times 100 \times 15 \\ &= \frac{10 \times 100 \times 15}{1000000} \\ &= \frac{15}{1000} = 0.015 \text{ cm} \end{aligned}$$

**Find out the temperature that the rod will extend by 0.54 mm in linear direction piece of metal rod is 2.5 metre long and the co-efficient of linear expansion is  $10.4 \times 10^{-6}$  per degree centigrade.**

$$\begin{array}{ll} \text{Initial length} & = 2.5 \text{ m} = 2500 \text{ mm} \\ \text{Increased length} & = 0.54 \text{ mm} \\ \text{Initial temperature} & = 20^\circ\text{C} \\ \text{Co-efficient of linear} & = 10.4 \times 10^{-6} \\ \text{expansion } (\alpha) & \end{array}$$

$$\left. \begin{array}{l} \text{Co-efficient of linear} \\ \text{expansion}(\alpha) \end{array} \right\} = \frac{\text{Increased length}}{\text{Initial length} \times \text{Increased temp}}$$

$$10.4 \times 10^{-6} = \frac{0.54}{2500 \times \text{Increased temp}}$$

$$\text{Increased temperature} = \frac{0.54}{2500 \times 10.4 \times 10^{-6}}$$

$$= \frac{0.54 \times 1000000}{2500 \times 10.4}$$

$$= \frac{5400}{260} = 20.77^\circ\text{C}$$

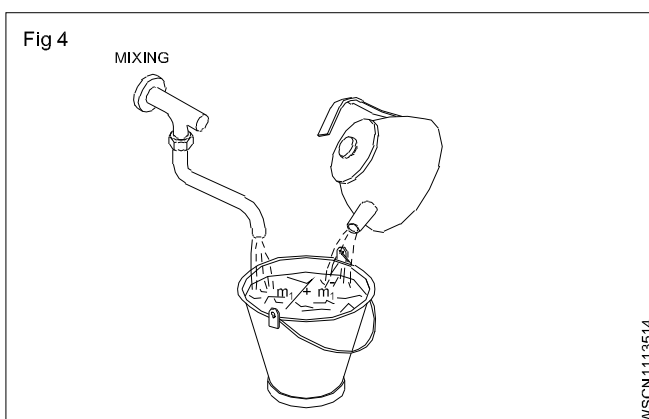
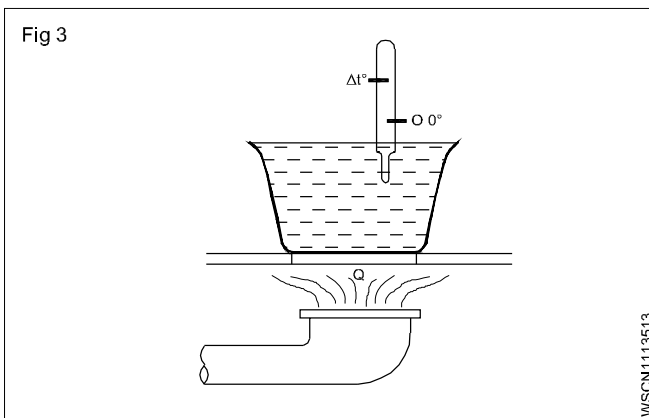
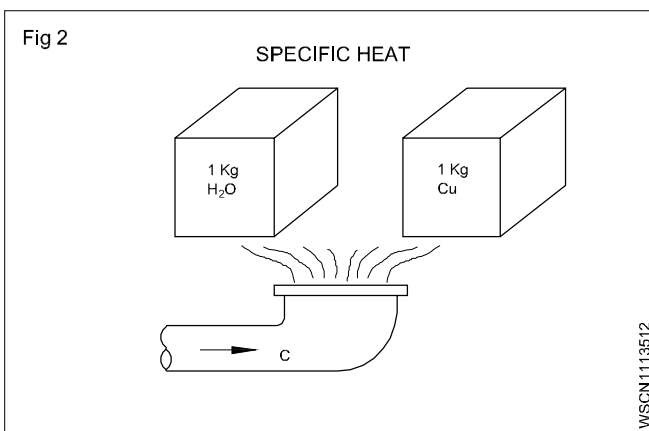
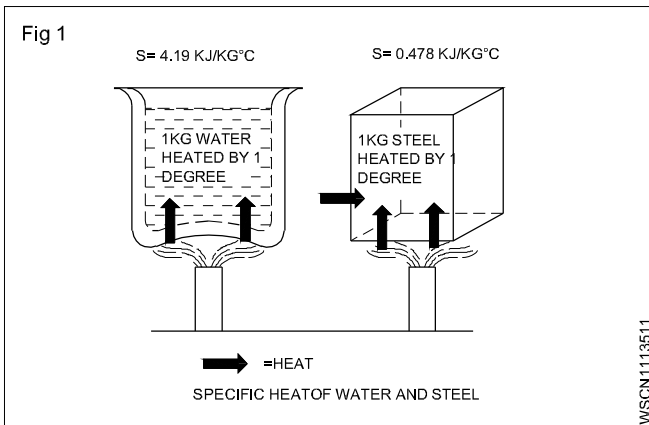
$$\begin{aligned} \text{Final temperature} &= 20 + 20.77 \\ &= 40.77^\circ\text{C} \end{aligned}$$

## ASSIGNMENT

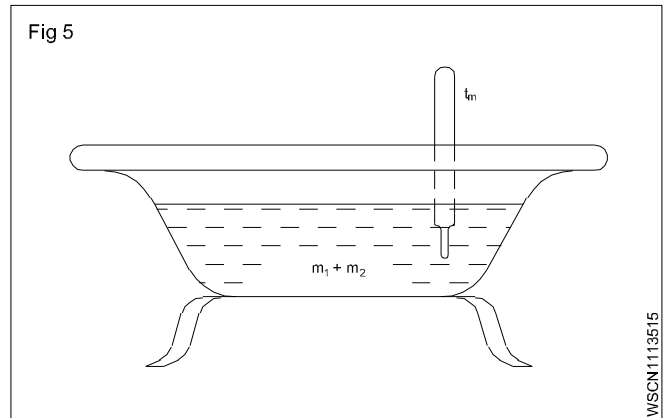
### Co-efficient of linear expansion

- Calculate the co-efficient of linear expansion of rod. If rod is found to be 100m long at 20°C and 100.14m long at 100°C.
- Find the change in length if the co-efficient of linear expansion of rod is 0.00024/°C and the temperature of a rod of 3.6m length is raised by 120°C,
- find the change in length if the co-efficient of linear expansion of rod is 0.00024/°C. If the temperature of a rod of 6m length is raised by 120°C,
- Find the increase in length 100 cm iron rod if the temperature raise from 40°C to 90°C. The co-efficient of linear expansion of the iron is  $10 \times 10^{-6}/^\circ\text{C}$
- If micrometer reading is standardised at 15°C. What will be the true reading of the micrometer if the reading taken at 35°C is 20.20 mm?  
The co-efficient of linear expansion of material of micrometer is  $11 \times 10^{-6}/^\circ\text{C}$ .

Mixing of heat



- $m_1$  - Mass of first substance
- $s_1$  - specific heat of first substance
- $m_2$  - mass of 2nd substance
- $s_2$  - specific heat of 2nd substance
- $t_m$  - temperature of mixture



- $m$  - mass
- $Q$  - Quantity of heat
- $\delta t/\Delta t$  - temperature difference
- $t_m$  - temperature of the mixture.

Unit of amount of heat

The derived unit for the amount of heat is S.I. unit is 1 joule (j).

Specific heat

It is also expressed as the amount of heat required to raise the temperature of unit mass of a substance through 1°C. In S.I. unit in order to heat a mass of 1 kg of water through 1°C,

the amount of heat needed or the mechanical equivalent of heat = 4186 joules  
= 4.2 kJ/kg°C.

Quantity of heat needed for a substance to rise the temperature

The amount of heat needed for heating 1 kg of the substance through 1°C is equal to the specific heat of the substance 's'. For heating a mass of 'm' kg of the substance to attain a temperature difference of t,

the quantity of heat needed =  $m \times s \times \Delta t$

Therefore  $Q = m \times s \times \Delta t$ .

Mixing

When there is an exchange of temperatures, there is an exchange in the amount of heat. When hotter bodies involve with colder substances, heat transference takes

place from hotter substances to the colder substances until the mixture or both the substances acquire the same temperature.

Heat lost by the bodies at higher temperature

= Heat gained by the bodies at lower temperature and hence the total amount of heat of the component substances

= amount of heat in the mixture.

$$\begin{aligned} \text{Heat loss by hot substance} &= \\ &= \text{Heat gained by colder substance} \\ \text{S of the component amounts of heat} &= \\ &= \text{amount of heat in the mixture} \\ m_1 \times s_1 \times t_1 + m_2 \times s_2 \times t_2 &= (m_1 s_1 + m_2 s_2) t_m. \end{aligned}$$

### Example

A bath tub contains 40 litres of water at 15°C and 80 litres of water at 60°C is poured to it. What is the temperature of the mixture.

$$\begin{aligned} m_1 \times s_1 \times t_1 + m_2 \times s_2 \times t_2 &= (m_1 s_1 + m_2 s_2) t_m \\ \therefore 40 \text{ kg} \times \frac{4.2 \text{ kJ}}{\text{kg}^\circ\text{C}} \times 15^\circ\text{C} + 80 \text{ kg} \times \frac{4.2 \text{ kJ}}{\text{kg}^\circ\text{C}} \times 60^\circ\text{C} \\ &= \left( 40 \text{ kg} \times \frac{4.2 \text{ kJ}}{\text{kg}^\circ\text{C}} \times 15 + 80 \text{ kg} \times \frac{4.2 \text{ kJ}}{\text{kg}^\circ\text{C}} \times 60 \right) t_m \\ t_m &= \frac{22680}{120 \times 4.2} ^\circ\text{C} = 45^\circ\text{C} \end{aligned}$$

### Examples

**A container contains 25 kg of water. Initial temperature of container and water is 25°C. Calculate the heat required to heat the water to the boiling temperature of water. Assume water equivalent of container = 1 kg.**

Mass of the water (m)	= 25 Kg.	
Initial temperature of water and container	= 25°C	
Final temperature of water and container	= 100°C	
Increased temperature (t)	= 100 - 25	
	= 75°C	
Water equivalent (m s)	= 1 Kg.	
Required amount of heat to container	= m s t	
	= 25 x 1 x 75	
	= 1875 K.cal.	
Required amount of heat to container	= m s t	
	= 1 x 75	
	= 75 K.cal.	
Total required amount of heat	= 1875 + 75	
	<b>=1950 K.cal.</b>	

**300 gram of water 25°C is mixed with 200 gram of water at 85°C. Find out the final temperature of the mixture assuming that no heat escapes.**

i) Weight of water = 300 gram  
Initial temperature = 25°C  
Final temperature = Assume 'X'  
Temperature gained = x - 25°C

ii) Mass of water = 200 gram  
Initial temperature = 85°C  
Temperature lost = 85°C - x

Heat gained by 300 gram water = m s t  
= 300 x 1 x (x - 25)  
= 300 x -7500 cal.

