

WORKSHOP CALCULATION & SCIENCE

(NSQF)

1st YEAR

(As per Revised Syllabus July 2022)

**Information & Communication Technology
System Maintenance**



Directorate General of Training

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



**NATIONAL INSTRUCTIONAL
MEDIA INSTITUTE, CHENNAI**

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

Workshop Calculation & Science

Information & Communication Technology System Maintenance - 1st Year NSQF

As per Revised Syllabus July 2022

Developed & Published by



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FOREWORD

The Government of India has set an ambitious target of imparting skills one out of every four Indians, 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 - Information & Communication Technology System Maintenance 1st Year** NSQF (Revised 2022) under CTS 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

New Delhi - 110 001

Ms. TRISHALJIT SETHI,
Additional Secretary / Director General (Training),
Ministry of Skill Development & Entrepreneurship,
Government of India.

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. 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 - Information & Communication Technology System Maintenance 1st Year NSQF (Revised 2022)** under CTS is one of the book developed by the core group members as per the NSQF syllabus.

The **Workshop Calculation & Science - Information & Communication Technology System Maintenance 1st Year NSQF (Revised 2022)** under CTS as per NSQF 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

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 - Information & Communication Technology System Maintenance 1st Year** as per NSQF Revised 2022.

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| | | |
|------------------------|---|--|
| Shri. Nirmalya Nath | - | Deputy General Manager, NIMI, Chennai - 32. |
| Shri. G. Michael Johny | - | 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:

Duration of 1st Year : 26 Hrs

Time allotment for each title of exercises has been given below. **Workshop Calculation & Science - Information & Communication Technology System Maintenance** 1st Year NSQF Revised Syllabus 2022.

| S.No | Title | Exercise No. | Time in Hrs |
|--------------|--|-----------------|----------------------|
| 1 | Unit, Fractions | 1.1.01 - 1.1.07 | 4 |
| 2 | Square root, Ratio and Proportions, Percentage | 1.2.08 - 1.2.14 | 6 |
| 3 | Basic Electricity | 1.3.15 - 1.3.20 | 12 |
| 4 | Trigonometry | 1.4.21 - 1.4.23 | 4 |
| Total | | | <u>26 Hrs</u> |

LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

- **Demonstrate basic mathematical concept and principles to perform practical operations.**
- **Understand and explain basic science in the field of study.**

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SYLLABUS

1st Year

Workshop Calculation & Science - Information & Communication Technology System Maintenance

Revised syllabus July 2022 under CTS

| S.No. | Title | Time in Hrs |
|------------|---|-------------|
| I | Unit, Fractions 1 Classification of Unit System 2 Fundamental and Derived Units F.P.S, C.G.S, M.K.S and SI Units 3 Measurement Units and Conversion 4 Factors, HCF, LCM and Problems 5 Fractions – Addition, Subtraction, Multiplication & Division 6 Decimal Fractions – Addition, Subtraction, Multiplication & Division 7 Solving Problems by using calculator | 4 |
| II | Square root, Ratio and Proportions, Percentage 1 Square and Square root 2 Simple problems using calculator 3 Applications of Pythagoras theorem and related problems 4 Ratio and Proportion 5 Ratio and Proportion - Direct and Indirect proportions 6 Percentage 7 Percentage - Changing percentage to decimal and fraction | 6 |
| III | Basic Electricity 1 Introduction and uses of electricity, molecule, atom, how electricity is produced, electric current AC, DC their comparison, voltage, resistance and their units 2 Conductor, Insulator, types of connections- Series and Parallel 3 Ohm's Law, relation between VIR & related problems 4 Electrical power, energy and their units, calculation with assignments 5 Magnetic induction, self and mutual inductance and EMF generation 6 Electrical Power, HP, Energy and units of electrical energy | 12 |
| IV | Trigonometry 1 Measurement of angles 2 Trigonometrical ratios 3 Trigonometrical tables | 4 |
| | Total | 26 |

Unit, Fractions - Classification of unit system

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/cm³?

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/cm³

Area of cross section of copper wire

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

Volume of copper wire

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

Length of copper wire

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

Length of copper wire = 1413cm.

Time: The S.I. unit of time, the second, is another 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 |

Unit, Fractions - Fundamental and Derived units F.P.S, C.G.S, M.K.S and SI units

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 | SIUnits | Symbol |
| 1 | Area | Square foot | ft ² | Square centimetre | cm ² | Square metre | m ² | Square metre | m ² |
| 2 | Volume | Cubic foot | ft ³ | Cubic centimetre | cm ³ | Cubic metre | m ³ | Cubic metre | m ³ |
| 3 | Density | Pound per cubic foot | lb/ft ³ | Gram per cubic centimetre | g/cm ³ | Kilogram per cubic metre | kg/m ³ | Kilogram per cubic metre | Kg/m ³ |
| 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 ² | Centimetre per square second | cm/sec ² | Metre per square second | m/sec ² | Metre per square second | m/sec ² |
| 7 | Retardation | Foot per square Second | ft/s ² | Centimetre per square second | cm/sec ² | Metre per square second | m/sec ² | Metre square second | m/sec ² |
| 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 | dyne | dyn | Kilogram force | kgf | Newton | N(kgm/sec ²) |
| 12 | Power | Foot pound per second | ft.lb/sec | Gram.centimetre/sec | g.cm/sec | kilogram metre per second | kg.m/sec | - | - |
| | | Horse power | hp | Erg per second | | watt | W | watt | W(J/sec) |
| 13 | Pressure, Stress | Pound per square inch | lb/in ² | Gram per square centimetre | g/cm ² | Kilogram per square metre | kg/m ² | Newton per square metre | N/m ² |
| 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 |

Unit, Fractions - Measurement units and conversion

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 ² |
| 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 ² kN/m ² |
| Angle | radian | rad |
| Angular speed | radians per second radians-per-square second revolutions per minute revolutions per second | rad/s rad/s ² Rpm rev/s |

Decimal multiples and parts of unit

| Decimal power | Value | Prefixes | Symbol | Stands for |
|-------------------|----------------|----------|--------|----------------------|
| 10 ¹² | 1000000000000 | tera | T | billion times |
| 10 ⁹ | 1000000000 | giga | G | thousand millintimes |
| 10 ⁶ | 1000000 | mega | M | million times |
| 10 ³ | 1000 | kilo | K | thousand times |
| 10 ² | 100 | hecto | h | hundred times |
| 10 ¹ | 10 | deca | da | ten times |
| 10 ⁻¹ | 0.1 | deci | d | tenth |
| 10 ⁻² | 0.01 | centi | c | hundredth |
| 10 ⁻³ | 0.001 | milli | m | thousandth |
| 10 ⁻⁶ | 0.000001 | micro | μ | millionth |
| 10 ⁻⁹ | 0.000000001 | nano | n | thousand millionth |
| 10 ⁻¹² | 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 ² = 3.281 ft/s ² | 1 ft/s ² = 0.305 m/s ² |
| Mass | 1 kg = 2.205 lb | 1 lb = 0.454 kg |
| Force | 1 N = 0.225 lbf 1 MN | 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 ² = 0.000145 lbf/in ² 1 Pa = 1 N/m ² 1 bar = 14.5038 lbf/in ² | 1 lbf/in ² = 6.896 kN/m ² 1 lbf/in ² = 6.895 kN/m ² |
| 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 |

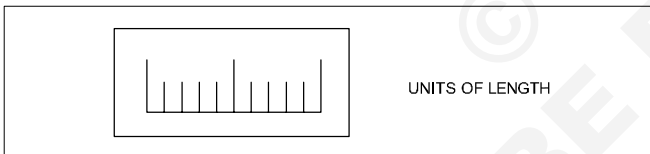
Prefixes for decimal multiples and submultiples

| 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 μ 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 g |
| 1 kg | = 2.205 lbs |
| 1 metric ton | = 0.98 ton |

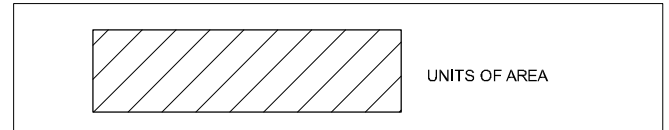
Units of physical quantities



Units of length

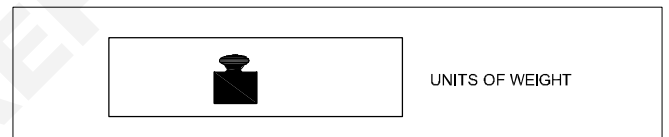
| | | |
|-------------------|---------|--------------|
| Micron | 1 μ | = 0.001 mm |
| Millimetre | 1 mm | = 1000 μ |
| Centimetre | 1 cm | = 10 mm |
| Decimetre | 1 dm | = 10 cm |
| Metre | 1 m | = 10 dm |
| Kilometre | 1 km | = 1000 m |
| Inch | 1" | = 25.4 mm |
| Foot | 1' | = 0.305 m |
| Yard | 1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

Units of area

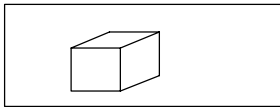


| | | |
|-------------------|-------------------|--------------------------------|
| Square millimetre | 1 mm ² | |
| Square centimetre | 1 cm ² | = 100 mm ² |
| Square decimetre | 1 dm ² | = 100 cm ² |
| Square metre | 1 m ² | = 100 dm ² |
| Are | 1 a | = 100 m ² |
| Hectare | 1 ha | = 100 a |
| Square kilometre | 1 km ² | = 100 ha |
| Square inch | 1 sq.in | = 6.45 cm ² |
| Square foot | 1 sq.ft | = 0.093 m ² |
| Square yard | 1 sq.yd | = 0.84 m ² |
| Square metre | 1 m ² | = 10.76 ft ² |
| Acre | 1 | = 40.5 a |
| 1 Acre | = 100 cent | 1 Hectare = 2.47 acres |
| 1 Cent | = 436 Sq. ft. | 1 acre = 0.4047 Hec tare |
| 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 |

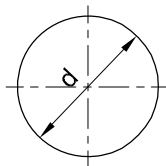


UNITS OF VOLUME AND CAPACITY

Units of volume and capacity

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

Circular unit



CIRCULAR OF UNIT

Radian

Relationship between Radian and Degree

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

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

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

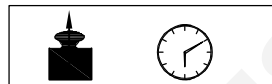
Work



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 ⁶ J |
| | | = 859.8456 kcal _{IT} |
| I.T.Kilocalorie | 1 kcal _{IT} | = 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 _{IT/h} = 1.163 W |

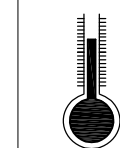
Pressure

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

TEMPERATURE

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

TEMPERATURE



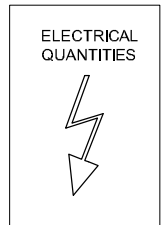
$$\frac{^\circ\text{R}}{80} = \frac{^\circ\text{C}}{100} = \frac{\text{K} - 273}{100} = \frac{^\circ\text{F} - 32}{180}$$

FORCE

| | |
|--------------|---|
| Force | In C.G.S. System : Force (Dyne) = Mass (gm) X Acceleration (cm/sec ²) |
| | In F.P.S. System : Force (Poundal) = Mass (lb) X Acceleration (ft./sec ²) |
| | In M.K.S System : Force (Newton) = Mass (Kg) x Acceleration (mtr./sec ²) |
| 1 Dyne | = 1 gm x 1 cm/sec ² |
| 1 Poundal | = 1 lb x 1 ft/sec ² |
| 1 Newton | = 1 kg x 1 mtr/sec ² = 10 ⁵ 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 | Ω | Ohm | Ω (V/A) |
| e | Specific resistance | Ω m | Ohm metre | Vm/A |
| G | Conductance | Ω ⁻¹ | Siemens | S |



Assignment - Answer the following question.

- Convert 320 kilometres into miles _____
- Convert 16 tons into kilograms _____
- Convert 40 inches into centimetres _____
- Convert 8 metres into feet _____
- Convert 2.5 gallons into litres _____
- Convert 5 litres into gallons _____
- 120°C = _____ °F.
- Expand the abbreviations of the following
 - N/m²
 - RPM
- Convert the following S.I. units as required.
 - Length
 - 3.4 m = _____ mm
 - 10.2 km = _____ mile
 - Mass
 - 650 g = _____ kg
 - 120 mg = _____ g
 - Force
 - 1.2 N = _____ kg
 - 25 kg = _____ N
 - Work, energy, amount of heat
 - 120 KJ = _____ J
 - 300 wh = _____ kwh
 - Power
 - 0.2 kW = _____ W
 - 350 W = _____ kW
 - Convert as required.
 - 5 N = _____ KN

Unit, Fractions - Factors, HCF, LCM and problems

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.

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

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

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

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

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

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

- 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

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

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

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

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

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

$$196 = 2 \times 2 \times 49$$

$$\text{HCF} = 2$$

- 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.

Unit, Fractions - Fractions - Addition, subtraction, multiplication & division

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.

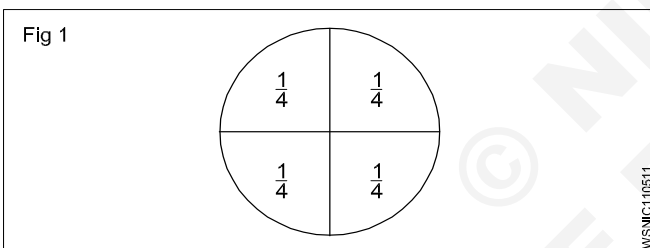
$$\frac{1}{4}, \frac{3}{4}, \frac{7}{12}$$

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

Fraction: Concept

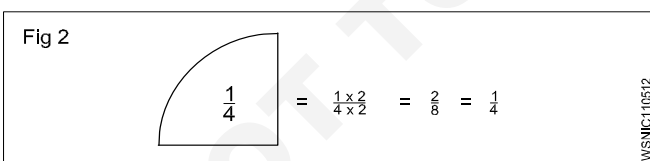
Every number can be represented as a fraction.e.g.

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



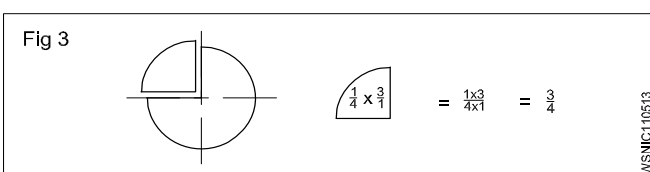
Fraction: Value

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)



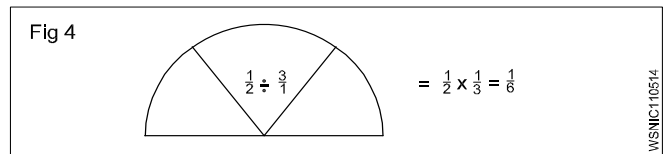
Multiplication

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)



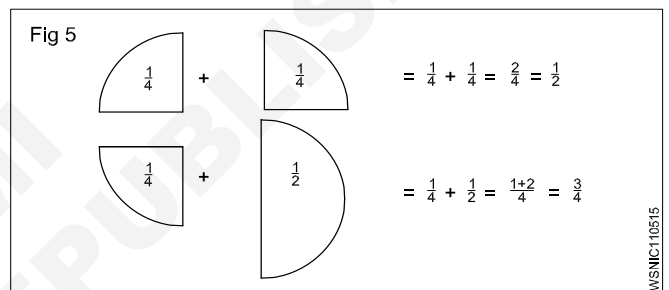
Division

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

| | |
|---|--------|
| 2 | 2,8,12 |
| 2 | 1,4,6 |
| | 1,2,3 |

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

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

Examples

Common fractions

- Multiply

$$\text{a } \frac{3}{8} \text{ by } \frac{4}{7} = \frac{3}{8} \times \frac{4}{7} = \frac{3}{14} \quad \text{b } \frac{2}{3} \times \frac{3}{4} \times \frac{5}{8} = \frac{5}{16}$$

- 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

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

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

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

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

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

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

Assignment

1 Convert the following into improper fractions.

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

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

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

2 Convert the following into mixed numbers.

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

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

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

3 Place the missing numbers.

a $\frac{11}{13} = \frac{x}{91}$ _____

b $\frac{3}{5} = \frac{42}{x}$ _____

c $\frac{9}{14} = \frac{x}{98}$ _____

4 Simplify.

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

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

5 Multiply.

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

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

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

6 Divide

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

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

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

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

8 Add the followings:

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

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

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

11 Express as improper fractions

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

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

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

Unit, Fractions - Decimal fractions - Addition, subtraction, multiplication & division

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.