Heat lost by 200 gram water = m s t  
= 200 x 1 x (85 - x)  
= 17000 - 200 x cal.

Heat gained = Heat lost  
300 x -7500 = 17000 - 200 x  
300 x + 200 x = 17000 + 7500  
500 x = 24500  
x =  $\frac{24500}{500} = 49^\circ\text{C}$

**Final temperature = 49°C**

**20gm of common salt at 91°C immersed in 250 gram of turpentine oil at 13°C. The final temperature is found to be 16°C. If the specific heat of turpentine oil is 0.428. Calculate the specific heat of common salt.**

Mass of the salt(m)	= 20 gram	
Initial temperature(t)	= 91°C	
Mass of the turpentine(m)	= 250 gram	
Initial temperature(t)	= 13°C	
Specific heat of turpentine(s)	= 0.428	
Final temperature of mixture	= 16°C	
Heat gained by turpentine(Q)	= m s t	
	= 250 x 0.428 x (16-13)	
	= 250 x 0.428	
	= 321 calories.	
Heat lost by salt (Q)	= m s t	
	= 20 x s x (91-16)	
	= 20 x s x 75	
	= 1500 s calories	
Heat lost = Heat gained		
	1500 s = 321	

$$s = \frac{321}{1500}$$

**Specific heat of salt = 0.214**

If copper calorimeter contains 80 gram of water at 20°C. The water equivalent of calorimeter is 20 gm. What will be resultant temperature of the mixture, when 100 gm of water at 40°C is added to the mixture?

Mass of the water in calorimeter = 80 gram

Temperature = 20°C

Final temperature of the mixture = Assume 'x'

Temperature raised in water = x - 20

Specific heat of calorimeter(ms) = 20 gram

Mass of water added = 100 gram

Temperature = 40°C

Temperature lost = 40 - x

### Heat gained

$$\begin{aligned} \text{Heat gained by water in calorimeter} &= m s t \\ &= 80 \times 1 \times (x - 20) \\ &= 80 \times (-1600) \end{aligned}$$

$$\begin{aligned} \text{Heat gained by calorimeter} &= m s t \\ &= 20 \times (x - 20) \\ &= 20 \times (-400) \end{aligned}$$

### Heat lost

$$\begin{aligned} \text{Heat lost by added water} &= m s t \\ &= 100 \times 1 \times (40 - x) \\ &= 4000 - 100x \end{aligned}$$

$$\text{Heat gained} = \text{Heat lost}$$

$$80x (-1600) + 20x (-400) = 4000 - 100x$$

$$100x - 2000 = 4000 - 100x$$

$$100x + 100x = 4000 + 2000$$

$$200x = 6000$$

$$x = \frac{6000}{200}$$

$$= 30$$

**Final temperature = 30°C**

Find the amount of heat required to boil 15 gram of ice at -8°C. Latent heat of ice = 336 joule/gm. Latent heat of steam = 2268 J/gm. Relative specific heat of ice = 0.5

### Heat of ice cube

$$\begin{aligned} -8^\circ\text{C to } 0^\circ\text{C Ice Q} &= m c t \text{ kJ} \\ &= m \times s \times 4.2 \times t \text{ kJ} \\ &= 0.015 \times 0.5 \times 4.2 \times 8 \text{ kJ} \\ &= 0.252 \text{ kJ} \end{aligned}$$

$$\begin{aligned} 0^\circ\text{C Ice to } 0^\circ\text{C water} &= m \times h_{sf} \text{ kJ} \\ &= 0.015 \times 336 \text{ kJ} \\ &= 5.04 \text{ kJ} \end{aligned}$$

$$\begin{aligned} 0^\circ\text{C water to } 100^\circ\text{C water} &= m c t \text{ kJ} \\ &= 0.015 \times 4.2 \times 100 \text{ kJ} \\ &= 6.3 \text{ kJ} \end{aligned}$$

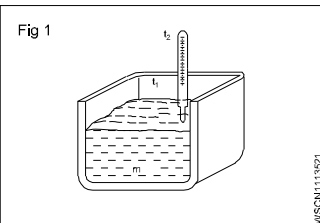
$$\begin{aligned} 100^\circ\text{C water to } 100^\circ\text{C steam Q} &= m \times h_{sfg} \text{ kJ} \\ &= 0.015 \times 2268 \text{ kJ} \\ &= 34.02 \text{ kJ} \end{aligned}$$

$$\text{Total amount of heat Q} = 0.252 + 5.04 + 6.3 + 34.02 \text{ kJ}$$

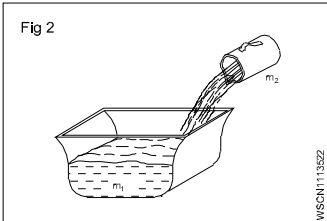
**Answer = 45.612 kJ**

## ASSIGNMENT

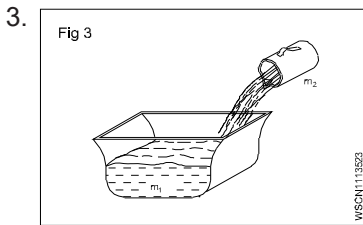
### Mixing of Heat

1.  Fig 1

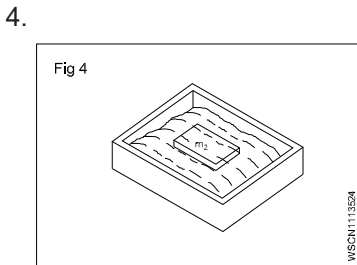
$$\begin{aligned} m &= 120 \text{ litres} \\ t_1 &= 20^\circ\text{C} \\ t_2 &= 85^\circ\text{C} \\ s &= 4.2 \\ Q &= \text{_____ kJ} \end{aligned}$$

2.  Fig 2

$$\begin{aligned} m_1 &= 80 \text{ litres of water} \\ m_2 &= 40 \text{ litres of water} \\ t_1 &= 10^\circ\text{C} \\ t_2 &= 70^\circ\text{C} \\ t_m &= \text{_____ } ^\circ\text{C} \end{aligned}$$



$m_1 = 25$  litres of water  
 $t_1 = 12^\circ\text{C}$   
 $t_2 = 70^\circ\text{C}$   
 $t_m = 33.75^\circ\text{C}$   
 $m_2 = \underline{\hspace{2cm}}$  litres

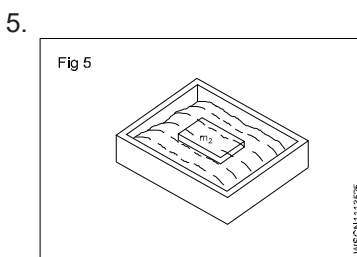


$m_1 = 100$  kg of water  
 $t_1 = 12^\circ\text{C}$   
 $m_2 = 50$  kg of steel  
 $t_2 = 600^\circ\text{C}$

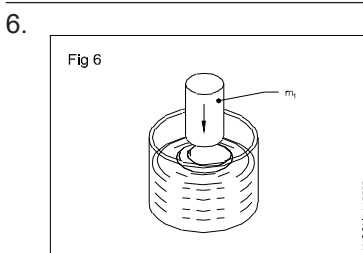
$S_1 = 4.2 \frac{\text{kJ}}{\text{Kg}^\circ\text{C}}$

$S_2 = 0.46 \frac{\text{kJ}}{\text{Kg}^\circ\text{C}}$

Rise in temperature =  $\underline{\hspace{2cm}}$   $^\circ\text{C}$  of water



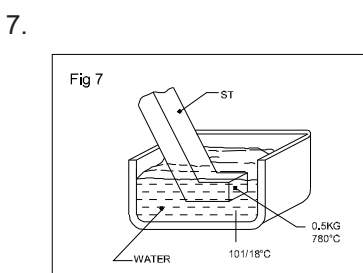
$m_1 = 250$  litres of water  
 $m_2 = 150$  kg of steel  
 $t_1 = 15^\circ\text{C}$   
 $t_m = 70^\circ\text{C}$   
 $t_2 = \underline{\hspace{2cm}}$   $^\circ\text{C}$



$t_1 = \underline{\hspace{2cm}}$   $^\circ\text{C}$

$m_1 = 20$  litres of machine oil  
 $m_2 = 30$  kg of steel  
 $t_2 = 160^\circ\text{C}$   
 $t_m = 60^\circ\text{C}$

density of oil =  $0.91 \frac{\text{gr}}{\text{cm}^3}$



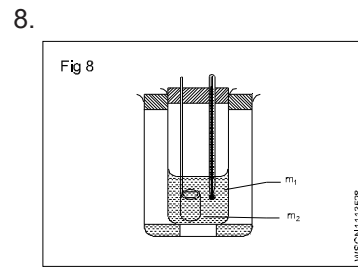
$m_1 = 10$  litres

$S_1 = 4.2 \frac{\text{kJ}}{\text{Kg}^\circ\text{C}}$

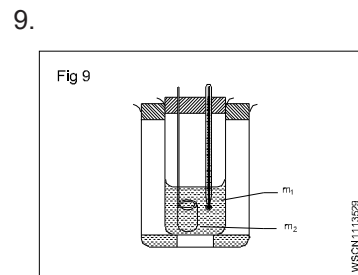
$S_2 = 0.46 \frac{\text{kJ}}{\text{Kg}^\circ\text{C}}$

$m_2 = 0.5$  kg  
 $t_1 = 18^\circ\text{C}$   
 $t_2 = 780^\circ\text{C}$

Rise in temperature =  $\underline{\hspace{2cm}}$   $^\circ\text{C}$  of water



$m_1 = 60$  gms of water  
 $m = 70$  gms of calorimeter  
 $m_2 = 80$  gms of metal  
 $t_1 = 20^\circ\text{C}$   
 $t_2 = 95^\circ\text{C}$   
 $t_m = 25^\circ\text{C}$   
 $s = 0.2$   
 $s_1 = 1$   
 $s_2 = \underline{\hspace{2cm}}$



$m_1 = 250$  gms of oil  
 $t_1 = 15^\circ\text{C}$   
 $m_2 = 150$  gms of brass  
 $t_2 = 90^\circ\text{C}$   
 $t_m = 25^\circ\text{C}$   
 $s_2 = 0.09$  water equivalent of = 3 gms calorimeter  
 $s_1 = \underline{\hspace{2cm}}$  gms

### Heat loss and heat gain

- 1 Calculate the amount of heat required to raise the temperature of 85.5 g. of sand from  $20^\circ\text{C}$  to  $35^\circ\text{C}$ . Specific heat of sand = 0.1
- 2 How much quantity of heat will be rejected in one hour, if the rate of flow of water is 11 kg/min and the raise of temperature of water is  $12^\circ\text{C}$ .
- 3 Find out its specific heat. If we require 510 calories to raise the temperature of 170/ gm of material  $50^\circ\text{C}$  to  $80^\circ\text{C}$ .
- 4 Calculate the specific heat of metal piece. If 500gm metal piece at  $300^\circ\text{C}$  is dropped in 5 kg of water. Its temperature raises from  $30^\circ\text{C}$  to  $75^\circ\text{C}$  are no heat losses.
- 5 Find out the final temperature of mixture, assuming that no heat escapes. If 300gm of water at  $25^\circ\text{C}$  is mixed with 200gm of water at  $85^\circ\text{C}$ .
- 6 What will be the resultant temperature of the mixture, when 100gm of water at  $40^\circ\text{C}$  is added to the mixture. If copper calorimeter contains 80 gm of water at  $20^\circ\text{C}$ . The water equivalent of calorimeter is 20 gm.

**Pressure**

F - Force, Thrust

P - Pressure

Concept of pressure

The action of a force on unit area of the body on which it acts is termed as pressure.

Pressure 'P' = Force or Thrust F per unit area 'A' (Fig 1)

A - Area of surface on which force acts

**Example**

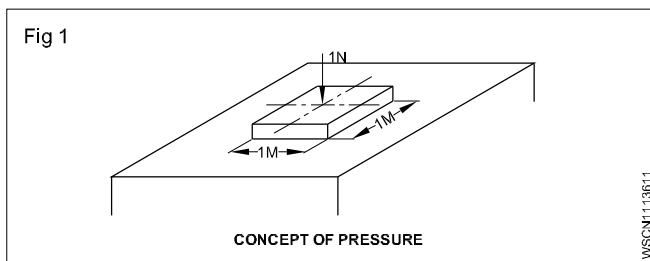
A liquid gives force of 100 N over an area of 2m<sup>2</sup>. What is the pressure?

Force = 100N

Area = 2m<sup>2</sup>

Pressure = ?

= 50 N/m<sup>2</sup>



Unit of pressure N/m<sup>2</sup>, 1 N/m<sup>2</sup> = 1 pascal.

This unit is too small (pressure of a fly on a area of 1cm<sup>2</sup>). Hence 'bar' is introduced as the unit of pressure. 1 bar = 10<sup>5</sup> pascal.

1 bar = 1000 mbar. [SI unit of pressure is pascal (Pa) and Metric unit of pressure is bar].

**Properties of pressure**

- 1 The pressure in a liquid increases with increase in depth.
- 2 The pressure at a point increases with the density of the liquid.
- 3 The pressure is same in all directions about a point in liquid at rest.
- 4 Upward pressure at a point in a liquid is equal to downward pressure.

**Saturation temperature of a fluid (liquid/vapour)**

The temperature at which a liquid changes to vapour by heating further at a given pressure. If this pressure is kept constant, the heat removal process changes the vapour into liquid at constant temperature. It is the saturated condition of a fluid (Liquid/vapour).

**Pressure**

British unit FPS	Pounds per square inch	lb/in <sup>2</sup>
Metric units CGS	Gram per square contribute	g/cm <sup>2</sup>
MKS	Kilogram per square metre	kg/m <sup>2</sup>
International circuits SI	Newtons per square metre	N/m <sup>2</sup>

**Saturation pressure of a fluid**

By adding or removing heat at a givcen temperature, there is physical change is fluid. The given constant pressure is known as saturation-pressure.

**Critical temperature and pressure**

Each fluid (liquid/gas) has its highest temperature and pressure; below which the removal or addition of heat changes physical state. If the conditions of temperature /

pressure exceeds the saturation level, the vapour cannot be condensed into liquid. This vapour which cannot be condensed into liquid, is called gas.

**Super heated vapour**

If the temperature of the vapour is raised above its saturated temperature, it is called super heated vapour, for a given pressure.



**Insulating materials:** Heat will flow from high temperature to low temperature. Heat flow by radiation, conduction and convection method through the wall, door, ceiling and glass door to the refrigerated space.

The material which restricts such heat flow is called insulating materials

### Properties of insulating materials

- It is low conductivity
- Resistance to fire
- Less moisture absorption
- Good rigidity
- Odourless
- Vapour permeability
- Light in weight

**Selection of insulating material:** The following factors are the prime importance in the selection of a proper insulating material.

- **Low thermal conductivity:** Thermal conductance value of a material is a measure of its effectiveness to allow the flow of heat through it by conduction, obviously an insulating material should have a very low thermal conductivity.
- Resistance to fire.
- Mechanical strength
- Low moisture absorption capacity
- Easy to lay
- Cost
- Easy of handling
- Low cost

### Types of insulating materials

Glass wool, PUF, Cork sheet, Thermocole, Insulating foil, fiber glass.

**Types of insulating materials:** Basic types of insulating materials are inorganic fibrous or cellular materials. Example, glass wool, slag wool ceramic products, as bestos, etc. Organic fibrous materials, cork, cotton, rubber foam, saw dust, rice husk, polystyrene, polyurethane, phenotherm, etc. The type and form available as the applications of various insulations as follows.

**Glass wool:** Available as semi-rigid, resin bonded slabs/sheets of different densities -higher density gives strength and lower conductivity but allows vapour transmission. Available with foil or other coverings.

**Cork:** Compressed and moulded into a rigid block, light but strong, can be cut easily with a saw, resists water but allows relatively high rate of water vapour transmission.

**Expanded polystyrene(Thermocole):** it is available as a rigid board, beads, moulded into shape for pipe/curved surface, can be cut easily with a saw, light weight allows relatively low vapour transmission.

**Polyurethane:** available as a rigid board, flexible board, liquid can be sprayed on surfaces and allowed to foam, can be used for in site applications.

**Wood shaving/Saw dust:** It needs good supporting compartment, can easily settle down. Fairly high conductivity absorbs moisture/water.

**Phenotherm:** Available slabs with different facings, and as performed pipe sections, can be easily cut with a saw.

### Insulating materials and properties/specifications:

There are many insulating materials used in refrigeration and air conditioning field. For our water tank only few of them were in use.

Now-a-days the following insulating materials were in broad use.

- Thermocole
- Glasswool/Tar felt
- Puf
- Fiberglass

**Thermocole:** It is one of the insulating materials in normal use. It is available in low and high density. This is available in various thicknesses ranging 0.25" to 5".

Thermocole is available in various shapes (moulded) of necessity.

Thermocole allows (Characteristically) low transmission of vapour, thereby heat entry through is cut short. This may vary with its low/high density.

It can be cut very easily even with knife to a required shape. Thermocole withstands cool/heat for a longer time.

The 'K' factor of an insulation material follows (thermocole).

**Thermocole** -0.20 btu/hr Ft<sup>2</sup> deg.f°/inch

**Fibreglass:** Also one of the insulating materials used for its manufactured from inorganic materials (sand, dolomite, limestone). Glass fibre insulation does not shrink due to temperature variation.

This insulation materials used for higher temperatures also upto 450°C (842°F).

Fibreglass products does not absorb moisture from the ambient air.

**Glass wool:** Normally glass wool material is heavily thin weighted object in layers, soft (touching). It comes off in various sizes (thickness from 0.5" to 2.5". it comes in white, yellow colours mixed up with broken glass pieces.

Handling glass wool is hazardous and harmful (if it is breathed). Always it is advisable to handle glass wool with gloves and goggles (eye) while working on it. It also comes off in various densities.

Glass wools are of two types of uses. One type of glass wool used for low temperature refrigeration/air conditioning purpose. The other type is used for boiler materials (heat prevention) purposes.

The 'K' factor of insulation material:

Glasswool: 0.230-.27 Btu/Hr ft<sup>2</sup> deg. F°/inch.

**Puf:** The other mode of insulating materials used in water cooler at the evaporator tank's external body.

For this kind of insulation two chemicals used namely isocyanide-R11., Both available in liquid form in bottles (for lesser capacities) and cans (for higher capacities).

Both the liquids (chemicals) should always kept cool. When both of them added in a container and stirred in few minutes it becomes foamy (initially with thin and becomes thicker and becomes hard (sticks with the unit).

We should be careful that there is no air gap in the tank covered. It foams out with high density and uneven finish at the outer level.

Puf (materials) insulations are widely used by our manufacturer's for their products as it keeps the temperature for a longer period.

The main disadvantage of the insulation is as soon as the chemicals are mixed and stirred it should be poured over the evaporator coil (or) outside the evaporator tank within the shortest period. If the time exceeds the solution starts framing at the container itself and becomes useless.

The evaporator tank should be covered well with wooden/ steel boards with required gaps for insulation tightened all the corners well giving small gaps to pour the solution.

**Method of laying duct insulation:** when there is no chance of moisture condensation on the duct, glass wool can be used. Since it is economical and fire resistant. However if moisture condensation can occur greater care should be exercised in case of glass wool. First a uniform coat of bitumen is applied to the duct surface and the wool is stuck to the bitumen. The insulation is then covered with a polythene sheet which acts as a vapour barrier. The surface can be plastered after spreading chicken wire mesh as reinforcement.

Expanded polystyrene can be laid easily as it is rigid. Bitumen is applied on the duct and the insulation is stuck joints are also sealed with bitumen. No separate vapour barrier is needed other than a coat of bitumen. The insulation can be finished with cement and plaster or metal cladding.

**Purpose of false ceiling:** The conditioned air arrives through the ducts at the supply air diffusers and enters the conditioned space. Most diffusers are attached to the false ceiling and a variety of diffusers are available for different air spreading needs. The return air grills will be fixed to the false ceiling. The false ceiling prevents mixing of conditioned air and return air.