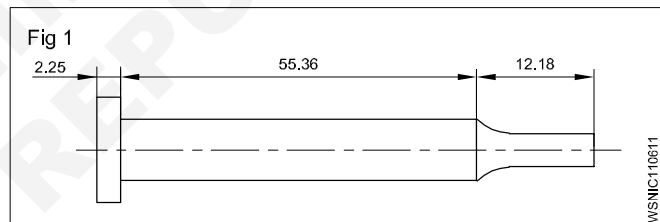
Divide 0.75 by 0.25

$$\begin{array}{r} 0.25 \overline{)0.75} \\ 0.75 \times \frac{100}{100} = \frac{75}{25} \\ 25 \overline{)75} = 3 \end{array}$$

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

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



Total Length of pin = $2.25 + 55.36 + 12.18$
= 69.79 mm

Cutting allowance = 3 mm

Total Length = length of pin + cutting allowance
= $69.79 \text{ mm} + 3 \text{ mm}$
= 72.79 mm

Length of the bar = 900 mm

No. of pins to be cut = $\frac{900}{72.79} = 12.394$
= 12 pins

Left out material = Total length - length of pin + cutting allowance
= $900 - 12 \times 69.79 + 12 \times 3$
= $900 - 837.48 + 36$
= $900 - 873.48$

Left out length = 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)

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

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

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

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

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

Method of writing approximations in decimals

$$\begin{array}{lll} 1.73556 & = & 1.7356 \quad \text{Correct to 4 decimal places} \\ 5.7343 & = & 5.734 \quad \text{Correct to 3 decimal places} \\ 0.9345 & = & 0.94 \quad \text{Correct to 2 decimal places} \end{array}$$

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

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

$$= 453 \frac{273}{1000}$$

- 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

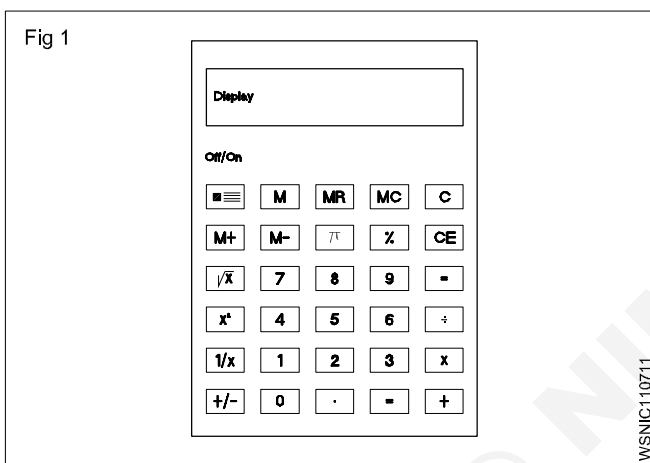
- 1 Write down the following decimal numbers in the expanded form.
- a 514.726
b 902.524
- 2 Write the following decimal numbers from the expansion.
- a $500 + 70 + 5 + \frac{3}{10} + \frac{2}{100} + \frac{9}{1000}$
b $200 + 9 + \frac{1}{10} + \frac{3}{100} + \frac{5}{1000}$
- 3 Convert the following 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 $1 \frac{3}{25}$
- 5 Addition of decimals
- a $4.56 + 32.075 + 256.6245 + 15.0358$
b $462.492 + 725.526 + 309.345 + 626.602$
- 6 Subtract the following decimals
- a $612.5200 - 9.6479$
b $573.9246 - 215.6000$
- 7 Add and subtract the following
- a $56.725 + 48.258 - 32.564$
b $16.45 + 124.56 + 62.7 - 3.243$
- 8 Multiply the following
- a By 10, 100, 1000
i 3.754×10
ii 8.964×100
iii 2.3786×1000
iv 0.005×1000
- b By whole numbers
i 8.4×7
ii 56.72×8
- c By another decimal figure (use calculator)
i 15.64×7.68
ii 2.642×1.562
- 9 Divide the following
- a $\frac{62.5}{25}$
b $\frac{64.56}{10}$
c $\frac{0.42}{100}$
d $\frac{48.356}{1000}$
- 10 Division
- a $\frac{16.8}{1.2}$
b $\frac{1.54}{1.1}$
- 11 Change the fraction into a decimal
- i $1 \frac{5}{8}$
ii $\frac{12}{25}$
- 12 Find the value
 $20.5 \times 40 \div 10.25 + 18.50$

Unit, Fractions - Solving problems by using calculator

A pocket calculator allows to spend less time in doing tedious calculations. A simple pocket calculator enables to do the arithmetical 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 capabilities. 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 recognizable areas and the display.

• Data entry keys

The entry keys are from 0to 9

and a key for the decimal point . .

• Clearing keys

These keys have the letter 'C'

C CLR Clear totally

CE Clear entry only

CM , MC Clear memory

- + Addition key
- Subtraction key
- x Multiplication key
- ÷ Division key
- = Equals key to display the result

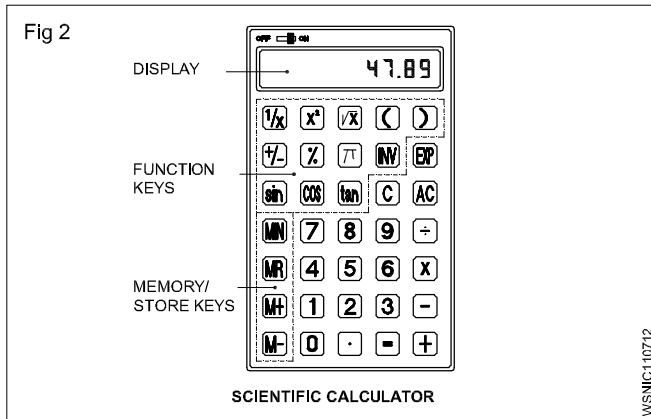
• Function keys

- π Pi key
- √x Square root key
- % Percentage key
- +/- Sign change key
- x² Square key
- 1/x Reciprocal key

• Memory keys

- M Store the display number
- M+ The displayed value is added to the memory
- M- The displayed value is subtracted from the memory
- MR RCL The stored value is recalled on to the display

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



$\boxed{\text{Sin}}$ $\boxed{\text{Cos}}$ $\boxed{\text{Tan}}$ $\boxed{(\quad)}$ $\boxed{)}$ 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 | $\boxed{1} \boxed{2} \boxed{8} \boxed{.} \boxed{8}$ | 128.8 |
| Press - key | $\boxed{-}$ | 128.8 |
| Enter the minuend. The subtrahend goes into the register | $\boxed{9} \boxed{2} \boxed{.} \boxed{9}$ | 92.9 |
| Press the = key | $\boxed{=}$ | 35.9 |

- **Multiplication:** Example 0.47×2.47

| 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 : $2.5 \times 7.2 / 4.8 \times 1.25$

| 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 Open bracket | (| |
| Enter 4.8 | 4 . 8 | 4.8 |
| Press x key | x | 4.8 |
| Enter 1.25 | 1 . 2 5 | 1.25 |
| Enter Close bracket |) | 6 |
| Press = key | = | 3.0 |

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

| Sequence | Input | Display |
|-------------------------------|-----------|---------|
| Workout for the first bracket | 2 | 2 |
| | + | 2 |
| | 6 | 6 |
| | = | 8 |
| Store the first result in | STO , M | 8 |
| x | or M+ | |
| Workout for the 2nd bracket | 4 | 4 |
| | + | 4 |
| | 3 | 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} | 1.414 |
| Press + key | + | 1.414 |
| Press bracket key | (| 1.414 |
| Enter 3 | 3 | 3 |
| Press \sqrt{a} key | \sqrt{a} | 1.732 |
| Press x key | x | 1.732 |
| Enter 5 | 5 | 5 |
| Press \sqrt{a} key | \sqrt{a} | 2.236 |
| Press bracket close key |) | 3.873 |
| Press = key | = | 5.2871969 |
| | 2 \sqrt{a} + (3 \sqrt{a} x 5 \sqrt{a}) = | 5.2871969 |

$$\sqrt{2} + \sqrt{3 \times 5} = 5.287$$

• **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 ² = | 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

- $625 + 3467 + 20 + 341 + 6278 = \underline{\hspace{2cm}}$
- $367.4 + 805 + 0.7 + 7.86 + 13.49 = \underline{\hspace{2cm}}$
- $0.043 + 1.065 + 13.0 + 34.76 + 42.1 = \underline{\hspace{2cm}}$
- $47160 + 1368.4 + 0.1 + 1.6901 + 134.267 = \underline{\hspace{2cm}}$

2 Using calculator simplify the following

- $24367 - 4385 = \underline{\hspace{2cm}}$
- $9.643 - 0.7983 = \underline{\hspace{2cm}}$
- $4382.01 - 381.3401 = \underline{\hspace{2cm}}$
- $693.42 - 0.0254 = \underline{\hspace{2cm}}$

3 Using calculator find the values of the following

- $23 \times 87 = \underline{\hspace{2cm}}$
- $1376 \times 0.81 = \underline{\hspace{2cm}}$
- $678 \times 243 = \underline{\hspace{2cm}}$
- $0.75 \times 0.24 = \underline{\hspace{2cm}}$

4 Using calculator solve the following

- $22434 \div 3 = \underline{\hspace{2cm}}$
- $4131 \div 243 = \underline{\hspace{2cm}}$
- $469890 \div 230 = \underline{\hspace{2cm}}$
- $3.026 \div 0.89 = \underline{\hspace{2cm}}$

5 Solve the following

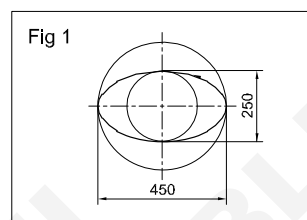
- $\frac{1170 \times 537.5}{13 \times 215} = \underline{\hspace{2cm}}$
- $\frac{28.2 \times 18 \times 3500}{1000 \times 3 \times 0.8} = \underline{\hspace{2cm}}$

6 Solve the following

- $\frac{(634 + 128) \times (384 - 0.52)}{8 \times 0.3} = \underline{\hspace{2cm}}$

$$b \frac{(389 - 12.2) \times (842 - 0.05 - 2.6)}{(3.89 - 0.021) \times (28.1 + 17.04)} = \underline{\hspace{2cm}}$$

7



2a = 450 mm (major axis)

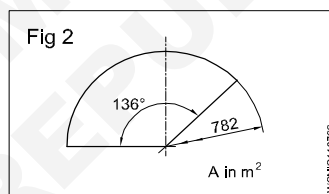
2b = 250 mm (minor axis)

Perimeter of the ellipse

A = $\underline{\hspace{2cm}}$ metre²

Hint A = $\pi \times a \times b$
unit²

8



$\phi = 782$ mm

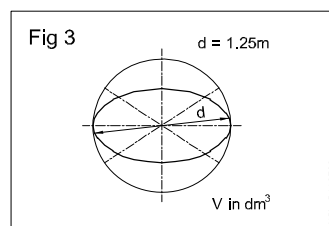
$\alpha = 136^\circ$

Area of the sector

A = $\underline{\hspace{2cm}}$

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

9



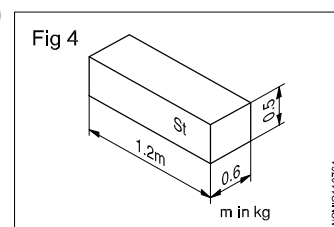
d = 1.25 metre

V = $\underline{\hspace{2cm}}$ dm³

Volume of sphere

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

10



L = 1.2 metres

B = 0.6 metre

H = 0.5 metre

' ρ ' (rho) density of steel
= 7.85 kg/dm³

m = $\underline{\hspace{2cm}}$ kg

(mass 'm' = V x ρ)

Square root, Ratio and Proportions, Percentage - Square and square root

- a basic number
- 2 exponent

√ radial sign indicating the square root.

√a² square root of 'a' square

a² radicand

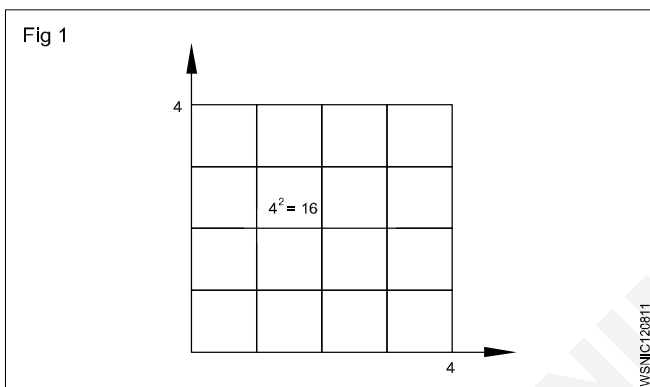
Square number

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

Basic number x basic number = Square number

a x a = a²

4 x 4 = 4² = 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.

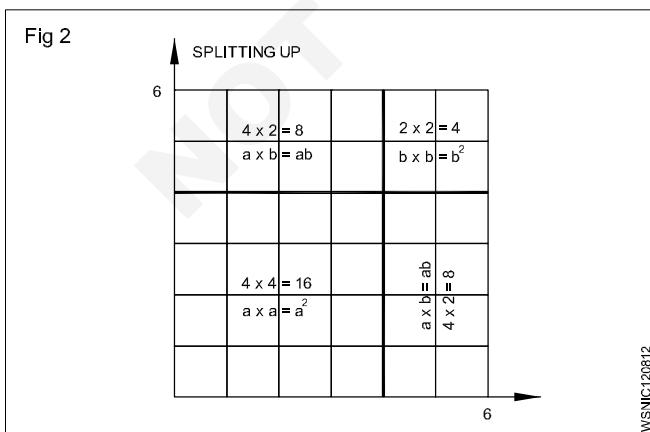
Large square 4 x 4 = 16 a²

Two rectangles 2 x 4 x 2 = 16 2ab

Small square 2 x 2 = 4 b²

Sum of sub-areas = 36 = a² + 2ab + b²

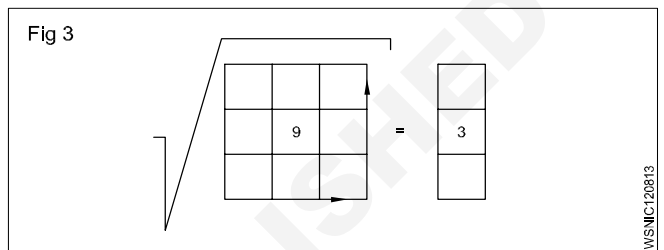
√36 = √a² + 2ab + b²



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. √4624.00
- 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.

| | |
|-----|-------|
| 6 | 46,24 |
| | 36 |
| 128 | 1024 |
| | 1024 |
| | 0 |

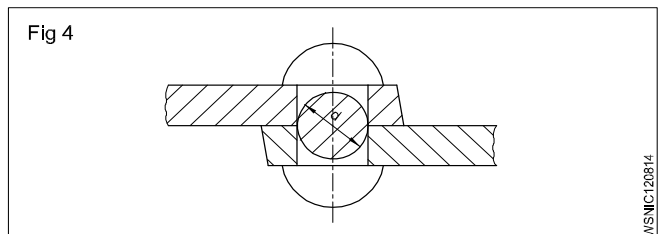
√4624 = 68

Basic number x basic number = Square

√Square number = basic number

Example

The cross-section of a rivet is 3.46 cm². Calculate the diameter of the hole.



Rivet cross-section is the hole cross-section.

To find 'd',

Given that Area = 3.46 cm²

Area = 0.785 x d² (formula)

3.46 cm² = d² x 0.785

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

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

d = 2.1 cm (or) 21mm

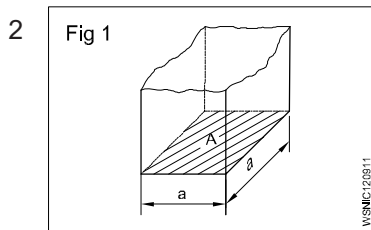
Square root, Ratio and Proportions, Percentage - Simple problems using calculator

1 a $\sqrt{2916} =$ _____.

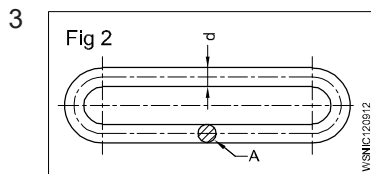
b $\sqrt{45796} =$ _____.

c $\sqrt{8.2944} =$ _____.

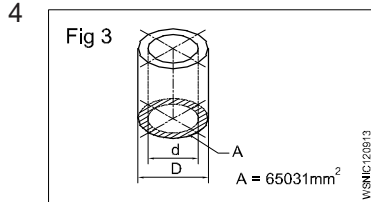
d $\sqrt{63.845} =$ _____.



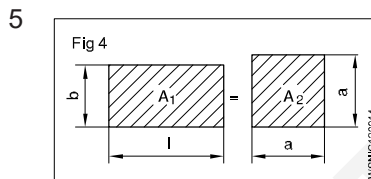
$A = 2025 \text{ mm}^2$
 $a =$ _____ mm



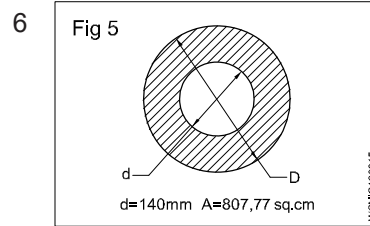
$A = 176.715 \text{ mm}^2$
 $d =$ _____ mm



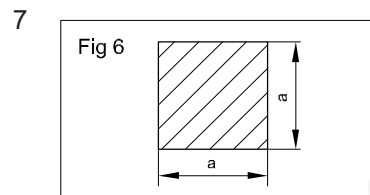
$A = 65031 \text{ mm}^2$
 $d = 140 \text{ mm}$
 $D =$ _____ mm



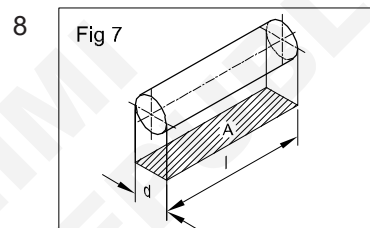
$l = 58 \text{ cm}$
 $b = 45 \text{ cm}$
 $A_1 = A_2$
 $a =$ _____ cm



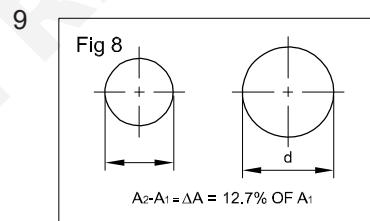
$A = 807.77 \text{ cm}^2$
 $d = 140 \text{ mm}$
 $D =$ _____ mm



$a \times a = 543169 \text{ mm}^2$
 $a =$ _____ mm



$d : l = 1 : 1.5$
 $A = 73.5 \text{ mm}^2$
 $d =$ _____ mm

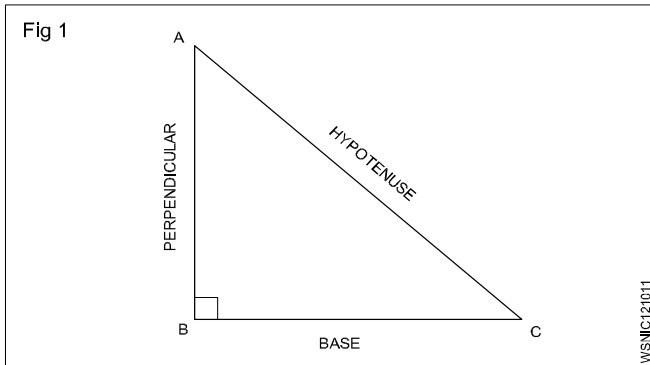


increase in area
 $A = 12.7\%$
 $A = 360 \text{ mm}^2$
 $d =$ _____ mm
 (d = diameter after the increase in area)

Square root, Ratio and Proportions, Percentage - Applications of pythagoras theorem and related problems

Applications of Pythagoras Theorem

Some of the applications of the Pythagoras theorem are; (Fig 1)



- 1 The Pythagoras theorem is commonly used to find the lengths of sides of a right-angled triangle.
- 2 It is used to find the length of the diagonal of a square.
- 3 Pythagoras theorem is used in trigonometry to find the trigonometric ratios like sin, cos, tan, cosec, sec and cot.
- 4 Pythagoras theorem is used in security cameras for face recognition.
- 5 Architects use the technique of the Pythagoras theorem for engineering and construction fields.
- 6 The Pythagoras theorem is applied in surveying the mountains.
- 7 It is also used in navigation to find the shortest route.
- 8 By using the Pythagoras theorem, we can derive the formula for base, perpendicular and hypotenuse.
- 9 Painters use ladders to paint on high buildings with the help of the Pythagoras theorem.
- 10 Pythagoras theorem is used to calculate the steepness of slopes of hills or mountains.
- 11 The converse of the Pythagoras theorem is used to check whether a triangle is a right triangle or not.

Application of pythagoras theorem in real life

Pythagoras theorem states that

"In a right-angled triangle, the square of the hypotenuse side is equal to the sum of squares of the other two sides".

- 1 The sides of this triangle have been named Perpendicular, Base and Hypotenuse.
- 2 The hypotenuse is the longest side, as it is opposite to the angle 90°.

- 3 The sides of a right triangle (say AB, BC and CA) which have positive integer values, when squared, are put into an equation, also called a Pythagorean triplet.
- 4 To calculate the length of staircase required to reach a window
- 5 To find the length of the longest item can be kept in your room.
- 6 To find the steepness of the hills or mountains.
- 7 To find the original height of a tree broken due to heavy rain and lying on itself
- 8 To determine heights and measurements in the construction sites.

Examples

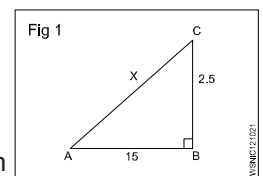
- 1 What is the side AC if AB = 15 cm, BC = 25 cm.

$$AC^2 = AB^2 + BC^2$$

$$= 15^2 + 25^2$$

$$= 225 + 625 = 850$$

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



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

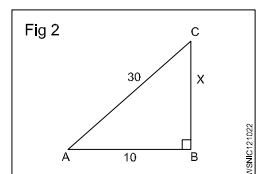
$$AC^2 = AB^2 + BC^2$$

$$30^2 = 10^2 + BC^2$$

$$900 = 100 + BC^2$$

$$BC^2 = 900 - 100 = 800$$

$$BC = 28.284 \text{ cm}$$



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

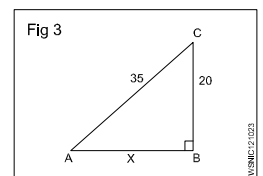
$$AC^2 = AB^2 + BC^2$$

$$35^2 = AB^2 + 20^2$$

$$1225 = AB + 400$$

$$AB^2 = 1225 - 400 = 825$$

$$AB = 28.72 \text{ cm}$$



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

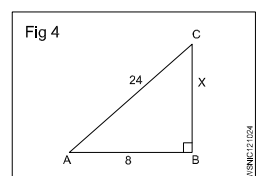
$$AC^2 = AB^2 + BC^2$$

$$24^2 = 8^2 + BC^2$$

$$576 = 64 + BC^2$$

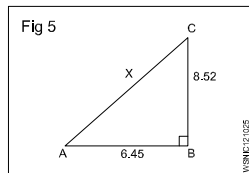
$$BC^2 = 576 - 64 = 512$$

$$BC = \sqrt{512} = 22.63 \text{ cm}$$



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

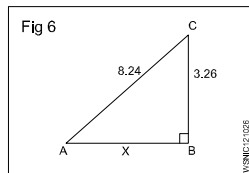
$$\begin{aligned} AC^2 &= AB^2 + BC^2 \\ AC^2 &= 6.45^2 + 8.52^2 \\ AC^2 &= 41.60 + 72.59 \\ &= 114.19 \end{aligned}$$



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

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

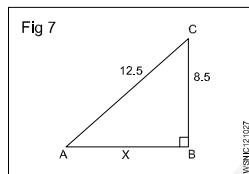
$$\begin{aligned} AC^2 &= AB^2 + BC^2 \\ 8.24^2 &= AB^2 + 3.26^2 \\ 67.9 &= AB^2 + 10.63 \\ AB^2 &= 67.9 - 10.63 \\ &= 57.27 \end{aligned}$$



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

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

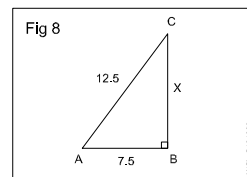
$$\begin{aligned} AC^2 &= AB^2 + BC^2 \\ 12.5^2 &= AB^2 + 8.5^2 \\ 156.25 &= AB^2 + 72.25 \\ AB^2 &= 156.25 - 72.25 \\ &= 84 \end{aligned}$$



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

- 8 A ladder of 12.5 metre long is placed with upper end against a wall. The lower end being 7.5 metres from the wall. What height is the upper end above the ground.

$$\begin{aligned} AC^2 &= AB^2 + BC^2 \\ BC^2 &= AC^2 - AB^2 \\ BC^2 &= x^2 \\ AC^2 &= AB^2 + BC^2 \\ 12.5^2 &= x^2 + 7.5^2 \end{aligned}$$

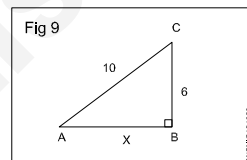


$$\begin{aligned} x^2 &= (12.5)^2 - (7.5)^2 \\ &= (12.5 + 7.5)(12.5 - 7.5)^2 \\ &= 20 \times 5 \\ &= \sqrt{100} = 10 \end{aligned}$$

$$x = 10 \text{ m}$$

- 9 What is the value of AB.

$$\begin{aligned} AC^2 &= AB^2 + BC^2 \\ AB^2 &= AC^2 - BC^2 \\ AB^2 &= x^2 \\ AC^2 &= AB^2 + BC^2 \\ 10^2 &= x^2 + 6^2 \\ x^2 &= 10^2 - 6^2 \\ &= 100 - 36 = 64 \end{aligned}$$



$$\begin{aligned} x &= \sqrt{64} \\ &= 8 \end{aligned}$$

$$AB = 8$$

Assignment

- 1 What is the value of side AB, in a right angled triangle of side AC = 10 cm and BC = 5 cm.
- 2 What is the value of side AC, in a right angled triangle of side AB = 6.5 cm and BC = 4.5 cm.
- 3 What is the value of side BC, in a right angled triangle of side AC = 14.5 cm and AB = 10.5 cm.
- 4 What is the value of side AC, in a right angled triangle of side AB = 7 cm and BC = 5 cm.
- 5 What is the value of side BC, in a right angled triangle of side AC = 13.25 cm and AB = 8.75 cm.

Square root, Ratio and Proportions, Percentage - Ratio and proportion

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

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

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

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

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

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

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

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

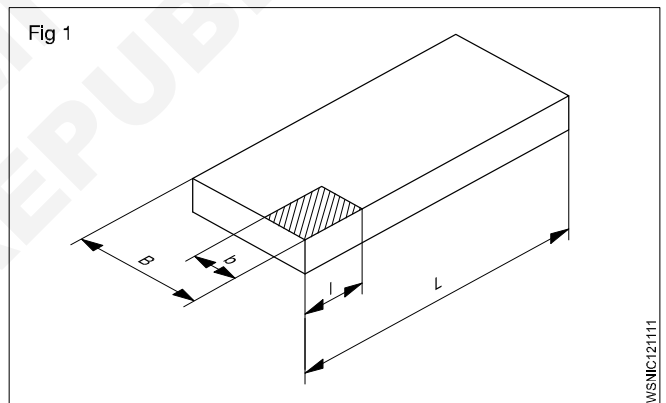
- $\frac{3-4}{4} = \frac{6-8}{8}$

- $\frac{3+6}{4+8} = \frac{9}{12} = \frac{3}{4}$

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.

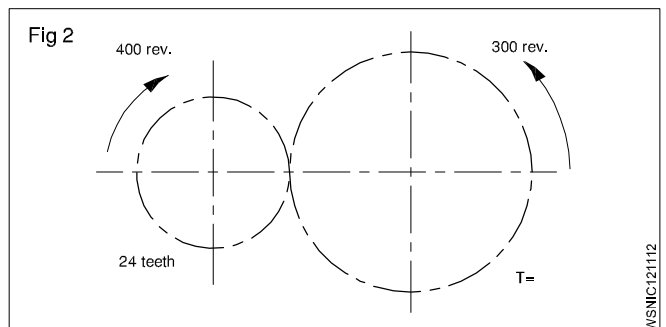


The reduction ratio is $\frac{1}{20}$.

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

$$A:B = 2:3$$

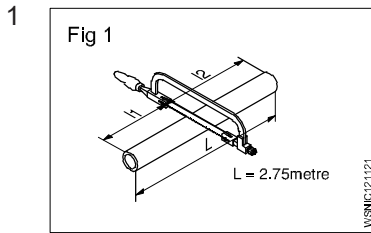
$$B:C = 4:5$$

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

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

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

Assignment

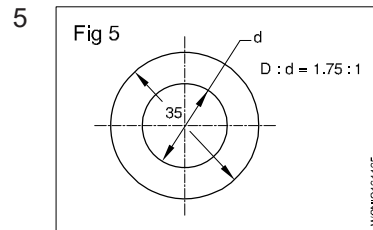


$$l_1 : l_2 = 2:3$$

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

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

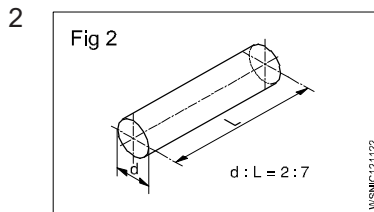
$$l_2 = \text{_____ metres}$$



$$D : d = 1.75 : 1$$

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

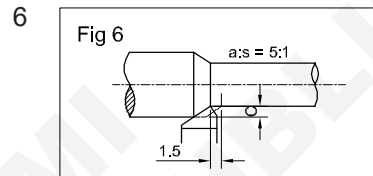
$$d = \text{_____ mm}$$



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

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

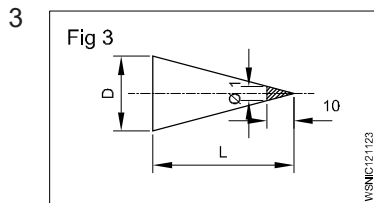
$$L = \text{_____ mm}$$



$$a : s = 5 : 1$$

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

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



$$D : L = 1 : 10$$

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

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

7 A:B=9:12

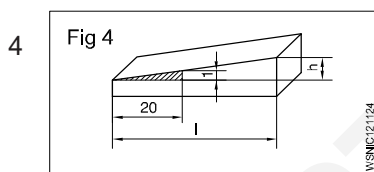
$$B:C=8:10$$

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

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

$$x = \text{_____}$$

Square root, Ratio and Proportions, Percentage - Ratio and Proportions - Direct and indirect proportions

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

$a : b :: c : d$ or e.g. $250 : 2000 :: 1 : 8$

Rule of three

A three step calculation

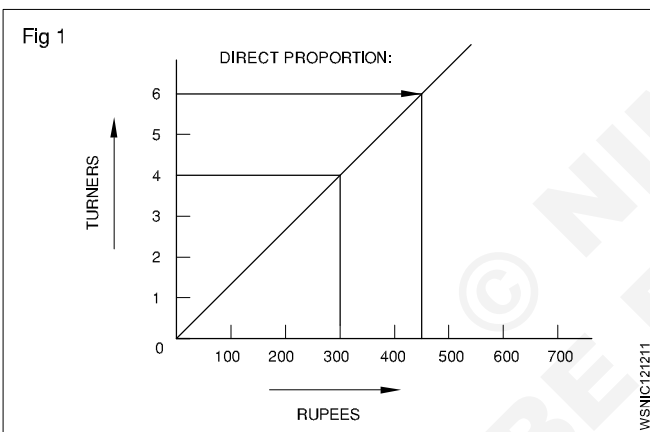
statement

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)



Examples

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

Statement

4 turners = 300 Rupees

Single

1 Turner = 75 Rupees

Multiple

6 Turners = $6 \times 75 = 450$ Rupees

- One vehicle consumes 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

= $6 \times 30 = 180$ litres/day.

- 4 vehicles consumes 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 Vehicle will use $\frac{120}{4} = 30$ gallons/day

12 vehicles will use $12 \times 30 = 360$ gallons/day

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

- If 2 litres of petrol costs Rs 60. Find the cost of 50 litres.

| | |
|--------------------|----------------|
| Quantity of Petrol | Cost of Petrol |
|--------------------|----------------|

| | |
|----------|-------|
| 2 litres | Rs.60 |
|----------|-------|

| | |
|-----------|-----|
| 50 litres | x |
|-----------|-----|

1 litre petrol = $\frac{60}{2} = \text{Rs.}30$

50 litres petrol = $30 \times 50 = \text{Rs } 1500$

- A 150mm dia gear meshes with 50mm dia gear. If the larger gear has 30 teeth. How many teeth will have the smaller gear have?

| | |
|----------|--------------|
| Gear dia | No. of Teeth |
|----------|--------------|

| | |
|--------|----|
| 150 mm | 30 |
|--------|----|

| | |
|-------|-----|
| 50 mm | x |
|-------|-----|

$x = \frac{50}{150} \times 30 = 10$ teeth.