Return air usually flow into the plenum or return air box through grill placed in the false ceiling. Since substantial amount of energy goes into the air in the first place. It is a practice to recycle to air. The air is therefore brought back to the air conditioning. Plant room it is common to route the return air through the gap between the false ceiling and the main ceiling. A space referred to as a plenum, the false ceiling is also known as a return air duct.

# Introduction, use of electricity, molecule, atom, electricity is produced, electric current, voltage, resistance and their units

## Exercise 1.13.38

Electricity is a kind of energy. It is the most useful sources of energy which is not visible but its presence can be felt by its effects. Electricity is obtained by conversion of other forms of energy like heat energy, chemical energy, nuclear energy, mechanical energy and energy stored in water etc.,

To understand electricity, one must understand the structure of an atom.

Basically an atom contains electrons, protons and neutrons. The protons and neutrons are located in the centre of an atom and the electrons, a negative electric charge particle revolving around the nucleus in an atom. The proton has a positive charge. Neutrons are neutral and have no charge.

### Sources of electricity

#### Battery

Battery stores electrical energy in the form of chemical energy and it gives power when required. Battery is used in automobiles and electronics, etc.,

#### Generator

It is a machine which converts the mechanical energy into electrical energy.

When a conductor rotates between a magnetic field using prime mover an emf will be induced. By using this method all types of AC and DC generator - generates power.

E.g. Thermal power station  
Hydro power station  
Nuclear power station  
Wind power station  
Solar power station

### Uses of Electricity

- |    |               |   |                                             |
|----|---------------|---|---------------------------------------------|
| 1  | Lighting      | - | Lamps                                       |
| 2  | Heating       | - | Heaters, ovens                              |
| 3  | Power         | - | Motor, fan                                  |
| 4  | Traction      | - | Electromotives, lift, crane                 |
| 5  | Communication | - | Telephone, telegraph, radio, wireless       |
| 6  | Entertainment | - | Cinema, radio, T.V.                         |
| 7  | Medical       | - | x-rays, shock treatment                     |
| 8  | Chemical      | - | Battery charging, electroplating            |
| 9  | Magnetic      | - | Temporary magnets                           |
| 10 | Engineering   | - | Magnetic chucks, welding, x-rays of welding |

### Molecule

All substances are made by tiny molecules. The smallest part on any matter which has the properties of the parent substance, is called molecule. The molecules of a substance are alike in shape and properties. Each molecule possesses the physical and chemical properties of the mother substance.

### Atom

There are three particles in an atom. They are:

- Proton:** The electron present in the middle of the atom is called proton. It is in the nucleus of the atom. The proton liquid-equivalent is 1840 times heavier than an electron liquid equivalent and is equal to the atom of hydrogen. It has a positive charge.
- Neutron:** It is a basic particle which is in the nucleus of atom. It is held fast with proton in the nucleus. It has no charge. It increases the liquid equivalent of the coulomb.
- Electron:** It is unstable or moving electron. It keeps moving round the nucleus on different orbits. It carries negative charge. It is 1/1840 of hydrogen atom liquid equivalent. Its charge is  $1.6 \times 10^{-19}$  coulomb.

### How electricity is produced

In the middle of each atom there is electricity. This is in form of electrons. Those parts which are stable known as protons and those moving are called electrons. The protons are of positive and electrons are negative charges. By external force only the moving electrons are reduced or increased as compared to protons and then only both the charges combine. When the number of electrons produced are less than the number of protons, then it becomes a positive charge. Conversely when the number of electrons produced are more than the number of protons it becomes negative. In this way electricity is produced by atom.

### Electrical terms and units

#### Quantity of electricity

The strength of the current in any conductor is equal to the quantity of electrical charge that flows across any section of it in one second. If 'Q' is the charge and 't' is the time taken

$$\text{then } I = \frac{Q}{t} \quad Q = I \times t$$

The SI unit of current is coulomb. Coulomb is equivalent to the charge contained in nearly  $6.24 \times 10^{18}$  electrons.

#### Coulomb

In an electric circuit if one Ampere of current passes in one second, then it is called one coulomb. It is also called ampere second (As). Its larger unit is ampere hour (AH)

$$1 \text{ AH} = 3600 \text{ As (or) } 3600 \text{ coulomb}$$

### **Electro motive force (EMF)**

It is the force which causes to flow the free electrons in any closed circuit due to difference in electrical pressure or potential. It is represented by 'E.' Its unit is Volt.

### **Potential difference (P.D)**

This is the difference in electrical potential measured across two points of the circuit. Potential difference is always less than EMF. The supply voltage is called potential difference. It is represented by V.

### **Voltage**

It is the electric potential between two lines or phase and neutral. Its unit is volt. Voltmeter is used to measure voltage and it is connected parallel between the supply terminals.

### **Volt**

It is defined as when a current of 1 ampere flows through a resistance of 1 ohm, it is said to have potential difference of 1 volt.

### **Current**

It is the flow of electrons in any conductor is called current. It is represented by I and its unit is Ampere. Ammeter is used to measure the current by connecting series with the circuit.

### **Ampere**

When  $6.24 \times 10^{18}$  electrons flow in one second across any cross section of any conductor, the current in it is one ampere.(or) If the potential difference across the two ends of a conductor is 1 volt and the resistance of conductor is 1 ohm then the current through is 1 ampere.

### **Resistance**

It is the property of a substance to oppose to the flow of electric current through it, is called resistance. Symbol: R, Unit : Ohm (W), Ohm meter is used to measure the resistance.

### **Ohm**

If the potential difference across the two ends of conductor is 1 volt and the current through it is 1 ampere, then the resistance of the conductor is 1 Ohm.

# Ohm's law, relation between V.I.R & problems, series & parallel circuits

## Exercise 1.13.39

### Ohm's law

V - Voltage in volts

I - Current in Ampere

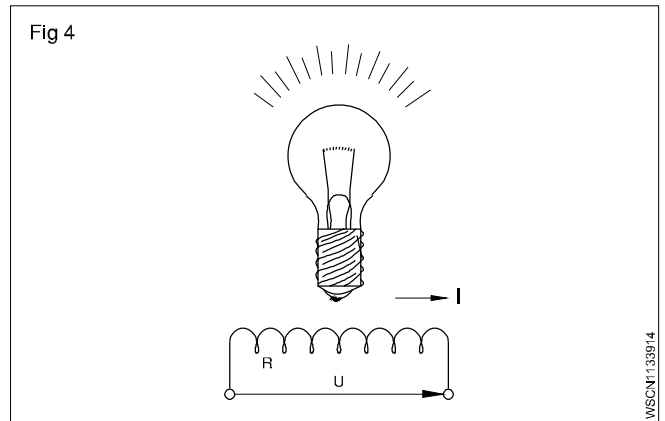
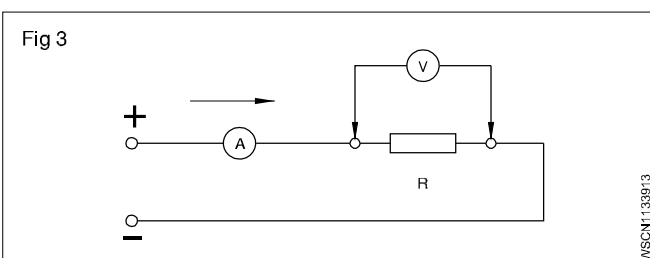
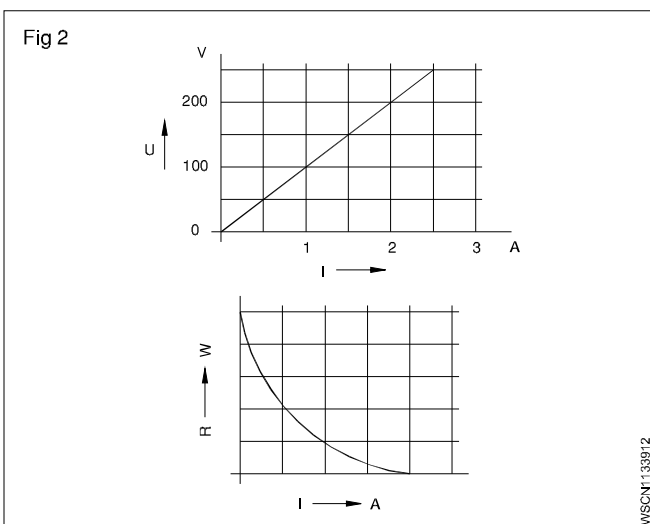
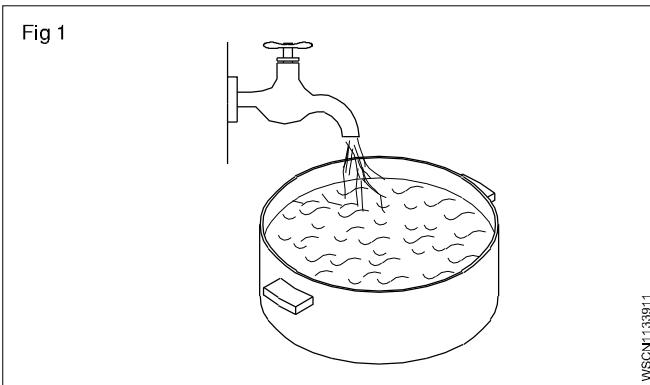
R - Resistance in ohms.

In any closed circuit the basic parametres of electricity (Voltage, Current and resistance) are in a fixed relationship to each other.

### Basic values

To clarify the basic electrical values, they can be compared to a water tap under pressure

Water pressure	- electron pressure	- Voltage
Amount of water	- electron flow	- Current
throttling of tap	- obstruction to electron flow	- Resistance



### Relationships

If the resistance is kept constant and the voltage is increased, the current is increased

$$I \propto V$$

If voltage is constant and the resistance is increased, current is decreased

$$I \propto \frac{1}{R}$$

### Ohm's law

From the above two relationships we obtain Ohm's law,

$$I = \frac{V}{R} \text{ which is conveniently written as } V = R.I.$$

**Ohm's law states that at constant temperature the current passing through a closed circuit is directly proportional to the potential difference, and inversely proportional to the resistance.**

By Ohm's law  $I = \frac{V}{R}$

### EXAMPLE

A bulb takes a current of 0.2 amps at a voltage of 3.6 volts. Determine the resistance of the filament of the bulb to find R. Given that V = 3.6 V and I = 0.2 A.