- A mechanic assembles 7 machines in $2\frac{1}{2}$ days. How long will it take time to assemble 70 machines at the same rate.

| | |
|----------|------|
| Machines | Days |
|----------|------|

| | |
|---|----------------|
| 7 | $2\frac{1}{2}$ |
|---|----------------|

| | |
|----|-----|
| 70 | x |
|----|-----|

$x = \frac{70 \times 2.5}{7} = 25$ days

Assemble for 70 machines will take 25 days.

- A roll of wire weighs 1.24 kg from this roll a piece of 3.7cm long is cut and it is found to weigh 2.93 gm. What is the length of the wire in the roll?

| | |
|----------------|----------------|
| Weight of wire | Length of wire |
|----------------|----------------|

| | |
|---------|--------|
| 2.93 gm | 3.7 cm |
|---------|--------|

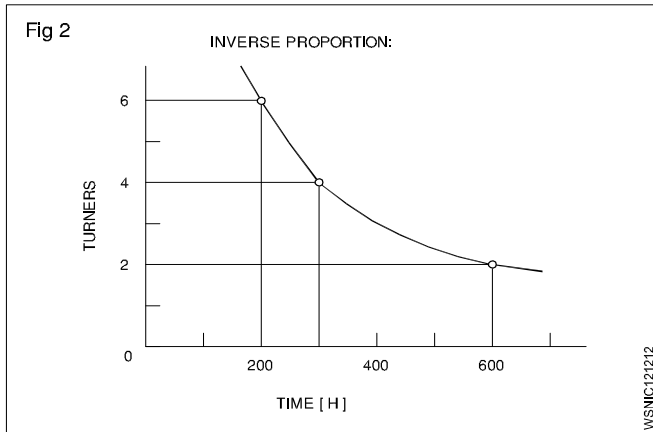
| | |
|-------------------|-----|
| 1.24 kg (1240 gm) | x |
|-------------------|-----|

$$x = \frac{1240}{2.93} \times 3.7 = 1566 \text{ cm}$$

Length of wire = 1566 cm.

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

- 1 4 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.

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

6 Turners = 200 hours

Result - The more the less.

- 2 8 workman take 6 days to complete a job. How many days it will take for 4 workman to complete the same job?

| Workman | Days |
|---------|------|
| 8 | 6 |
| 4 | x |

$$x = \frac{8}{4} \times 6 = 12 \text{ days}$$

4 workers complete the work = 12 days.

- 3 5 men working on a job finished it in 32 days. Find out in how many days 8 men will finish the same job?

| Men | Days |
|-----|------|
| 5 | 32 |
| 8 | x |

$$x = \frac{5 \times 32}{8} = 4 \times 5 = 20 \text{ days}$$

8 men will complete the job = 20 days.

- 4 An engine running at 150 rpm drives a shaft by pulley diameter is 55cm and that of the driven shaft pulley is 33 cm. Find the speed of the shaft?

| Dia of pulley | Rpm of shaft |
|---------------|--------------|
| 55 cm | 150 |
| 33 cm | x |

$$x = \frac{55 \times 150}{33} = 250 \text{ rpm.}$$

Speed of the 33cm diameter will run 250 rpm.

- 5 A pulley of 80 cm diameter is rotating at 100 rpm and drives another pulley of 40 cm diameter. Find the rpm of driven pulley. If slip is 2.5% find the rpm?

| Dia of pulley | Rpm of pulley |
|---------------|---------------|
| 80 cm | 100 |
| 40 cm | x |

40 cm diameter = 200 rpm.

Slip is 2.5% = 195 rpm.

Problems involving both

Example

2 turners need 3 days to produce 20 pieces. How long will it take for 6 turners to produce 30 such pieces?

Statement

2 turners, 20 pieces = 3 days

6 turners, 30 pieces = how many days.

First step (Fig 3)

Statement 2 turners for 20 pieces = 3 days

1 turner for 20 pieces = $3 \times 2 = 6$ days

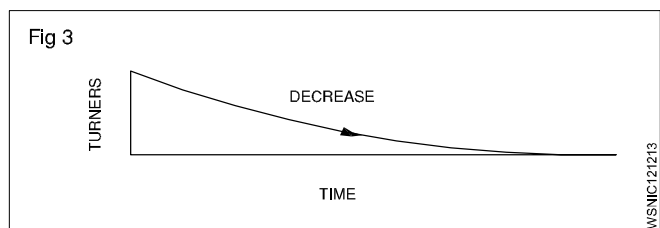
Multiple 6 turners for 20 pieces = $\frac{6}{6} = 1$ day

Statement 6 turners for 20 pieces = 1 day

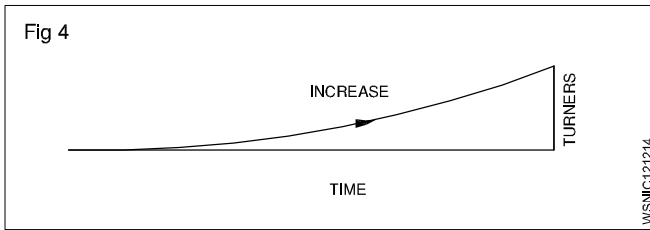
Single 6 turners for 1 piece = $\frac{1}{20}$ days

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

Inverse proportion - More the less.



Second step (Fig 4)



Direct proportion - 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

Compound and Inverse proportions

- Compound proportions

Example

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

| Fitters | Vehicle | Days |
|---------|---------|------|
| 5 | 6 | 21 |
| 7 | 8 | x |

$$\left(\frac{21 \times 5}{6 \times 7} \times 8\right) = 20 \text{ days}$$

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.

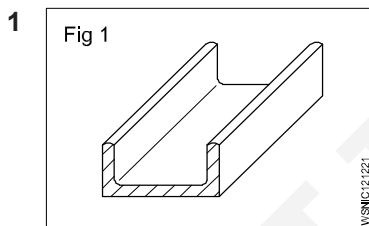
The time should not be doubled.

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

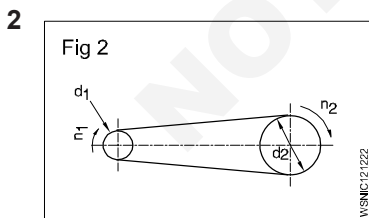
| Pump | Time |
|------|------|
| 2 | 30 |
| 6 | x |

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

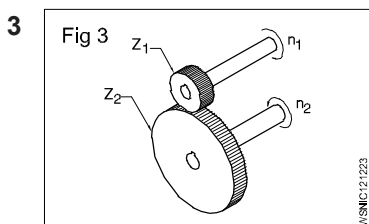
Assignment



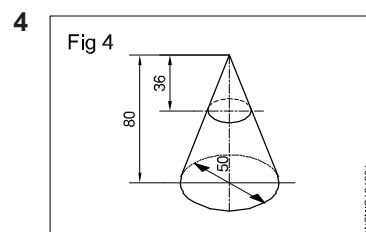
Length = 6.1 metre
Weight = 32 kgf
Weight of 1 metre of the same channel = _____ kgf



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



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



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

- If a mechanic assembles 8 machines in 3 days, how long he will take to assemble 60 machines.
- In an auto shop 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.
- 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.
- 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.

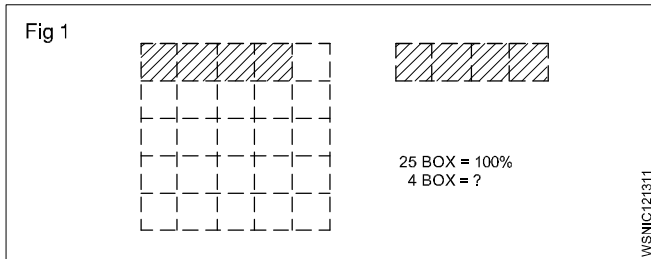
Square root, Ratio and Proportions, Percentage - Percentage

Percentage

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

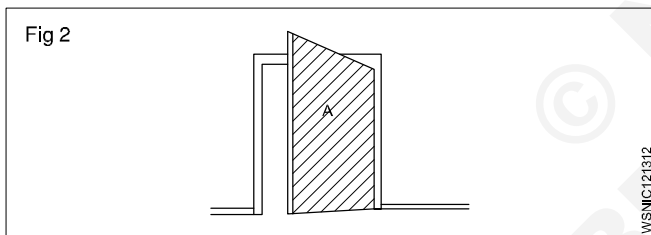
Ex. $\frac{16}{100} = 0.16$

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. (Fig 1)



Example

The amount of total raw sheet metal to make a door was 3.6 metre² and wastage was 0.18 metre². Calculate the % of wastage. (Fig 2)



Solution procedure in three steps.

Statement:

Area of door (A) = 3.6 m² = 100 %.

Wastage = 0.18 m²

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

Multiple: for 0.18 m² = $\frac{100}{3.6} \times 0.18$.

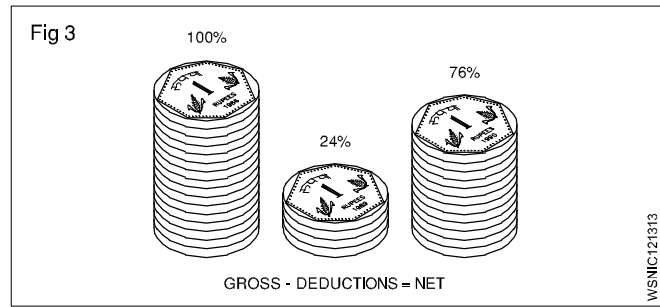
Wastage = 5%.

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

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

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

Profit = SP-CP = 15000-13043.47 = 1956.53

Purchase price = Rs.13,043/, Profit = 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

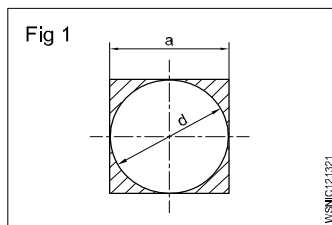
$$= (100 - 90) \frac{\text{litres}}{100} \times 100$$

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

= 10% Saving in fuel.

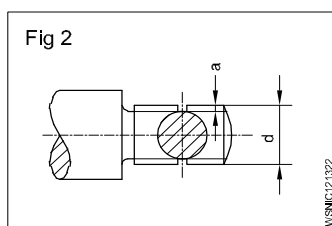
Assignment

1



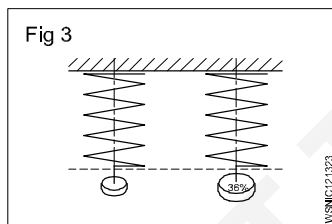
a = 400mm (side of square)
d = 400 mm
Wastage = _____ %.

2



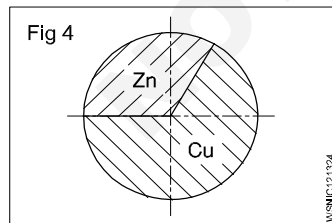
d = 26mm
'a' depth of u/cut = 2.4mm
reduction of area at cross-section = _____ %

3



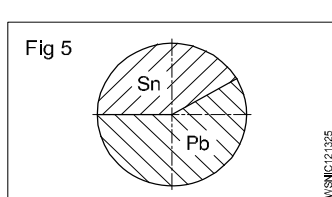
Percentage of increase = 36%
Value of increase = 611.2 N/mm²
Original tensile strength = _____ N/mm².

4



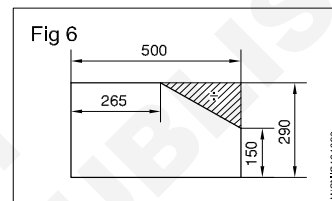
Copper in alloy = 27 kg
Zinc in alloy = 18 kg
% of Copper = _____ %
% of Zinc = _____ %.

5



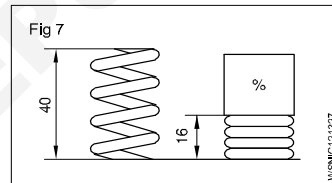
Weight of alloy = 140 Kgf
Weight of Sn 40%
Pb = _____ Kgf
Sn = _____ Kgf.

6



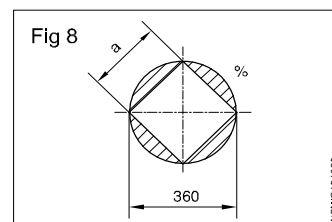
Shaded portion = _____ %.

7



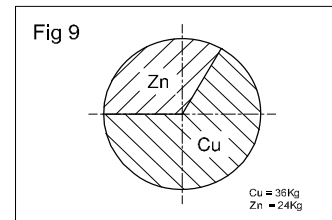
Compression length = _____ %.

8



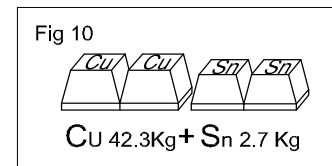
d = 360 mm
a = 0.707 x d
Wastage = _____ %.

9



Cu = 36 Kg
Zn = 24 Kg
Cu = _____ %
Zn = _____ %

10



Cu = 42.3 Kg
Sn = 2.7 Kg
Cu _____ %
Sn = _____ %.

Square root, Ratio and Proportions, Percentage - Changing percentage to decimal and fraction

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 12.5%

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%

Basic Electricity - Introduction and uses of electricity, molecule, atom, how electricity is produced, electric current AC,DC their comparison, voltage, resistance and their units

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

Thermo couple

If two dissimilar pieces of metals are twisted together and its joined end is heated in a flame, then a potential difference or voltage will be induced across the ends of the wires. Such a device is known as a Thermo couple. Thermo couple is used to measure very high temperature of furnaces.

Effects of electric current

When an electric current flows through a medium, its presence can be felt by its effects, which are given below.

1 Physical effect

Human body is a good conductor. when the body touches the bare current carrying conductor, current flows through the human body to earth and body gets severe shock or cause even death in many cases.

2 Magnetic effect

When an electric current passes through a coil, a magnetic field is produced around it.

E.g. : Electromagnet Motor, Generator, Electric bell

3 Chemical effect

When an electric current passes through an electrolyte, chemical action takes place. Because of that, an electrical energy is stored in a battery as a chemical energy.

E.g.: Electroplating, Cells and battery charging, refining of metals etc.,

4 Heating effect

When an electric current passes through any conductor, heat is produced in the conductor due to its resistance.

E.g. : Electric heater, Electric iron box, Electric lamp, Geyser, Soldering iron, Electric kettles, Electric welding etc.,

5 X-ray and Laser rays effect

When a high frequency voltage is passed through a vacuum tube, a special type of rays come out, which is not visible. These rays are called x-rays. Laser rays also can be produced by electric current.

6 Gas effect

When electrons pass through a certain type of sealed glass shell containing gas, then it emits light rays.

E.g: Mercury vapour lamp, Sodium vapour lamp, Fluorescent lamp, Neon lamp etc.,

Uses of Electricity

- | | |
|-----------------|---|
| 1 Lighting | - Lamps |
| 2 Heating | - Heaters, ovens |
| 3 Power | - Motor, fan |
| 4 Traction | - Electromotive, 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 |

Classification

- Static electricity
- Dynamic electricity

STATIC ELECTRICITY

If a dry glass rod is rubbed with silk cloth the glass rod gives out negative electrons, and therefore, becomes positively charged. The silk cloth receives negative electrons and therefore it becomes negatively charged. They acquire the property of attracting small pieces of paper etc. because like charges repel and unlike charges attract each other. The electric charge on the silk cloth is stationary and is called static electricity. This type of electricity cannot be transmitted from one place to another.

DYNAMIC ELECTRICITY

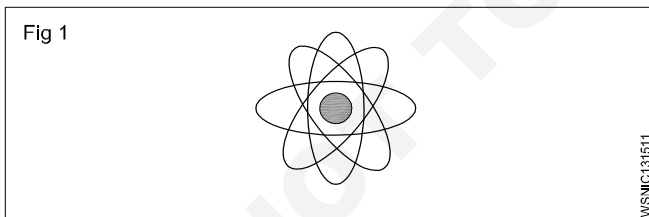
The electrons in motion are called current electricity or electric current. This type of electricity is carried through wires and cables. Therefore, this electricity can be transmitted from one place to another. This type of electricity can be produced by cells, batteries, generators alternators etc.

What is the difference between an atom and an element? How are molecules different from atoms? I am often asked these questions in my sessions over and over again and so I finally decided to write a comprehensive post on them. Find answers to all your questions in this section that is designed to help students explore and understand the relationship between atoms, elements, molecules, compounds and mixtures in a manner that is simple and easy to understand.

What is an Atom?

All the matter in the universe is made of tiny particles called atoms. There are 92 different kinds of atoms in nature. These 92 different atoms combine with one another to form different kinds of matter that we see in nature. (Fig 1)

Gold, for example, is made of only gold atoms. When matter is made of only one kind of atom, it is called an element. In the same way, silver is another element which is made of only silver atoms. Because there are 92 different kinds of atoms in nature, there are 92 different kinds of elements. Other examples of an atom are K (potassium) and Fe (iron).