To find 'R'. Given that V = 3.6V and I = 0.2 A

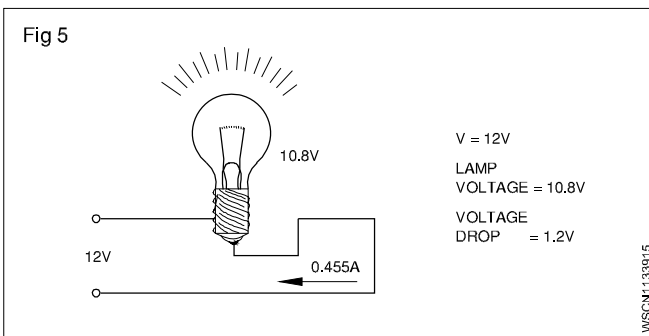
Therefore  $V = I \times R$

$3.6 \text{ V} = 0.2 \text{ A} \times R$

Therefore  $R = \frac{3.6V}{0.2A} = 18 \text{ ohms}$

### Example

The voltage supply to a filament lamp is 10.8V. The voltage should be 12V. Find out loss of voltage.(Fig 5)



$$\text{Voltage drop} = 12\text{V} - 10.8 = 1.2\text{V}$$

**The supply voltage is called Potential difference.**

### Example

The Internal resistance of a dynamo is 0.1 ohm. The voltage of dynamo is 12V. What is the Voltage dynamo when a current of 20 amps being supplied to an outside circuit.

#### Solution

$$\text{Voltage drop} = \text{Current} \times \text{Internal resistance}$$

$$= 20 \times 0.1 \text{ volts}$$

$$= 2 \text{ volts}$$

#### Example (Fig 6)

The Internal resistance of a Battery is 2 ohms. When a resistance of 10 ohms is connected to a battery it draws 0.6 amps. What is the EMF of the battery.

$$\text{P.D} = \text{Current flowing} \times \text{Resistance}$$

$$= 0.6 \text{ A} \times 10\Omega$$

$$= 6 \text{ volts}$$

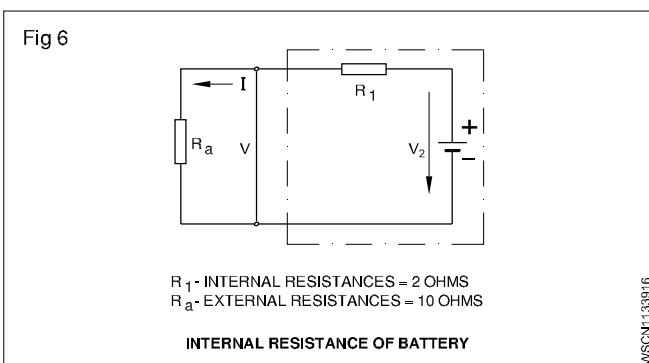
$$\text{V.D} = \text{Current flowing} \times \text{Internal resistance of battery}$$

$$= 0.6 \times 2 \text{ volts}$$

$$= 1.2 \text{ volts}$$

$$\text{EMF of the Battery} = (6.00 + 1.2)\text{V}$$

$$= 7.2 \text{ volts}$$



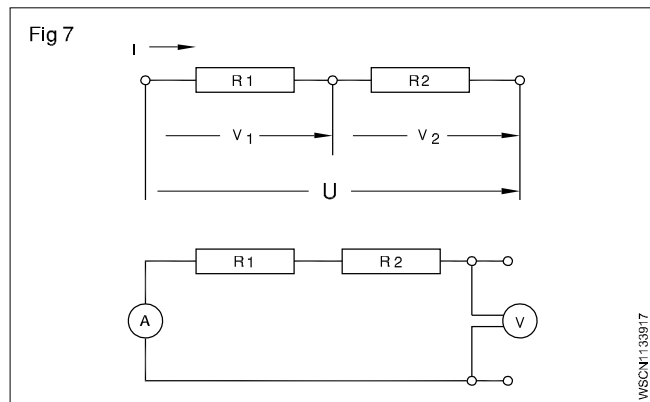
### Resistance connections

V - Voltage (in volts)

R - Resistance (in ohms)

I - Current intensity (in Amperes)

#### Series Connection



The total resistance is equal to the sum of all the resistances. In a series connection the end of the first load is connected to the beginning of the second load and all loads are connected end to end.

Features of series connection:

- The same current flows through all the loads.
- The voltage across each load is proportional to the resistance of the load.
- The sum of the voltages across each load is equal to the applied voltage.
- The Total resistance is equal to the sum of all the resistances.

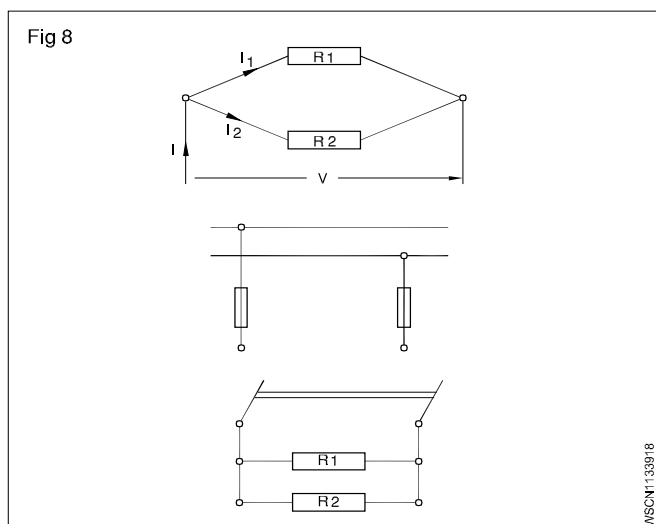
$$I = I_1 = I_2 = \dots$$

$$V = V_1 + V_2 + \dots$$

$$R = R_1 + R_2 + \dots$$

#### Parallel connection

In a parallel connection the beginning and the ends of the loads are connected together.



### Features of parallel connection:

- The current flowing through each load depends upon the resistance of the load.
- The voltage across each load is the same and is equal to the voltage applied to the circuit.
- The total resistance of a parallel connection is always smaller than the smallest resistance in the circuit.
- In parallel connection the reciprocal of the total resistance is equal to the sum of the reciprocals of all resistances in the circuit.

$$I = I_1 + I_2 + \dots$$

$$V = V_1 = V_2 \dots$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

### Example

Two resistances of 4 ohms and 6 ohms are connected in parallel. Determine the total resistance.

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots \quad (\text{since parallel connection})$$

$$\text{Therefore } \frac{1}{R} = \frac{1}{4} + \frac{1}{6} = \frac{10}{24}$$

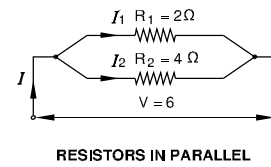
$$\text{Therefore } R = \frac{24}{10} \text{ ohms} = 2.4 \text{ ohms}$$

### Example

Two resistors of 2 and 4 ohms are switched in parallel to a 6V battery

- Calculate the total resistance
- Find the total current and partial current.

Fig 9



WSCN1133919

### Solution

Total resistance

$$\begin{aligned} \frac{1}{R_{\text{tot}}} &= \frac{1}{R_1} + \frac{1}{R_2} \\ &= \frac{1}{2} + \frac{1}{4} = \frac{2+1}{4} \\ &= \frac{3}{4} \Omega \end{aligned}$$

$$R_{\text{tot}} = \frac{4}{3} = 1\frac{1}{3} \Omega$$

I Total =  $I_1 + I_2$  current

$$\text{But } I_1 = \frac{U}{R_1} = \frac{6V}{2\Omega} = 3A$$

$$I_2 = \frac{U}{R_2} = \frac{6V}{4\Omega} = 1.5A$$

$$\begin{aligned} I_{\text{total}} &= 3A + 1.5A \\ &= 4.5 \text{ Amp} \end{aligned}$$

**Assume the given resistors in the assignment as bulb with filaments and other current consuming devices like Horn, Wiper etc of the vehicle.**

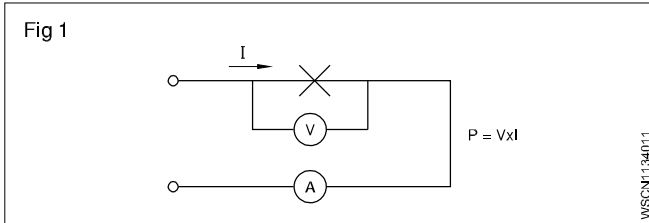
# Electrical power, energy and their units, calculation with assignment

## Exercise 1.13.40

V - Voltage (Volts) V

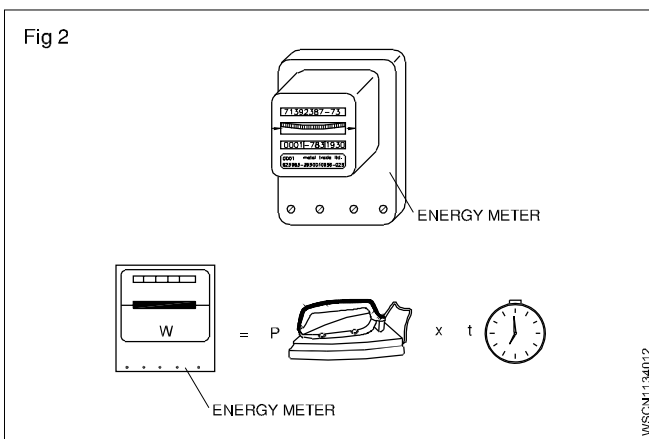
i - Current Intensity (Amperes) A

P - Power (Watts, Kilowatts) W, kW



W - Work, Energy (Watt hour, Kilowatt hour) wh, Kwh

t - time (hours) h



### Electric Power

In mechanical terms we defined power as the rate of doing work. The unit of power is Watt. In an electrical circuit also the unit of electrical power is 1 Watt. In mechanical terms 1 Watt is the work done by a force of 1 N to move the body through 1 metre in one second. In an electrical circuit, the electromotive force overcomes the resistance and does work. The rate of doing work depends upon the current flowing in the circuit in amperes. When an e.m.f of one volt causes a current of 1 ampere to flow the power is 1 Watt.