What is a Molecule?

A molecule is the smallest unit of a chemical compound and it exhibits the same chemical properties of that specific compound. As molecules are made up of atoms jointly held by chemical bonds, they can vary greatly in terms of complexity and size. The oxygen we breathe has a molecular formula O_2 . Should we consider this as an element or compound? When two or more atoms of the same elements combine together, we call them Molecules. So, we call O_2 as an oxygen molecule. In the same way, we find hydrogen molecules H_2 , chlorine molecules Cl_2 and others in nature.

Types of electric current

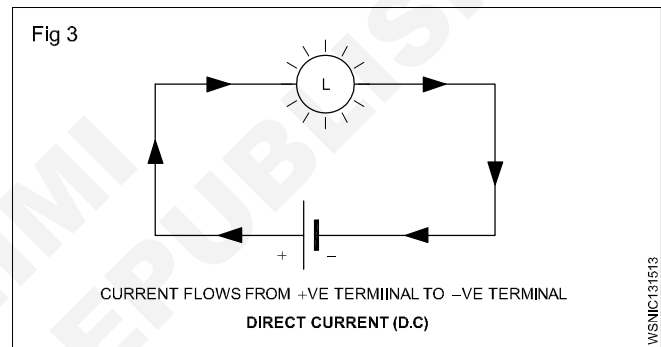
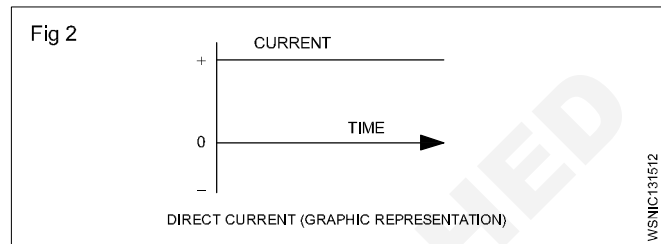
- Direct current
- Alternating current

Direct current

In direct current (DC) the direction and magnitude of the current does not change (Fig 2). The steady current flow will be from the positive terminal to the negative terminal. (Fig 3)

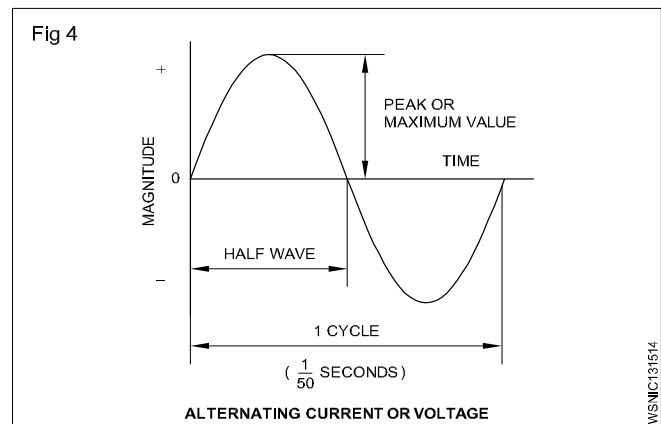
Examples

DC Sources : Cells, batteries and DC generators (Fig 3)



Alternating current (Fig 4)

The current flow will be from the phase terminal to the Neutral terminal. In the alternating current (AC) both the direction and magnitude of the current will be changing at definite intervals of time. The graph shows how an AC current or voltage changes with time. The current increases to the maximum value in one direction, falls to zero and increases to the maximum value in the other (opposite) direction before falling to zero again. Thus a cycle is one complete series of changes. The normal supply frequency is 50 cycles per second.



Difference between AC and DC

| AC | DC |
|---|--|
| 1 It is generated in the ranges of 6,600 V, 11000 V and 33,000 V. | It is generated up to 6,600 V only |
| 2 Voltage can be stepped up or stepped down by using transformer | It is not possible |
| 3 Transmission cost is less | Cost High |
| 4 Less maintenance | High maintenance |
| 5 Power up to 5,00,000 kw can be generated in a single alternator. | Power up to 10,000 kw can be generated in a single generator |
| 6 AC generator can run at high speeds. So, speed control is not easy. | It can't run at high speeds. Speed control is easy. |
| 7 Slip rings and brushes are used to collect the current. | Commutator and brushes are used to collect the current |

Advantages of A.C.

- i In transmission there is saving in copper wire.
- ii Since there is no spark in A.C. machine there is no interference in Radio sound.
- iii This can be produced to maximum voltage i.e. 33000volts.
- iv Voltage can be dropped or raised with the help of transformers.
- v Its mechanism is simple and cheap.
- vi Output is more due to availability of more than one phase.

Disadvantages of A.C.:

- i A single phase motor is not self-starter.
- ii Due to thin wire in A.C., the voltage drop is more.
- iii It cannot be used for electroplating and in charging secondary cells.
- iv The speed of motors run by it is difficult to change.
- v There is danger to security due to high voltage.

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

then $I = \frac{Q}{t}$ $Q = I \times t$

The SI unit of current is coulomb. Coulomb is equivalent to the charge contained in nearly 6.24×10^{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 AH = 3600 As (or) 3600 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 6.24×10^{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 (Ω), Ohm meter is used to measure the resistance.

Ohm

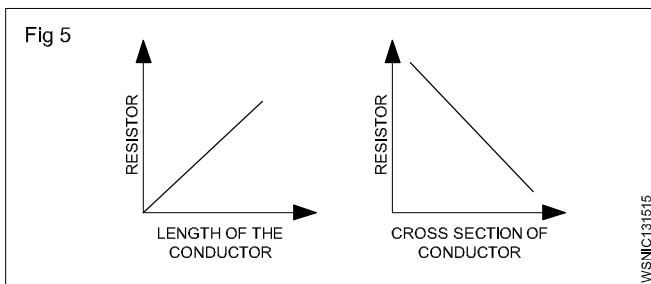
If the potential difference across the two ends of conductor is 1 volt and the current through it is 1 ampere, then the resistance of the conductor is 1 Ohm.

Laws of resistance

The resistance offered by conductor depends on the following factors.

The resistance of the conductor

- 1 is directly proportional to the length of the conductor ($R \propto L$)
- 2 Varies inversely proportional to its cross sectional area of the conductor ($R \propto \frac{1}{A}$)
- 3 Depends on the material with which it is made.



- 4 depends on the temperature of the conductor

$$R \propto L ; R \propto \frac{1}{A} ; R \propto \frac{L}{A} ; R = \rho \frac{L}{A}$$

Specific resistance

The specific resistance of a material is the resistance offered to a current it passed between the opposite faces of the unit cube of the material. Specific resistance is measured in Ohm - m or micro ohm - cm.

Each material has its own specific resistance or resistivity.

E.g. : Copper - $1.72 \mu\Omega \text{ cm}$, Silver - $1.64 \mu\Omega \text{ cm}$,
Eureka - $38.5 \mu\Omega \text{ cm}$, Iron - $9.8 \mu\Omega \text{ cm}$,
Aluminium - $2.8 \mu\Omega \text{ cm}$, Nickel - $7.8 \mu\Omega \text{ cm}$.

$$R = \frac{\rho l}{A} \text{ ohm cm}$$

R = Resistance in ohms

l = Length of the conductor in cm

ρ = Specific Resistance in ohm cm
(symbol pronounced as rho)

A = Area of cross - section in cm^2

Basic Electricity - Conductor, insulator, types of connections - series and parallel

Conductors

Some materials and metals readily allow passage for electric current to flow. In such materials, called conductors, electrons are able to pass readily from atom to atom.

Properties of conductors

A good conductor should have the following properties.

Electrical properties

- The conductivity must be good.
- Electrical energy spent in the form of heat must be low.
- Resistivity must be low (to reduce voltage drop and loss).
- Increase in resistance with temperature must be low.

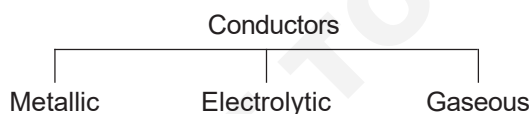
Mechanical properties

- Ductility (the property of being drawn into thin wires).
- Solderability: the joint should have minimum contact resistance.
- Resistance to corrosion: should not get rusted when used outdoors.
- Should withstand stress and strain.
- It should be easy to fabricate.

Economical factors

- Low cost.
- Easy availability.
- Easy to manufacture.

Classification of conductors



The best conductors are metallic. The commonly used conductors in electrical appliances and machines are described hereunder.

Silver

It is a soft and extremely malleable metal. Even though it is the best conductor, its use is limited because of its high cost.

Copper

It is a very good conductor. It is malleable and ductile, and also has high resistance to corrosion by liquids. Therefore, it is widely used for wires, cables, overhead conductors, bus bars and conducting parts of various electrical appliances.

Aluminium

It is a metal light in weight. It is also ductile, malleable and a good conductor of electricity. Nowadays, it is more widely used (since it is cheaper than copper) for wires and cables. All aluminium conductors (AAC) and aluminium conductors (steel reinforced) (ACSR) are used in overhead and transmission lines. (More details on copper and aluminium are furnished under the topic 'non-ferrous metals and alloys as applicable to electrical trades').

RESISTANCE WIRES

These are conductors with very high resistance for specific applications like filaments of incandescent lamps, heating elements etc. The following are a few examples:

- | | | |
|-----------------|------------|------------|
| 1 Tungsten | 2 Nichrome | 3 Eureka |
| 4 German silver | 5 Manganin | 6 Platinum |
| 7 Mercury | 8 Carbon | 9 Brass. |

The resistance values of the metallic resistances will increase with increase in temperature.

insulators

Description

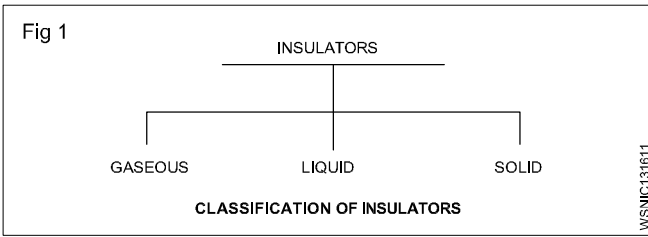
These are the materials which offer very high resistance to the flow of current and make current flow very negligible or nil. These materials have very high resistance - usually of many megohms (1 megohm = 10⁶ ohms) per centimetre cube. The insulators should also possess high dielectric strength. This 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.)

Classification of insulators (Fig 1)



Air is an example of a gaseous insulator. Other examples are hydrogen, nitrogen and inert gases.

Liquid insulators

Mineral oils, synthetic liquids, resins and varnishes are the liquid insulators.

Transformer oil

In transformers the oil is used as an insulator and also for cooling of the transformer windings by convection. Therefore, the transformer oil should be dry and purified, since the presence of moisture will reduce the dielectric strength of the oil.

Purpose of transformer oil

- Transfer of heat by convection, from winding and core to the cooling surfaces.
- It maintains the insulation of winding and also extinguishes fire that occurs due to faults occurring in the windings.

Precaution

The insulating value of a transformer oil is reduced due to the formation of sludge as a result of oxidation due to air and temperature. To minimise oxidation, the oil should not be exposed to air.

Sludge is also formed due to the presence of acids and alkalis.

Sludge formation

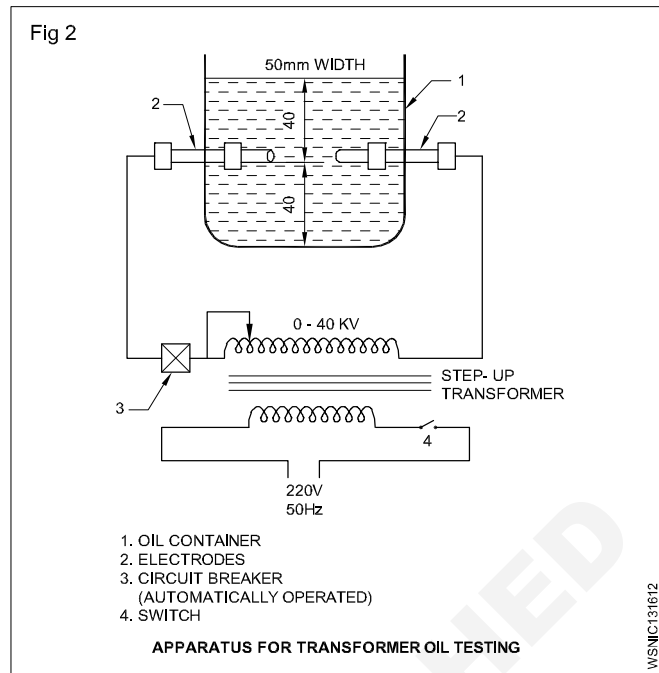
- Reduces the rate of heat transfer.
- Blocks the ducts.
- Increases the operating temperature.

To prevent moisture from entering the oil, the whole apparatus is made airtight, and calcium chloride, silicagel fillers are used.

Testing of transformer oil as per ISI Standard (Fig 2)

Dielectrical strength test (Refer to Fig 2): The oil should be 40 mm above and 40 mm below the electrodes. The gap between the two electrodes should be kept at $4 \text{ mm} \pm 0.02 \text{ mm}$.

A high voltage is applied across the electrodes through a step-up transformer, and increased till there is a spark in between the electrodes. The voltage noted on the voltmeters, when the spark occurs, is the breakdown voltage or dielectric strength of the oil. This is the maximum voltage the oil can withstand.



According to ISI specifications, the oil should be able to withstand 40 kV for one minute with a gap ($4 \text{ mm} \pm 0.02 \text{ mm}$) between the electrodes and with the diameter of the electrodes as 13 mm.

Moisture test : In this test, an oil sample is cooled in a closed vessel down to $15\text{-}25^\circ$. A dry test tube, 12.5 mm in diameter and 125 mm long, is taken and an adequate quantity of oil is poured into it.

The tube containing the oil is heated rapidly with the help of an electric heater till the oil begins to boil. During the process, oil should not produce cracking.

The other tests are:

- acidity test
- sludge resistance test.

Electrical insulating varnishes

They are of two types

Oil and resin varnishes.

Solid insulators/insulating materials

| Sl. No. | Classification | Examples |
|---------|----------------------------|---|
| 1 | Mineral insulators | Mica, marble, slate. |
| 2 | Vitreous materials | Glass, quartz, procelain. |
| 3 | Rubber and rubber products | Rubber, vulcanised (India) rubber (V.I.R) ebonite |
| 4 | Waxes and compounds | Paraffin wax, bitumen. |
| 5 | Fibrous materials | Asbestos, paper, wood, Press pahn, leatheroid, cotton, silk, tapes etc. |
| 6 | Synthetic products | Bakelite, shellac, oil (for Transformer, Switchgear etc). |

Paper

Various grades of insulating paper are available for use in capacitors, cables, etc. Paper, if moist, loses its insulating property. Therefore, it is used in an impregnated condition.

Wood

It is impregnated with oil or other substance for use as an insulator.

For example, in machine windings, bamboo wood is used as slot wedges.

Press board

It is widely used in windings to insulate parts which support windings. It is also used as spacers in electrical devices and transformers.

Asbestos

A fibrous, incombustible, fire-proof material - used for panel boards and as frames for winding resistance wires of regulators, rheostats etc.

Cotton

It is soaked in paraffin to avoid moisture. It is a good insulator for low voltages. It is used in conductors for armatures and field coils.

Silk

Like cotton, it is used for small jobs like telephone coils.

Tapes

Tapes of various types are used, such as cotton, silk, jute etc either pure or in impregnated form.

Empire cloth

It is made by varnishing a cotton cloth, silk or paper. It is not effected by moisture. It is available in yellow and black colours in different sizes. It is used as slots insulation in winding works and for coil insulation.

Press pahn

Press pahn is a form of paper made from hemp, rags, and wood pulp by special chemical treatment. It is widely used for lining armature slots, insulating coil sides, etc.

Leatheroid

It is a tough material made from cotton rags with chemical treatment. It is unaffected by grease or oil and is used for slot and coil insulation, transformer core coverings, etc.

Adhesive tape

It is used widely for taping of ends of conductors, leads and connections. Adhesive tape is made from cotton fabric coated with a compound of rubber, bitumen, resin, gum,

etc. It dries when exposed to air. It is available in sizes $\frac{1}{2}$, $\frac{3}{4}$ ", 1" etc. These are also available as P.V.C. adhesive tape, cotton and bitumen tapes.

Bitumen

It is used for filling cable jointing boxes and for sealing the tops of the batteries etc. It is waterproof, but it will crack

under certain conditions. It can be vulcanised in the same manner as rubber.

Mica

It is a mineral and available as large slabs. It can be easily separated into thin sheets. It is fireproof, waterproof, and is a good insulator. It should be used carefully since it is liable to crack. It is used in heating elements of electric iron etc.

Marble and slate

Marble and slate are mechanically strong insulators and are non- hygroscopic. When polished they form good mountings for switchboards, switches, resistance frames, etc. Slate is used generally for low voltages.

Micanite

It is made by sticking together pieces of mica with insulating cement like shellac. It can be bent to any shape by heating and pressing. Therefore, it is used as insulator for slots of armatures and to insulate the commutator from the shaft.

Paraffin wax

It melts at 55°C and does not absorb water. It is used to impregnate paper, wood, pressboard etc to reduce their moisture absorption.

Bakelite

It can be moulded to any shape. It is heat-resistant and highly insulating. It will not absorb oil and moisture. It is used for bodies of switches, plugs, holders, regulators etc.

Rubber

It has high insulating properties. It is used mainly on lighting cables and for flexible cables. It deteriorates gradually when exposed to atmosphere. Rubber is being replaced now by elastic plastics such as PVC or polyethylene which can resist alkalis, acids and mineral oils.

Valcanised India Rubber (VIR)

This is manufactured by treating pure rubber with sulphur. It is stronger than pure rubber and is not affected much by change in temperatures. It is used as coverings for low and medium voltage wires and cables.

Ebonite or vulcanite

Ebonite or Vulcanite is vulcanised rubber containing about 30% to 50% of sulphur, and subjected to a prolonged heating at 150°C. The material is hard and can be moulded into different shapes. It is less affected by chemicals and moisture. It is used for making containers of lead acid batteries, cases for instruments and switchgears, terminal plates and low voltage panel boards etc. It should not be subjected to heat.

Shellac

It is a good varnish which is used to improve the insulation and moisture resisting properties of paper, cloth, wood, slate etc.

Enamel

By this, an insulation coating is given on winding wires.

Polychloroprene (PCP)

It is a plastic material used for insulation of cables. It is resistant to oil and petrol. It can be used in conditions of exposure to sulphur fumes, steam, ammonia, lactic acid and direct sunlight.

Glass

It is heat-resistant and suitable for high temperatures. It is used as insulators, envelopes for lamps, radio tubes etc.

Quartz

Quartz (Silica) is a good insulator. As it has a very low temperature coefficient of expansion, it does not crack with sudden variations in temperature. It is used for pyrometer sheaths, for heating elements, sparking plugs, etc.

Porcelain

Porcelain is not so brittle as glass and is very widely used for carrying bare conductors, for making fuse carriers and other electrical fittings.

Red fibre

Mainly used in motor and transformer winding work, for slot insulation, separators etc.

Insulators classified according to their temperature limits

The permissible temperature limit at which the insulators may be worked safely without deterioration, depends upon the type and class of the insulation as detailed below. (IS:1271/1958)

Class Y – maximum temperature 90°C

Cotton, silk, paper products, press board, wood, vulcanised fibre - not impregnated or immersed in oil.

Class A – maximum temperature 105°C

Cotton, silk, paper products, wood, vulcanised fibre when impregnated or immersed in liquid dielectric, varnished paper and wire enamel (class A).

Class E – maximum temperature 120°C

Wire enamel, cotton fabric and paper laminates treated with oil, modified asphalt and synthetic resins, varnished polyethylene, textile treated with suitable varnish.

Class B – Maximum temperature 130°C

Glass fibre, asbestos, varnished glass fibre, textile, varnished asbestos, built up mica treated with synthetic resin varnishes.

Class F – maximum temperature 155°C

Similar to class B materials but treated with silicone resins.

Class H – maximum temperature 180°C

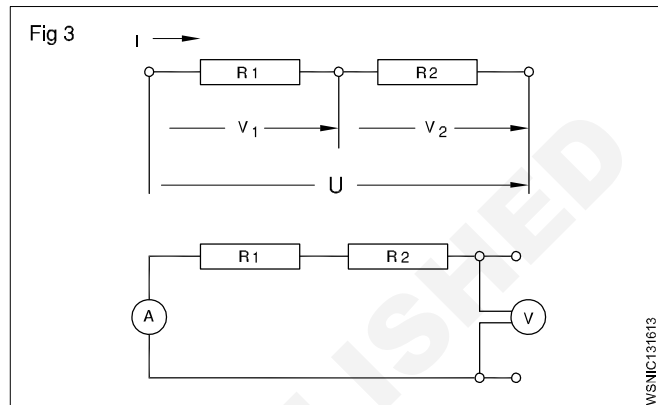
Same as class F materials but treated with silicone resins of higher thermal stability than class F.

Class C – maximum temperature above 180°C

Mica, porcelain and other ceramics, glass, quartz, asbestos, treated glass fibre textile, treated asbestos, built up mica treated with silicone resins possessing superior thermal stability (limited stability up to 225°C).

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. (Fig 3)



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.

$$I = I_1 = I_2 = \dots$$

$$V = V_1 + V_2 + \dots$$

$$R = R_1 + R_2 + \dots$$

Example

Three resistances of 3 ohms, 9 ohms and 5 ohms are connected in series. Find their resultant resistance.

Solution

$$\begin{aligned} R &= R_1 + R_2 + R_3 \\ &= 3 \Omega + 9 \Omega + 5 \Omega \end{aligned}$$

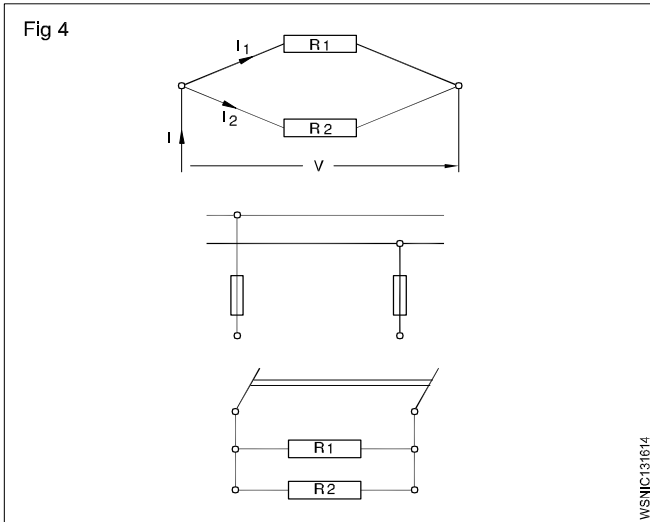
$$\text{Total resistance} = 17 \Omega$$

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.

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots \quad (\text{since parallel connection})$$

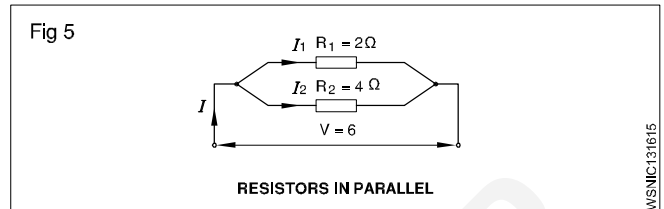
$$\text{Therefore } \frac{1}{R} = \frac{1}{4} + \frac{1}{6} = \frac{10}{24} = \frac{5}{12}$$

$$\text{Therefore } R = \frac{24}{10} \text{ ohms} = 2.4 \text{ ohms}$$

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.



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

$$\text{But } I_1 = \frac{U}{R_1} = \frac{6V}{2\Omega} = 3A$$

$$I_2 = \frac{U}{R_2} = \frac{6V}{4\Omega} = 1.5A$$

I total = 3A + 1.5A

$$= 4.5 \text{ Amp}$$

Basic Electricity - Ohm's law, relation between V.I.R & related problems

Ohm's law

V - Voltage in volts

I - Current in Ampere

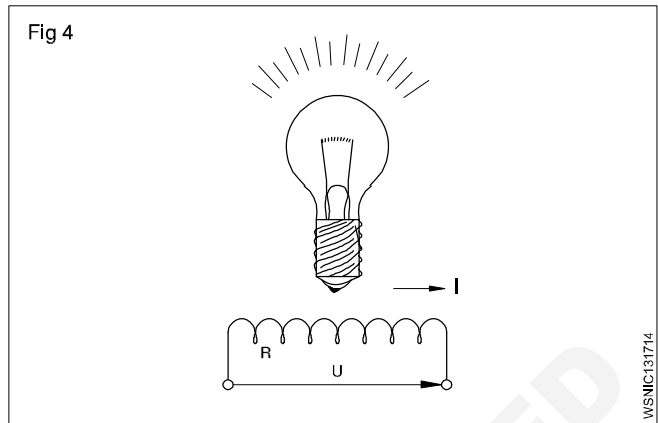
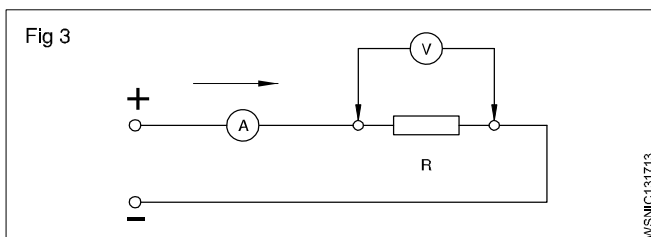
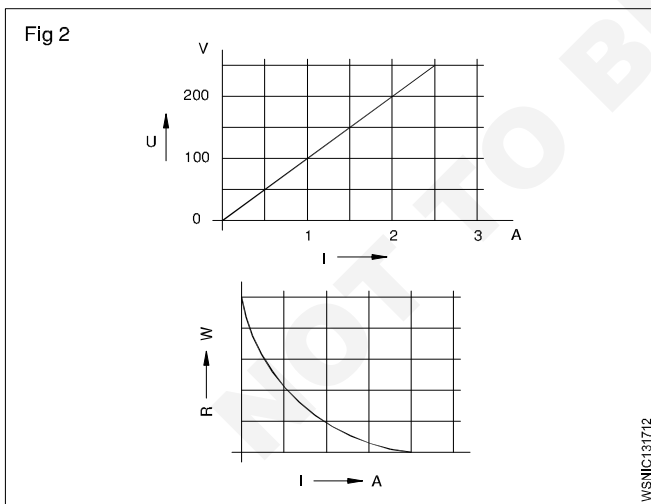
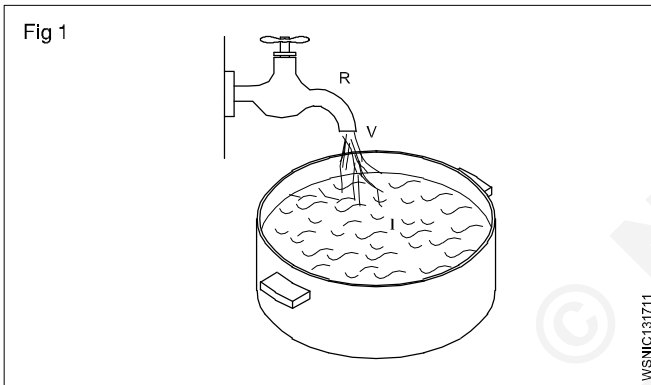
R - Resistance in ohms.

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.

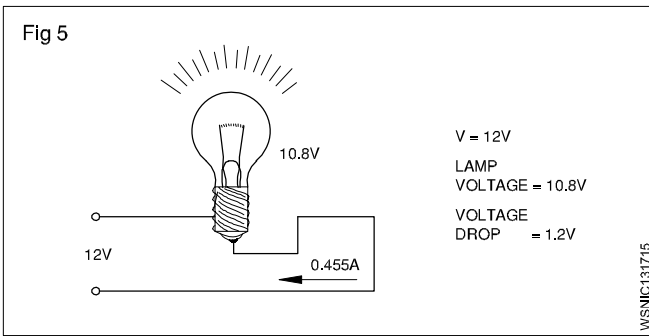
To find 'R'. Given that V = 3.6V and I = 0.2 A

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)



Voltage drop = $12V - 10.8 = 1.2V$

The supply voltage is called Potential difference.

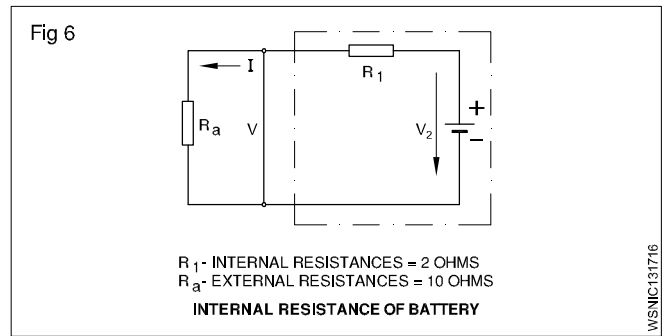
Example

The Internal resistance of a dynamo is 0.1 ohm. The voltage of dynamo is 12V. What is the Voltage of dynamo when a current of 20 amps being supplied to an outside circuit.

Solution

Voltage drop = Current x Internal resistance
 = 20×0.1 volts
 = 2 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.

P.D = Current flowing x Resistance

= $0.6 \text{ A} \times 10\Omega$

= 6 volts

V.D = Current flowing x Internal resistance of battery

= 0.6×2 volts

= 1.2 volts

EMF of the Battery = $(6.00 + 1.2)V$

= 7.2 volts

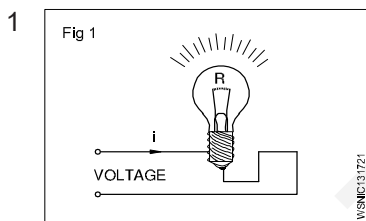
Resistance connections

V - Voltage (in volts)

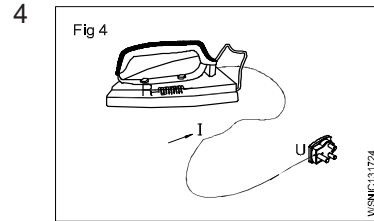
R - Resistance (in ohms)

I - Current intensity (in Amperes)

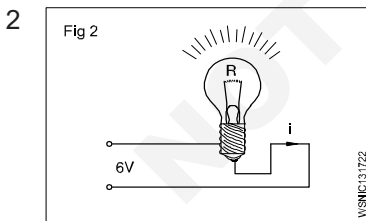
Assignment



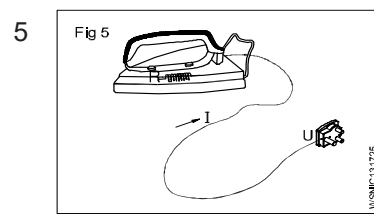
R = 40 Ohms
 I = 6.5 Amps
 V = _____ Volts



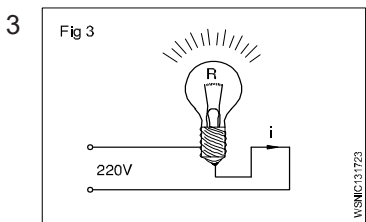
I = 4.5 Amps
 V = 220 Volts
 R = _____ Ohms



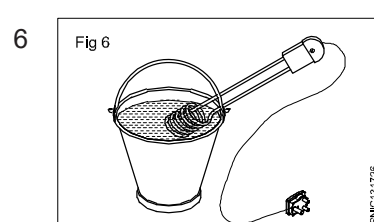
V = 6 Volts
 I = 0.5 Amps
 R = _____ Ohms



R = 50 Ohms
 V = 220 Volts
 I = _____ Amps



V = 220 Volts
 R = 820 Ohms
 I = _____ Amps



V = 110 Volts
 I = 4.55 Amps
 R = _____ Ohms

Basic Electricity - Electrical power, energy and their units, calculation with assignments

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 sec
 $W = P \times t$

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.

$$1 \text{ W.h} = 3600 \text{ Watt sec.}$$

$$1 \text{ Kwh} = 1000 \text{ Wh} = 3600000 \text{ Watt sec}$$

FPS System

$$1 \text{ HP} = 746 \text{ watts}$$

$$= 0.746 \text{ K.W}$$

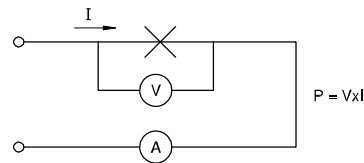
Metric System

$$1 \text{ HP} = 735.6 \text{ watts}$$

$$= 0.7356 \text{ K.W}$$

Note: The charge for electric consumption is the energy cost per Kwh and it varies according to the country and states.