Hence Power = Voltage x Current

$$P = V \times I$$

Power in Watts = Voltage in Volts x Current in Amperes

### Electric work, energy

Electrical work or energy is the product of electrical power and time

Work in Watt seconds = Power in Watts x time in seconds

$$W = P \times t$$

Since 1 joule represents 1 Watt x 1 sec, which is very small, larger units such as 1 Watt hour and 1 kilowatt hour are used.

$$1 \text{ W.h} = 3600 \text{ Watt sec.}$$

$$1 \text{ Kwh} = 1000 \text{ Wh} = 3600000 \text{ Watt sec}$$

**Note: The charge for electric consumption is the energy cost per Kwh and it varies according to the country and states.**

Table of analogies between mechanical and electrical quantities

Mechanical quantity	Unit	Electrical quantity	Unit
Force 'F'	N	Voltage 'V'	V
Velocity $v = \frac{\text{Displacement}}{\text{Time}}$	m/s	Current 'I'	A
Time 't'	seconds	Time 't'	seconds
Power $P = F \times v$	$\text{N} \frac{\text{m}}{\text{sec}}$	Power $P = V \times i$	$W = V \times A$
Energy = $F \times v \times t$	$j = \text{Nm}$	Energy $W = V \times i \times t$	$j = W \times s$

$$\begin{aligned}
 W &= VI \\
 &= I^2R \\
 &= \frac{V^2}{R}
 \end{aligned}$$


---


$$\begin{aligned}
 R &= \frac{V}{I} \\
 &= \frac{V^2}{W} \\
 &= \frac{W}{I^2}
 \end{aligned}$$

$$\begin{aligned}
 V &= IR \\
 &= \frac{W}{I} \\
 &= \sqrt{WR}
 \end{aligned}$$


---


$$\begin{aligned}
 I &= \frac{V}{R} \\
 &= \frac{W}{V} \\
 &= \sqrt{\frac{W}{R}}
 \end{aligned}$$



### Example

- 1 Calculate the power rating of the lamp in the circuit, if 0.25 amperes of current flows and the voltage is 240 volts.

$$P = V \times I$$

$$V = 240 \text{ Volts}$$

$$I = 0.25 \text{ Amperes}$$

$$\begin{aligned} \text{Therefore Power} &= 240 \text{ Volts} \times 0.25 \text{ Amperes} \\ &= 60 \text{ Volts Ampere} \end{aligned}$$

$$\text{But } 1 \text{ Watt} = 1 \text{ Volt} \times 1 \text{ Amphere}$$

$$\text{Therefore Power} = 60 \text{ Watts}$$

- 2 A current of 15 amperes flow through a resistance of 10 Ohms. Calculate the power in kilowatts consumed.

$$\text{Given that } R = 10 \text{ and } I = 15 \text{ A}$$

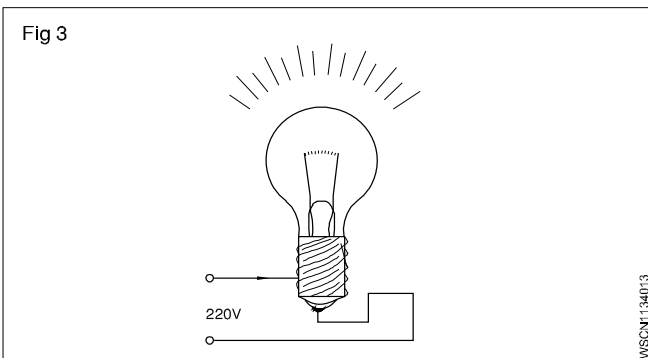
$$\text{Power} = V \times I = I \times R \times I = I^2 \times R$$

$$\text{Therefore Power} = 15^2 \times 10 = 2250 \text{ Watts} = 2.25 \text{ kW}$$

- 3 At a line voltage of 200 Volts a bulb consumes a current of 0.91 amperes. If the bulb is on for 12 hour calculate the work in Wh to find the work given that V = 200 Volts.

$$I = 0.91 \text{ Amps.}$$

$$t = 12 \text{ hours}$$



$$\begin{aligned} \text{Therefore Power} &= V \times I = 200 \text{ Volts} \times 0.91 \text{ Amps} \\ &= 182 \text{ Watts} \end{aligned}$$

$$\begin{aligned} \text{Therefore Work} &= P \times t = 182 \text{ Watts} \times 12 \text{ hours} \\ &= 2184 \text{ Watt hour.} \end{aligned}$$

- 4 An adjustable resistor bears the following label: 1.5 k Ohms/0.08 A. What is its rated power?

$$\text{Given: } R = 1.5 \text{ k Ohms; } I = 0.08 \text{ A}$$

Find: P

$$V = R \times I = 1500 \text{ Ohms} \cdot 0.08 \text{ A} = 120 \text{ volts}$$

$$P = V \times I = 120 \text{ volts} \cdot 0.08 \text{ A} = 9.6 \text{ W alternatively:}$$

$$P = I^2 \cdot R = (0.08 \text{ A})^2 \cdot 1500 \text{ Ohms} = 9.6 \text{ W.}$$

- 5 Find the current and power consumed by an electric iron having 110Ω resistance when feed from a 220 v supply

$$\text{Resistance of electric iron (R)} = 110 \text{ ohms}$$

$$\text{Voltage (V)} = 220 \text{ volts}$$

$$\begin{aligned} \text{Current (I)} &= \frac{V}{R} \\ &= \frac{220}{110} = 2 \text{ amperes} \\ \text{Power (w)} &= V \times I \\ &= 220 \times 2 \\ &= 440 \text{ watts} \end{aligned}$$

- 6 Find the total power if four 1000 W, 180 volt heaters are connected in series across 240 V supply and current carrying capacity is 15 amp. Find the total power.

$$\text{Connection} = \text{Series}$$

$$\text{No. of heaters} = 4$$

$$\text{Heater power (W)} = 1000 \text{ watts}$$

$$\text{Heater voltage} = 180 \text{ V}$$

$$\text{Supply voltage} = 240 \text{ V}$$

$$\begin{aligned} \text{Heater resistance (R)} &= \frac{V^2}{W} \\ &= \frac{180 \times 180}{1000} = \frac{324}{10} \\ &= 32.4 \text{ ohms} \end{aligned}$$

$$\text{Total resistance} = 32.4 \times 4 = 129.6 \text{ ohms}$$

$$\begin{aligned} \text{Total current (I)} &= \frac{V}{R} \\ &= \frac{240}{129.6} = 1.85 \text{ amperes} \end{aligned}$$

$$\begin{aligned} \text{Total Power (W)} &= V \times I \\ &= 240 \times 1.85 = 444 \text{ watts} \end{aligned}$$

- 7 If a 40 watt fluorescent lamp draws a current of 0.10 ampere. How much voltage will be required to illuminate it?

$$\text{Lamp power (W)} = 40 \text{ watt}$$

$$\text{Current (I)} = 0.10 \text{ ampere}$$

$$\begin{aligned} \text{Voltage (V)} &= \frac{W}{I} \\ &= \frac{40}{0.1} = 400 \text{ volts} \end{aligned}$$

- 8 Find the cost if running 15 HP motor for 15 days @ 6 hrs per day and the cost of energy is Rs. 3 per unit.

$$\begin{aligned} \text{Motor power (w)} &= 15 \text{ HP} \\ &= 15 \times 746 = 11,190 \text{ watts} \end{aligned}$$

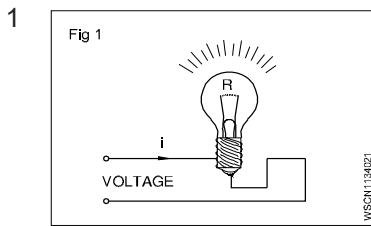
$$\begin{aligned} \text{Consumption per day} &= 11,190 \times 6 \\ &= 67140 = 67.14 \text{ KWH} \end{aligned}$$

$$\begin{aligned} \text{Consumption for 15 days} &= 67.14 \times 15 \\ &= 1007 \text{ KWH (or) unit} \end{aligned}$$

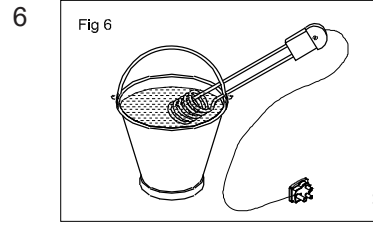
$$\text{Cost per unit} = \text{Rs. } 3$$

$$\text{Cost for total energy} = 3 \times 1007 = \text{Rs. } 3021$$

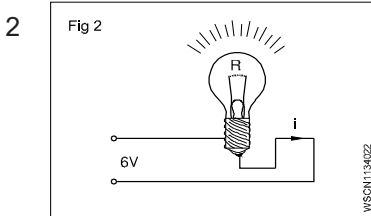
# 1 ASSIGNMENT



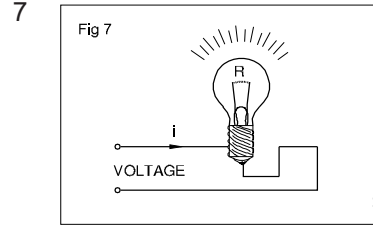
$R = 40 \text{ Ohms}$   
 $I = 6.5 \text{ Amps}$   
 $V = \text{_____ Volts}$



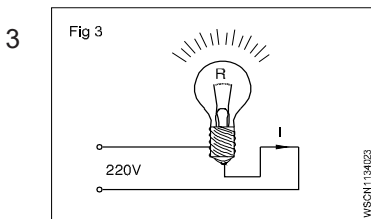
$V = 110 \text{ Volts}$   
 $I = 4.55 \text{ Amps}$   
 $R = \text{_____ Ohms}$



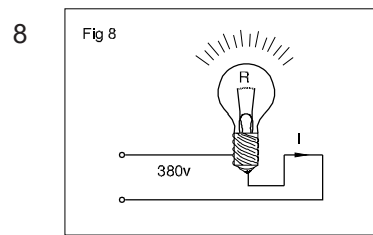
$V = 6 \text{ Volts}$   
 $I = 0.5 \text{ Amps}$   
 $R = \text{_____ Ohms}$



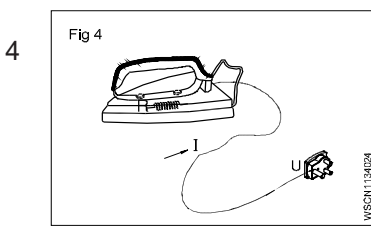
$R = 250 \text{ Ohms}$   
 $I = 0.44 \text{ Amps}$   
 $V = \text{_____ Volts}$