Fig 1



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

Fig 2

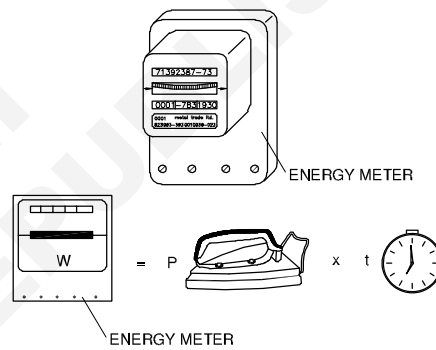


Table of analogies between mechanical and electrical quantities

| 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 $P = F \times v$ | $N \frac{m}{sec}$ | Power $P = V \times i$ | $W = V \times A$ |
| Energy = $F \times v \times t$ | $j = Nm$ | Energy $W = V \times i \times t$ | $j = W \times s$ |

$$W = VI$$

$$= I^2R$$

$$= \frac{V^2}{R}$$

$$R = \frac{V}{I}$$

$$= \frac{V^2}{W}$$

$$= \frac{W}{I^2}$$

$$V = IR$$

$$= \frac{W}{I}$$

$$= \sqrt{WR}$$

$$I = \frac{V}{R}$$

$$= \frac{W}{V}$$

$$= \sqrt{\frac{W}{R}}$$

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.

$$P = V \times I$$

$$V = 240 \text{ Volts}$$

$$I = 0.25 \text{ Ampere}$$

$$\begin{aligned} \text{Therefore Power} &= 240 \text{ Volts} \times 0.25 \text{ Amperes} \\ &= 60 \text{ Volts Ampere} \end{aligned}$$

$$\text{But } 1 \text{ Watt} = 1 \text{ Volt} \times 1 \text{ Ampere}$$

$$\text{Therefore Power} = 60 \text{ Watts}$$

- 2 A current of 15 amperes flow through a resistance of 10 Ohms. Calculate the power in kilowatts consumed.

$$\text{Given that } R = 10 \text{ and } I = 15 \text{ A}$$

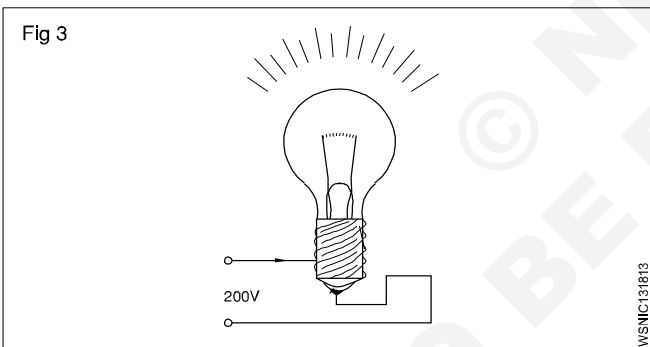
$$\text{Power} = V \times I = I \times R \times I = I^2 \times R$$

$$\text{Therefore Power} = 15^2 \times 10 = 2250 \text{ Watts} = 2.25 \text{ kW}$$

- 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 of running 15 HP motor for 15 days @ 6 hrs per day and the cost of energy is Rs. 3 per unit.

$$\begin{aligned} \text{Motor power (w)} &= 15 \text{ HP} \\ &= 15 \times 746 = 11,190 \text{ watts} \end{aligned}$$

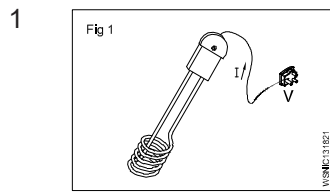
$$\begin{aligned} \text{Consumption per day} &= 11,190 \times 6 \\ &= 67140 = 67.14 \text{ KWH} \end{aligned}$$

$$\begin{aligned} \text{Consumption for 15 days} &= 67.14 \times 15 \\ &= 1007 \text{ KWH (or) unit} \end{aligned}$$

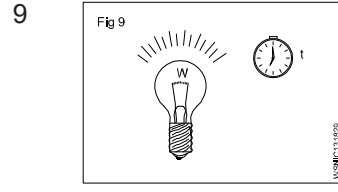
$$\text{Cost per unit} = \text{Rs. } 3$$

$$\text{Cost for total energy} = 3 \times 1007 = \text{Rs. } 3021$$

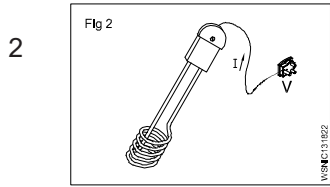
Assignment



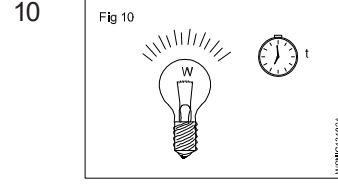
Current Consumed
 $I = 0.136 \text{ A}$
 Voltage 'V' = 220 V
 $P = \underline{\hspace{2cm}}$ Watts



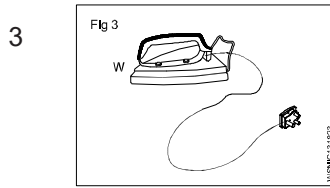
$P = 100 \text{ W}$
 $t = 1 \text{ hour}$
 Energy consumption
 = $\underline{\hspace{2cm}}$ kWh



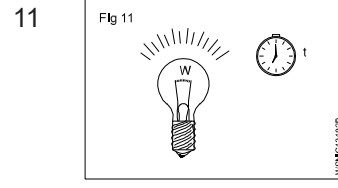
$P = 500 \text{ Watts}$
 $I = 2.27 \text{ A}$
 $V = \underline{\hspace{2cm}}$ v



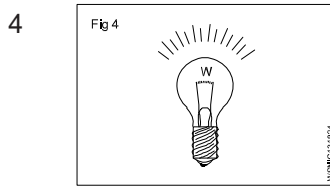
Energy consumed
 'W' = 1 kWh
 Power 'P' = 100 W
 $t = \underline{\hspace{2cm}}$ hr



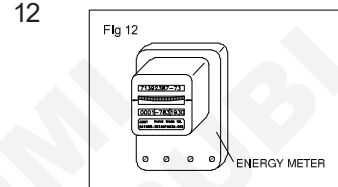
$P = 750 \text{ W}$
 $V = 220 \text{ v}$
 $I = \underline{\hspace{2cm}}$ A



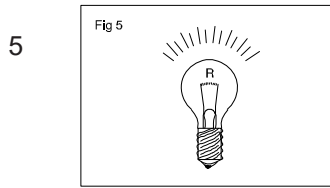
$W = 1.5 \text{ kWh}$
 $t = 45 \text{ min.}$
 $P = \underline{\hspace{2cm}}$ kW.



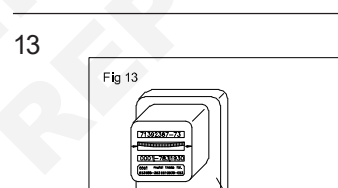
$P = 60 \text{ W}$
 $V = 200 \text{ v}$
 $R = \underline{\hspace{2cm}}$ ohms



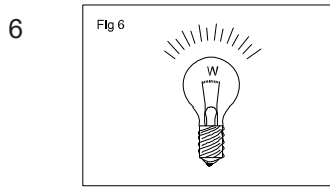
Energy metre reading
 $W_1 = 6755.3 \text{ kWh}$
 Increases to W_2
 = 6759.8 kWh
 $t = 45 \text{ min.}$
 $P = \underline{\hspace{2cm}}$ kW.



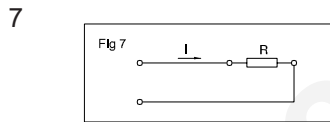
$I = 0.455 \text{ A}$
 $R = 484 \text{ ohms}$
 $P = \underline{\hspace{2cm}}$ Watts



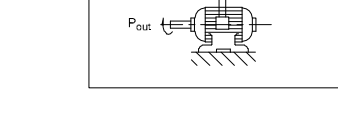
Power consumed
 'P' = 6.2 kW
 $t = 8 \text{ hours}$
 Charge per kwh
 = 1.25 Rupees
 Total cost
 = $\underline{\hspace{2cm}}$ Rupees



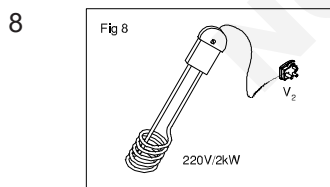
$P = 550 \text{ W}$
 $R = 22 \text{ ohms}$
 $I = \underline{\hspace{2cm}}$ A



$P \text{ consumed} = 1.8 \text{ kW}$
 $R = 8 \text{ ohms}$
 $V = \underline{\hspace{2cm}}$ v



$I = 5.45 \text{ A}$
 $V = 220 \text{ v}$
 Energy consumed
 = 1 kWh
 $t = \underline{\hspace{2cm}}$ hr.



$I \text{ consumed} = \underline{\hspace{2cm}}$ A
 $P = 2 \text{ kW}$
 $V_1 = 220 \text{ V}$ (Heating
 element voltage)
 $R = \underline{\hspace{2cm}}$ W

Basic Electricity - Magnetic induction, self and mutual inductance and EMF generation

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 given 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 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 stationery magnetic field or by changing magnetic flux over a stationery 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 stationery 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.

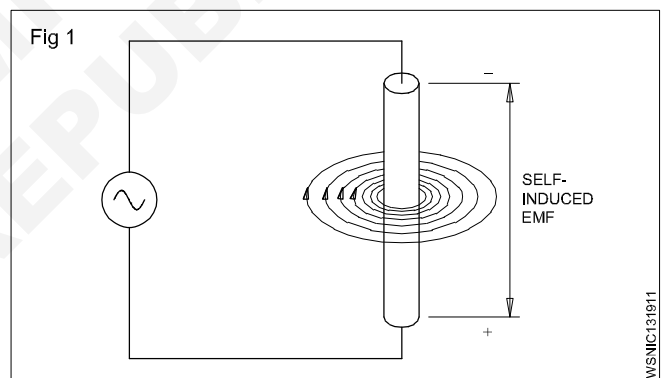
Self-induction: The production of an electromotive force in a circuit, when the magnetic flux linked with the circuit changes as a result of the change in a current inducing in the same circuit.

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).

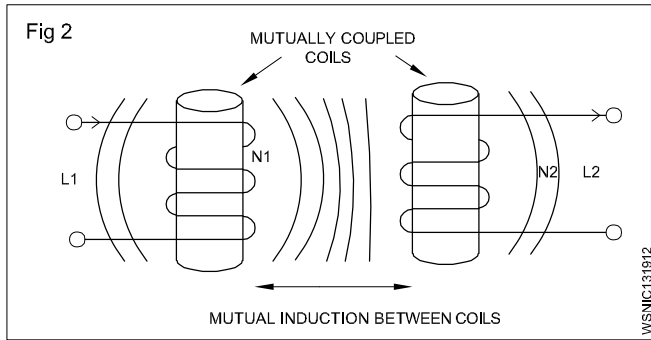


Mutual induction

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 the Fig 2 current flowing in coil L1 sets up a magnetic field around it self with some of its magnetic field line passing through coil L2 giving in mutual inductance coil one L on has a current of I, and N, turns while coil two L2, has N2 turns therefore mutual inductance M, of coil two that exists with respect to coil one L, depend 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 on wound be found in a transformer.



The two coils are tightly wound one on top of the other over a common soft iron core unit 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 3a or by the movement of the magnetic field on a stationary conductor as shown in Fig 3b, the induced emf is called dynamically induced emf.

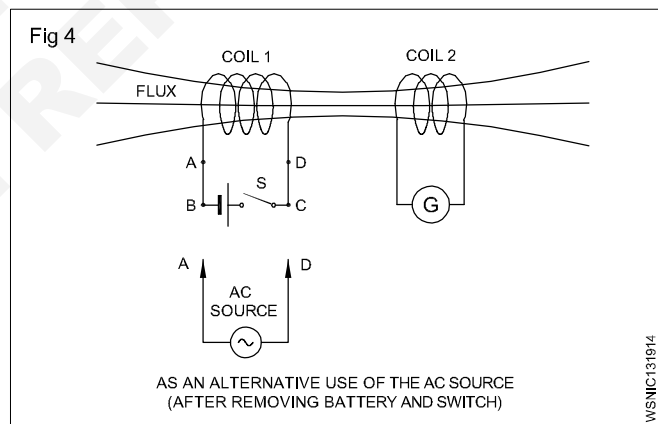
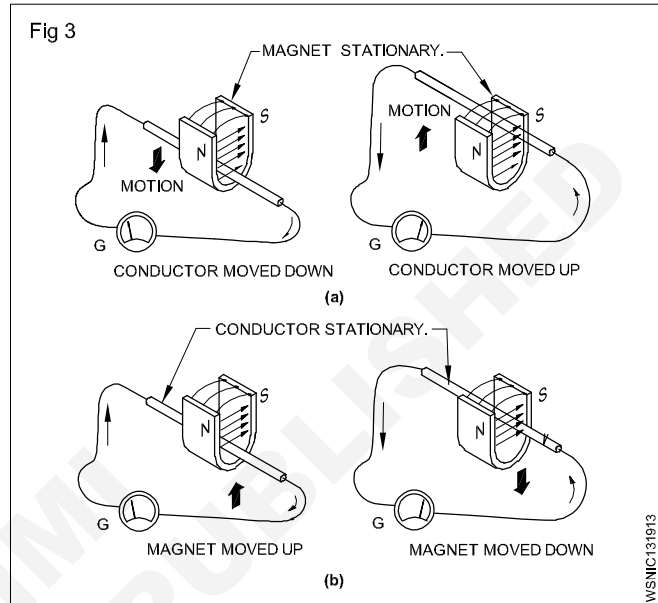
As shown in Fig 3a & 3b, the conductor cuts the lines of force in both cases to induce an emf, and the presence of the emf could be found by the deflection of the needle of the galvanometer 'G'. This principle is used in DC and AC generators to produce electricity.

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 no electrical connection between them.

According to Fig 4, 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 4. 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: (Fig 5) 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:

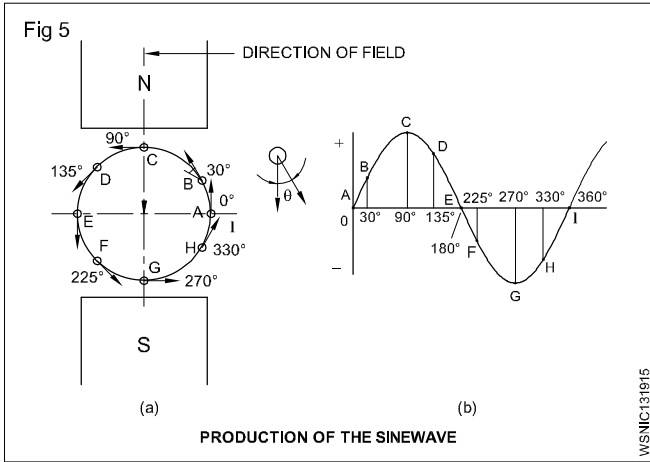
- magnetic field
- conductor
- relative motion between the conductor and the magnetic field.

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.
- θ = the angle at which the conductor cuts the magnetic field.

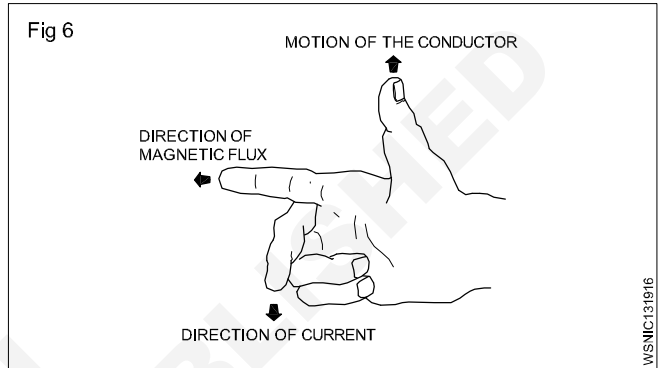


Likewise for every position of the remaining conductors in the periphery, the emf induced could be calculated. If these values are plotted on a graph, it will represent the sine wave

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 6 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.



Basic Electricity - Electrical power, HP, energy and units of electrical energy

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.

The rate of work is called Power. Its units is watt. In a circuit with one volt pressure the quantity of electric current produced represents one watt of power. Power is obtained from circuit voltage multiplied by current.

If voltage is V and current I , then power

$$P = V \times I \text{ watts}$$

According to Ohm's law

$$V = I \times R$$

$$P = I \times R \times I$$

$$= I^2 \times R \text{ watts}$$

Horsepower Definition Science

Horsepower is defined as the work done per unit time and this term was invented by James Watt. It is a unit of power that relates a machine's power to the muscle power of a horse. It was once used to compare the output of steam engines to the power of draught horses. It was later expanded to include other piston engines, electric motors, turbines, and other machinery.