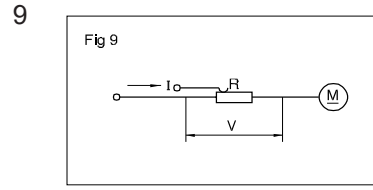
$V = 220 \text{ Volts}$   
 $R = 820 \text{ Ohms}$   
 $I = \text{_____ Amps}$



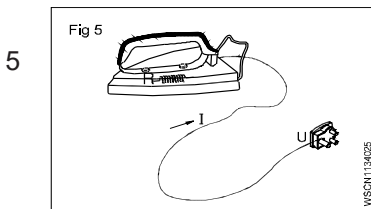
$I = 11.5 \text{ Amps}$   
 $V = 380 \text{ Volts}$   
 $R = \text{_____ Ohms.}$



$I = 4.5 \text{ Amps}$   
 $V = 220 \text{ Volts}$   
 $R = \text{_____ Ohms}$

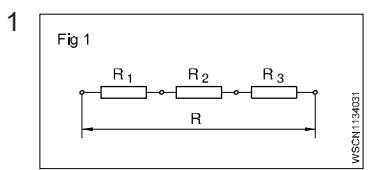


$R = 22 \text{ Ohms}$   
 $I = 7.8 \text{ Amps}$   
 (Voltage drop)  
 $V = \text{_____ Volt}$

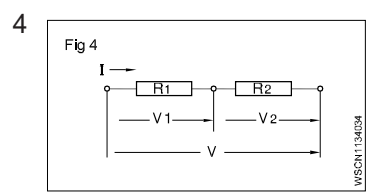


$R = 50 \text{ Ohms}$   
 $V = 220 \text{ Volts}$   
 $I = \text{_____ Amps}$

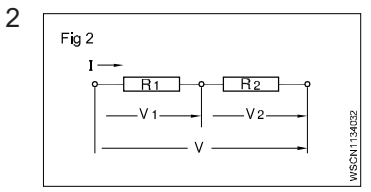
# 2 ASSIGNMENT



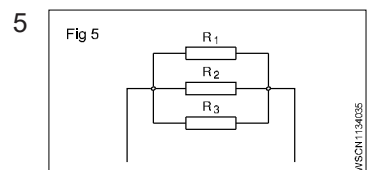
$R_1 = 12 \text{ ohms}$   
 $R_2 = 22 \text{ ohms}$   
 $R_3 = 24 \text{ ohms in series}$   
 $R = \text{_____ ohms}$



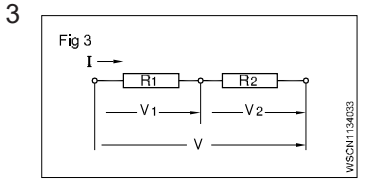
$V = 80 \text{ V}$   
 $I = 2 \text{ A}$   
 $R_1 = 30 \text{ ohms}$   
 (in series)  
 $R_2 = \text{_____ ohms}$



$R_1 = 15 \text{ ohms}$   
 $R_2 = 25 \text{ ohms}$   
 $V = 220 \text{ V}$   
 $V_1 = \text{_____ V}$   
 $V_2 = \text{_____ V}$   
 $V = 220 \text{ V}$

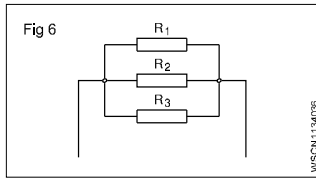


$R_1 = 6 \text{ ohms}$   
 $R_2 = 12 \text{ ohms}$   
 $R_3 = 18 \text{ ohms}$   
 (in parallel)  
 $R = \text{_____ ohms}$



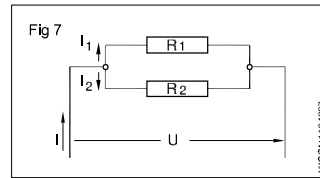
$R_1 = 40 \text{ ohms}$   
 $V_1 = 100 \text{ V}$   
 (in series)  
 $R_2 = \text{_____ ohms}$

6



$R = 6$  ohms  
 $R_1, R_2, R_3$  are in parallel  
 $R_1 = 12$  ohms  
 $R_2 = 16$  ohms  
 $R_3 = \underline{\hspace{2cm}}$  ohms

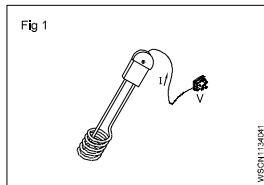
7



$R_1 = 40$  ohms  
 $R_2 = 60$  ohms  
 $V = 220$  V  
 $I = \underline{\hspace{2cm}}$  A  
 $I_1 = \underline{\hspace{2cm}}$  A  
 $I_2 = \underline{\hspace{2cm}}$  A

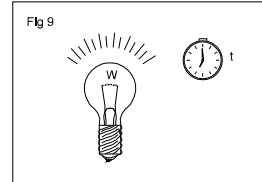
### 3 ASSIGNMENT

1



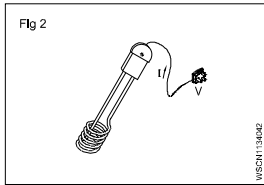
Current Consumed  
 $I = 0.136$  A  
 Voltage 'V' = 220 V  
 $P = \underline{\hspace{2cm}}$  Watts

9



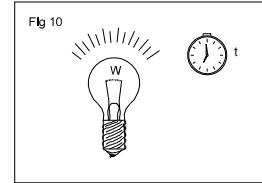
$P = 100$  W  
 $t = 1$  hour  
 Energy consumption  
 $= \underline{\hspace{2cm}}$  kWh

2



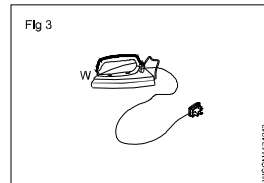
$P = 500$  Watts  
 $I = 2.27$  A  
 $V = \underline{\hspace{2cm}}$  v

10



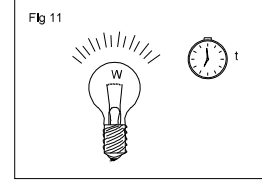
Energy consumed  
 'W' = 1 kWh  
 Power 'P' = 100 W  
 $t = \underline{\hspace{2cm}}$  hr

3



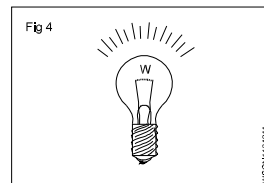
$P = 750$  W  
 $V = 220$  v  
 $I = \underline{\hspace{2cm}}$  A

11



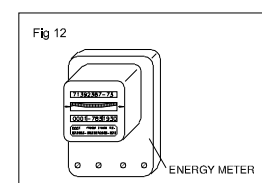
$W = 1.5$  kWh  
 $t = 45$  min.  
 $P = \underline{\hspace{2cm}}$  kW.

4



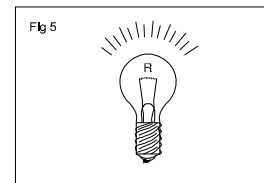
$P = 60$  W  
 $V = 200$  v  
 $R = \underline{\hspace{2cm}}$  W

12



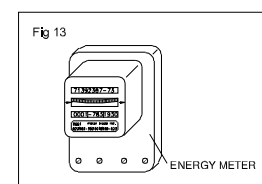
Energy metre reading  
 $W_1 = 6755.3$  kWh  
 Increases to  $W_2$   
 $= 6759.8$  kWh  
 $t = 45$  min.  
 $P = \underline{\hspace{2cm}}$  kW.

5



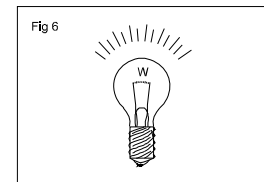
$I = 0.455$  A  
 $R = 484$  ohms  
 $P = \underline{\hspace{2cm}}$  Watts

13



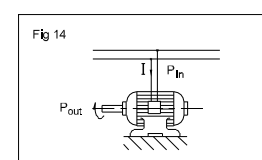
Power consumed  
 'P' = 6.2 kW  
 $t = 8$  hours  
 Charge per kwh  
 $= 1.25$  Rupees  
 Total cost  
 $= \underline{\hspace{2cm}}$  Rupees

6



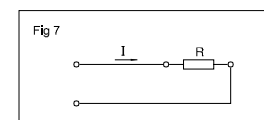
$P = 550$  W  
 $R = 22$  ohms  
 $I = \underline{\hspace{2cm}}$  A

14



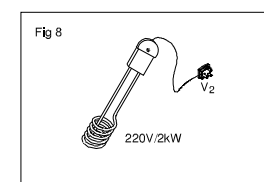
$I = 5.45$  A  
 $V = 220$  v  
 Energy consumed  
 $= 1$  kWh  
 $t = \underline{\hspace{2cm}}$  hr.

7



$P$  consumed = 1.8 kW  
 $R = 8$  ohms  
 $V = \underline{\hspace{2cm}}$  v

8



$I$  consumed =  $\underline{\hspace{2cm}}$  A  
 $P = 2$  kW  
 $V_1 = 220$  v-Heating  
 element voltage  
 $R = \underline{\hspace{2cm}}$  W

### Magnetic induction

When a magnet is brought near to an iron bar is brought near to a magnet, a magnetism is produced in the iron bar. The phenomenon is known as magnetic induction. Actually, before attracting an iron bar towards it, a magnet induces an opposite polarity in the iron bar and then due to attraction between unlike poles, magnet attracts the iron bar. The magnet need not to touch the iron bar for magnetic induction.

In various electrical measuring instruments, soft iron pole pieces are used along with bar magnets in order to give the desired shape to the magnet used, such pole piece work on the principle of magnetic induction.

### Intensity of magnetic field

The force acting on a unit pole placed in a magnetic field (attractive or repulsive force) is called the intensity of magnetic field. It is denoted by letter  $H$  and its unit is  $\text{Wb/m}$ .

### Principles and laws of electromagnetic induction

Faraday's laws of electromagnetic induction are also applicable for conductors carrying alternating current.

### Faraday's laws of electromagnetic induction

**Faraday's first law** states that whenever the magnetic flux is linked with a circuit changes, an emf is always induced in it.

**The second law** states that the magnitude of the induced emf is equal to the rate of change of flux linkage.

### Dynamically induced EMF

Accordingly induced emf can be produced either by moving the conductor in a stationary magnetic field or by changing magnetic flux over a stationary conductor. When conductor moves and produces emf, the emf is called as dynamically induced emf Example: Generators.

### Statically induced EMF

When changing flux produces emf the emf is called as statically induced emf as explained below. Example: Transformer.

**Statically induced emf:** When the induced emf is produced in a stationary conductor due to changing magnetic field, obeying Faraday's laws of electro magnetism, the induced emf is called as statically induced emf.

There are two types of statically induced emf as stated below:

- 1 **Self induced emf** produced with in the same coil.
- 2 **Mutually induced emf** produced in the neighbouring coil.

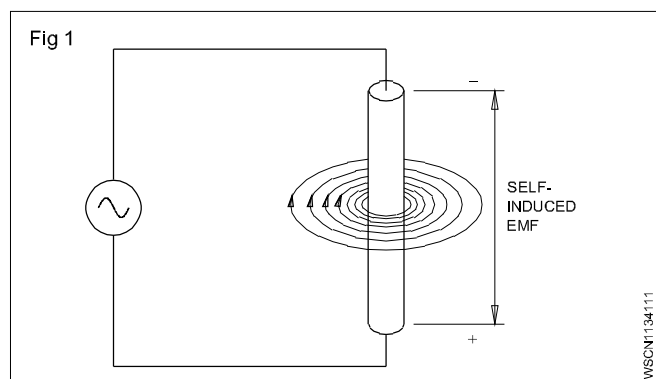
**Self-induction:** The production of an electromotive force in a circuit, when the magnetic flux linked with the circuit changes as a result of the change in a current inducing in the same circuit.

At any instant, the direction of the magnetic field is determined by the direction of the current flow.

With one complete cycle, the magnetic field around the conductor builds up and then collapses. It then builds up in the opposite direction, and collapses again. When the magnetic field begins building up from zero, the lines of force or flux lines expand from the centre of the conductor outward. As they expand outward, they can be thought of cutting through the conductor.

### Self induction

According to Faraday's Laws, an emf is induced in the conductor. Similarly, when the magnetic field collapses, the flux lines cut through the conductor again, and an emf is induced once again. This is called self-induction (Fig 1).

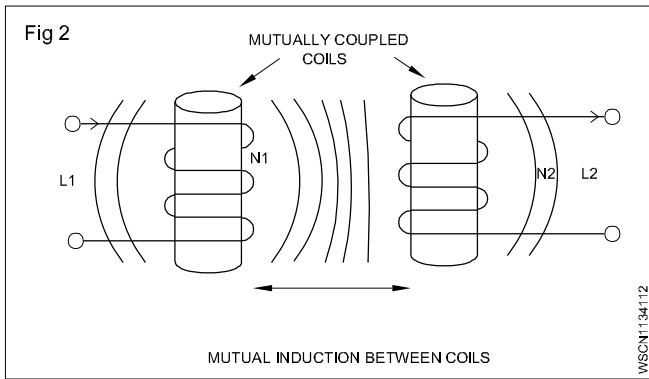


### Mutual induction

When two or more coils are magnetically linked together by a common magnetic flux, they are said to have the property of mutual inductance. It is the basic operating principle of the transformer, motor generators and any other electrical component that interacts with another magnetic field. It can define mutual induction on the current flowing in one coil that induces a voltage in an adjacent coil.

In Fig 2 current flowing in coil  $L_1$  sets up a magnetic field around it with some of its magnetic field lines passing through coil  $L_2$  giving rise to mutual inductance. Coil one  $L_1$  has a current of  $I$ , and  $N_1$  turns while coil two  $L_2$  has  $N_2$  turns therefore mutual inductance  $M$ , of coil two that exists with respect to coil one  $L_1$ , depends on their position with respect to each other.

The mutual inductance  $M$  that exists between the two coils can be greatly measured by positioning them on a common soft iron core or by measuring the number of turns of either coil as would be found in a transformer.



The two coils are tightly wound one on top of the other over a common soft iron core unity said to exist between them as any losses due to the leakage of flux will be extremely small. Then assuring a perfect flux linkage between the two coils the mutual inductance  $M$ .

### Dynamically induced EMF

**Generator:** An electrical generator is a machine which converts mechanical energy into electrical energy.

**Principle of the Generator:** To facilitate this energy conversion, the generator works on the principle of Faraday's Laws of Electromagnetic induction.

**Faraday's laws of electromagnetic induction:** There are two laws

The first law states:

- whenever the flux linking to a conductor or circuit changes, an emf will be induced.

The second law states:

- the magnitude of such induced emf ( $e$ ) depends upon the rate of change of the flux linkage.

**Types of emf:** According to Faraday's Laws, an emf can be induced, either by the relative movement of the conductor and the magnetic field or by the change of flux linking on a stationary conductor.

**Dynamically induced emf:** In case, the induced emf is due to the movement of the conductor in a stationary magnetic field as shown in Fig 1a or by the movement of the magnetic field on a stationary conductor as shown in Fig 1b, the induced emf is called dynamically induced emf.

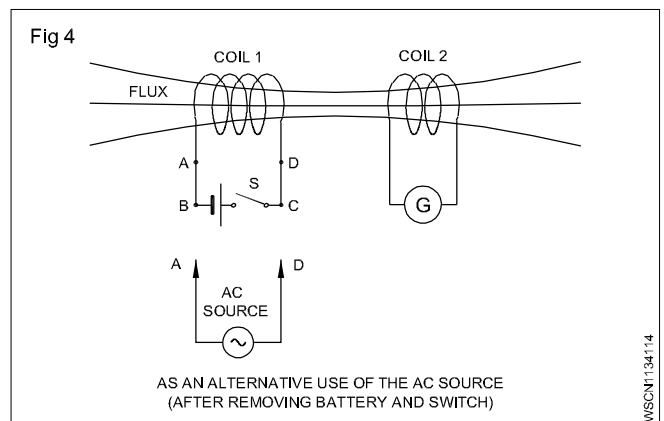
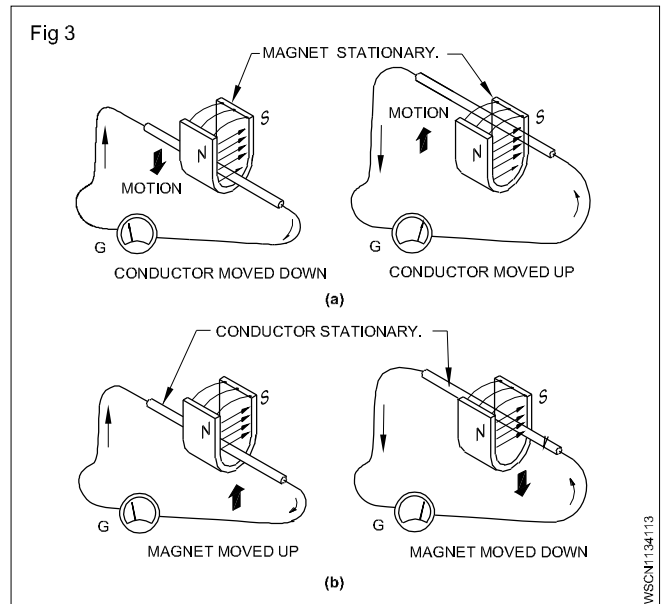
As shown in Fig 1a & 1b, the conductor cuts the lines of force in both cases to induce an emf, and the presence of the emf could be found by the deflection of the needle of the galvanometer 'G'. This principle is used in DC and AC generators to produce electricity.

**Statically induced emf:** In case, the induced emf is due to change of flux linkage over a stationary conductor as shown in Fig 2, the emf thus induced is termed as statically induced emf. The coils 1 and 2 shown in Fig 2 are not touching each other, and there is not electrical connection between them.

According to Fig 2, when the battery (DC) supply is used in coil 1, an emf will be induced in coil 2 only at the time of closing or opening of the switch S. If the switch is

permanently closed or opened, the flux produced by coil 1 becomes static or zero respectively and no emf will be induced in coil 2. EMF will be induced only when there is a change in flux which happens during the closing or opening of the circuit of coil 1 by the switch in a DC circuit.

Alternatively the battery and switch could be removed and coil 1 can be connected to an AC supply as shown in Fig 2. Then an emf will be induced in coil 2 continuously as long as coil 1 is connected to an AC source which produces alternating magnetic flux in coil 1 and links with coil 2. This principle is used in transformers.



**Production of dynamically induced emf:** Whenever a conductor cuts the magnetic flux, a dynamically induced emf is produced in it. This emf causes a current to flow if the circuit of the conductor is closed.

For producing dynamically induced emf, the requirements are:

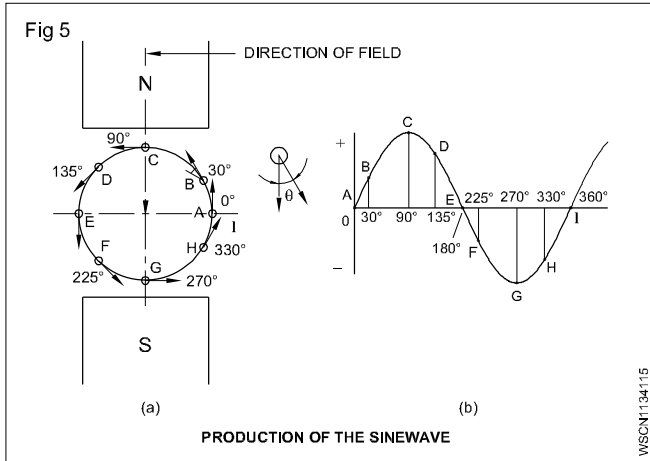
- magnetic field
- conductor
- relative motion between the conductor and the magnetic field.

If the conductor moves with a relative velocity ' $v$ ' with respect to the field, then the induced emf ' $e$ ' will be

$$= BLV \sin\theta \text{ Volts}$$

where

- B = magnetic flux density, measured in tesla
- L = effective length of the conductor in the field in metres
- V = relative velocity between field and conductor in metre/second.
- $\theta$  = the angle at which the conductor cuts the magnetic field.



Likewise for every position of the remaining conductors in the periphery, the emf induced could be calculated. If these values are plotted on a graph, it will represent the sine wave

pattern of induced emf in a conductor when it rotates under N and S poles of uniform magnetic field.

The emf induced by this process is basically alternating in nature, and this alternating current is converted into direct current in a DC generator by the commutator.

**Fleming's right hand rule:** The direction of dynamically induced emf can be identified by this rule. Hold the thumb, forefinger and middle finger of the right hand at right angles to each other as shown in Fig 4 such that the forefinger is in the direction of flux and the thumb is in the direction of the motion of the conductor, then the middle finger indicates the direction of emf induced, i.e. towards the observer or away from the observer.