Horsepower

The practical unit of power is Horsepower.

one horsepower = 735.6 watts

FPS System

$$1 \text{ HP} = 746 \text{ watts}$$

$$= 0.746 \text{ K.W}$$

Metric System

$$1 \text{ HP} = 735.6 \text{ watts}$$

$$= 0.7356 \text{ K.W}$$

Energy

The capacity to work is called energy. In electricity energy is produced by power through work in a given time. In a circuit, power W is spent in time (t) then it will be said that energy used in circuit = $W \times t$. The unit of energy is watt seconds or joule.

$$\therefore \text{Energy} = \text{Power in watt} \times \text{time in seconds}$$

Unit of Electrical Energy

This is bigger unit of energy. Its full name is Board of Trade Unit but in short it is called Unit. In this, power is measured in kW and the time is in hours. Its unit is kilowatt hour or kWh.

$$1 \text{ kWh} = 1000 \text{ watt hours}$$

$$= 1 \text{ unit of electricity}$$

Example

1 A D.C motor takes 7.106 amps at 110 volts and has an efficiency of 80%. How much HP does it deliver?

$$\text{Current } (I) = 7.106 \text{ amp}$$

$$\text{volt } (V) = 110 \text{ volts}$$

$$\text{efficiency} = 80\%$$

$$\text{Horsepower} = \text{Output ?}$$

$$\text{Input} = V \times I \text{ watts}$$

$$\text{Power Input} = 110 \times 7.106 = 781.66 \text{ watts}$$

$$\eta = \frac{\text{Output}}{\text{Input}} \times 100\%$$

$$80 = \frac{\text{Output}}{781.66} \times 100$$

$$\text{Power Output} = \frac{80 \times 781.66}{100} = 625.3 \text{ watts}$$

$$1 \text{ HP} = 746 \text{ watts}$$

$$\text{HP} = \frac{625.3}{746} = 0.8382$$

$$\text{Motor power} = 0.8382 \text{ HP}$$

2 A factory having 4 motors each 5 HP runs 8 hours per day for 30 days. Calculate the electricity expenditure if Rs.2 per unit.

$$\text{Motor} = 5 \text{ HP}$$

$$\text{No. of Motor} = 4$$

$$\text{Runs per day} = 8 \text{ hours}$$

$$\text{No. of days run} = 30 \text{ days}$$

$$\text{Total HP} = 4 \times 5 = 20 \text{ HP}$$

$$\text{Total running} = 8 \times 30 = 240 \text{ hours}$$

$$1 \text{ HP} = 746 \text{ watts}$$

$$1 \text{ kW} = 1000 \text{ watts}$$

$$\text{Total kWh} = \frac{20 \times 240 \times 746}{1000}$$

$$= 3580.8 \text{ kWh}$$

$$1 \text{ kWh electricity charge} = \text{Rs.}2$$

$$\text{Total charge} = 2 \times 3580.8$$

$$\text{Total electricity expenditure} = \text{Rs. } 7161.60/-$$

Trigonometry - Measurement of angles

Introduction:

Trigonometry is the branch of mathematics which deals with the study of measurement and relationship of the three sides and three angles of a triangle.

Units:

Measurement of Angles

There are three systems of measuring the angle:

(i) Sexagesimal System

This is called British System. In this system, one right angle is divided into 90 equal parts which are called degrees. Each part is divided into 60 parts which are called minutes. Each minute is divided into 60 parts which are called seconds. The parts so divided respectively are called:

One degree (1°), one minute ($1'$) and one second ($1''$)

It means 1 right angle = 90° (90 degrees)

1 degree (1°) = 60' (60 minutes)

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

In Trigonometry, mostly this system is used.

(ii) Centesimal System

This is called French System. In this system, the right angle is divided into 100 equal parts which are called grades. Each grade is divided into 100 minutes and each minute is divided into 100 seconds.

Parts so divided are respectively called:

One grade (1 g), one minute ($1'$), one second ($1''$).

It means 1 right angle = 100 grades (100g)

1 grade (1 g) = 100 minutes ($100'$)

1 minute ($1'$) = 100 seconds ($100''$)

$90^\circ = 100g$ (because each is a right angle)

This system is easier than Sexagesimal System. But to use this system many other systems will have to be devised that is why this system is not used.

(iii) Circular System

In this system, the unit of measuring angles is radian. It is that angle which is formed at the centre and is formed of an arc of length equal to radius in a circle.

There is one constant ratio between the circumference and dia of a circle. This is represented by π .

$$\frac{\text{Circumference}}{\text{Diameter}} = \text{constant point} = \pi$$

$$\begin{aligned} \text{Circumference} &= \pi \times \text{dia} \\ &= 2\pi r \text{ (where } r \text{ is radius of the circle)} \end{aligned}$$

$$\pi = \frac{22}{7}$$

Circumference makes an angle ($2\pi r$) = 360°

Radius of the circle makes an angle (r) = 1 Radian

$$\text{ie : } \frac{C}{r} = \frac{360^\circ}{1\text{Radian}}$$

$$\frac{2\pi r}{r} = \frac{360^\circ}{1\text{Radian}}$$

$$2\pi = \frac{360^\circ}{1\text{Radian}}$$

$$2\pi \text{ Radian} = 360^\circ$$

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

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

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

Examples

- 1 Convert $45^\circ 36' 20''$ into degree and decimal of degree.

$$60 \text{ seconds} = 1 \text{ minute}$$

$$20 \text{ seconds} = \frac{20}{60} = 0.333'$$

$$60 \text{ minutes} = 1 \text{ degree}$$

$$36.333 \text{ minutes} = \frac{36.333}{60} = 0.606^\circ$$

$$45^\circ 36' 20'' = 45.606^\circ$$

- 2 Convert 24.59° into degree, minute and second

$$1 \text{ degree} = 60 \text{ minutes}$$

$$0.59 \text{ degree} = 0.59 \times 60 = 35.4'$$

$$1 \text{ minute} = 60 \text{ seconds}$$

$$0.4 \text{ minute} = 60 \text{ sec} \times 0.4$$

$$= 24''$$

$$\text{Therefore } 24.59^\circ = 24^\circ 35' 24''$$

- 3 Change $50^\circ 37' 30''$ into degrees

By changing angle degrees into decimals

$$30'' = \frac{30}{60} = 0.50'$$

$$37' 30'' = 37.5'$$

$$37.5' = \frac{37.5}{60} = 0.625^\circ$$

$$50^\circ 37' 30'' = 50.625^\circ$$

4 Convert $23^{\circ}25'32''$ into radians

We know $1^{\circ} = 60' = 3600''$

Therefore $23^{\circ}25'32''$

$$\begin{aligned} &= \left(23 + \frac{25}{60} + \frac{32}{3600} \right) \text{ degrees} \\ &= \frac{82800 + 1500 + 32}{3600} \\ &= \frac{84332}{3600} \end{aligned}$$

But $180^{\circ} = \pi$ radians

Therefore 23.4255 degrees

$$\begin{aligned} &= \frac{23.4255}{180} \pi \text{ radians} \\ &= \frac{23.4255}{180} \times \frac{22}{7} \text{ radians} \\ &= \mathbf{0.4089 \text{ radians}} \end{aligned}$$

5 Convert $87^{\circ}19'57''$ into Radian.

$$\begin{aligned} 19'57'' &= 19' + \frac{57''}{60} \\ &= 19' + 0.95'' \\ &= 19.95' \end{aligned}$$

$$\begin{aligned} 87^{\circ}19.95' &= 87^{\circ} + \frac{19.95'}{60} \\ &= 87^{\circ} + 0.332^{\circ} = 87.33^{\circ} \end{aligned}$$

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

$$\begin{aligned} 87.33^{\circ} &= \frac{\pi}{180} \times 87.33 \text{ radian} \\ &= 1.524 \text{ radian} \end{aligned}$$

6 Convert $67^{\circ}11'43''$ into Radian

$$\begin{aligned} 11'43'' &= 11' + \frac{43''}{60} \\ &= 11' + 0.716'' \\ &= 11.72' \end{aligned}$$

$$\begin{aligned} 67^{\circ}11.72' &= 67^{\circ} + \frac{11.72'}{60} \\ &= 67^{\circ} + 0.195^{\circ} \\ &= 67.2^{\circ} \end{aligned}$$

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

$$\begin{aligned} 67.2^{\circ} &= \frac{\pi}{180} \times 67.2 \text{ radian} \\ &= 1.173 \text{ radian} \end{aligned}$$

7 Convert $\frac{4}{7} \pi$ radian into degrees

$$1 \text{ radian} = \frac{180}{\pi} \text{ degree}$$

$$\begin{aligned} \frac{4}{7} \pi \text{ radian} &= \frac{180}{\pi} \times \frac{4}{7} \pi \text{ degree} \\ &= 102.9 \text{ degree} \\ &= 102^{\circ} 0.9 \times 60' \\ &= 102^{\circ} 54' \end{aligned}$$

8 Convert 0.8357 radian into degrees

$$1 \text{ radian} = \frac{180}{\pi} \text{ degree}$$

$$\begin{aligned} 0.8357 \text{ radian} &= \frac{180}{\pi} \times 0.8357 \text{ degree} \\ &= 47.88^{\circ} \\ &= 47^{\circ} 0.88 \times 60' \\ &= 47^{\circ} 52.80' \\ &= 47^{\circ} 52' 0.8 \times 60'' \\ &= 47^{\circ} 52' 48'' \end{aligned}$$

9 Convert 2.752 radian into degrees

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

$$\begin{aligned} 2.7520 \text{ radian} &= \frac{180}{\pi} \times 2.752 \text{ degree} \\ &= 157.7^{\circ} \\ &= 157.7^{\circ} \times 60' \\ &= 157^{\circ} 42' \end{aligned}$$

10 Convert $\frac{3}{5} \pi$ radian into degrees

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

$$\begin{aligned} \frac{3}{5} \pi \text{ radian} &= \frac{180}{\pi} \times \frac{3}{5} \pi \text{ degree} \\ &= 108^{\circ} \end{aligned}$$

Assignment

Convert into Degree

1 12 Radian

Convert into Radians

2 78°

3 $47^{\circ}20'$

4 $52^{\circ}36'45''$

5 $25^{\circ}38''$

Convert into degree, minute and seconds

6 46.723°

7 68.625°

8 0.1269 Radian

9 2.625 Radians

10 $\frac{3}{5}$ Radian

Trigonometry - Trigonometrical ratios

Dependency

The sides of a triangle bear constant ratios for a given definite value of the angle. That is, increase or decrease in the length of the sides will not affect the ratio between them unless the angle is changed. These ratios are trigonometrical ratios. For the given values of the angle a value of the ratios

$\frac{BC}{AB}, \frac{AC}{AB}, \frac{BC}{AC}, \frac{AB}{BC}, \frac{AB}{AC}$ and $\frac{AC}{BC}$ do not change even when the sides AB, BC, AC are increased to AB', BC' and AC' or decreased to AB'', BC'' and AC''.

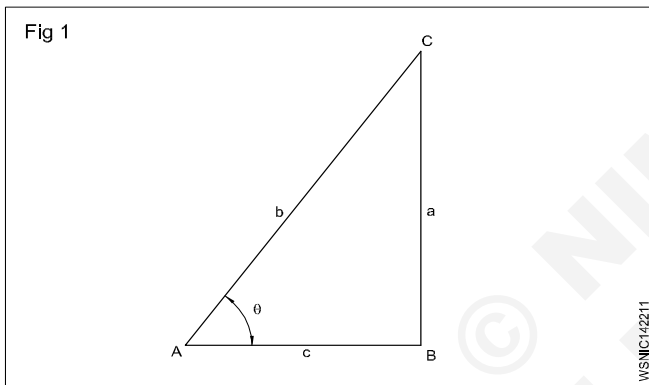
For the angle

AC is the hypotenuse

AB is the adjacent side

BC is the opposite side.

The ratios



The six ratios between the sides have precise definitions.

$$\text{Sine } \theta = \frac{BC}{AC} = \frac{\text{Opposite side}}{\text{Hypotenuse}} = \text{Sin } \theta$$

$$\text{Cosine } \theta = \frac{AB}{AC} = \frac{\text{Adjacent side}}{\text{Hypotenuse}} = \text{Cos } \theta$$

$$\text{Tangent } \theta = \frac{BC}{AB} = \frac{\text{Opposite side}}{\text{Adjacent side}} = \text{Tan } \theta$$

$$\text{Cosecant } \theta = \frac{AC}{BC} = \frac{\text{Hypotenuse}}{\text{Opposite side}} = \text{Cosec } \theta$$

$$\text{Secant } \theta = \frac{AC}{AB} = \frac{\text{Hypotenuse}}{\text{Adjacent side}} = \text{Sec } \theta$$

$$\text{Cotangent } \theta = \frac{AB}{BC} = \frac{\text{Adjacent side}}{\text{Opposite side}} = \text{Cot } \theta$$

Relationship between the ratios

$$\text{Cosec } \theta = \frac{AC}{BC} = \frac{1}{\frac{BC}{AC}} = \frac{1}{\text{sin } \theta}$$

$$\text{sec } \theta = \frac{AC}{AB} = \frac{1}{\frac{AB}{AC}} = \frac{1}{\text{cos } \theta}$$

$$\text{cot } \theta = \frac{AB}{BC} = \frac{1}{\frac{BC}{AB}} = \frac{1}{\text{tan } \theta}$$

$$\text{sin } \theta = \frac{\text{side BC}}{\text{side AC}} = \frac{a}{b}$$

$$\text{cos } \theta = \frac{\text{side AB}}{\text{side AC}} = \frac{c}{b}$$

$$\frac{\text{sin } \theta}{\text{cos } \theta} = \frac{\frac{a}{b}}{\frac{c}{b}} = \frac{a}{b} \times \frac{b}{c} = \frac{a}{c}$$

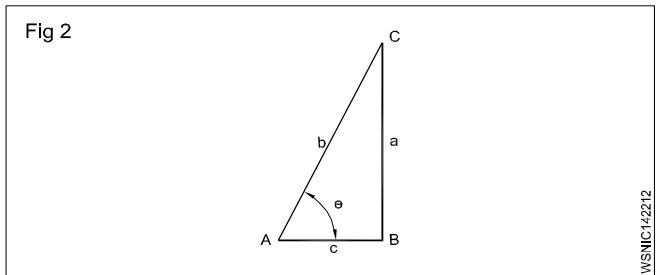
$$= \frac{\text{side BC}}{\text{side AB}} = \text{tan } \theta$$

$$\text{sin } \theta = \frac{1}{\text{cosec } \theta} \text{ or } \text{cosec } \theta = \frac{1}{\text{sin } \theta} \text{ or } \text{sin } \theta \cdot \text{cosec } \theta = 1$$

$$\text{cos } \theta = \frac{1}{\text{sec } \theta} \text{ or } \text{sec } \theta = \frac{1}{\text{cos } \theta} \text{ or } \text{cos } \theta \cdot \text{sec } \theta = 1$$

$$\text{tan } \theta = \frac{1}{\text{cot } \theta} \text{ or } \text{cot } \theta = \frac{1}{\text{tan } \theta} \text{ or } \text{cot } \theta \cdot \text{tan } \theta = 1$$

By pythagoras theorem we have, $AC^2 = AB^2 + BC^2$



Dividing both sides of the equation by AC^2 , we have

$$\frac{AC^2}{AC^2} = \frac{AB^2}{AC^2} + \frac{BC^2}{AC^2}$$

$$= \left[\frac{AB}{AC} \right]^2 + \left[\frac{BC}{AC} \right]^2$$

$$1 = (\text{cos } \theta)^2 + (\text{sin } \theta)^2$$

$$\text{sin}^2 \theta + \text{cos}^2 \theta = 1$$

Sine, Cosine, Tangent, Cosec, Sec and Cotangent are the six trigonometrical ratios

$$\text{tan } \theta = \frac{\text{Sin } \theta}{\text{Cos } \theta} \text{ and } \text{sin}^2 \theta + \text{cos}^2 \theta = 1$$

$$\sin^2 \theta + \cos^2 \theta = 1$$

It can be transformed as

$$\sin^2 \theta = 1 - \cos^2 \theta$$

$$\sin \theta = \sqrt{1 - \cos^2 \theta}$$

$$\text{or } \cos^2 \theta = 1 - \sin^2 \theta$$

$$\cos \theta = \sqrt{1 - \sin^2 \theta}$$

$$\tan \theta = \frac{\sin \theta}{\cos \theta} = \frac{\sqrt{1 - \cos^2 \theta}}{\cos \theta}$$

$$\tan \theta = \frac{\sin \theta}{\sqrt{1 - \sin^2 \theta}}$$

We know $\sin^2 \theta + \cos^2 \theta = 1$

Dividing both sides by $\cos^2 \theta$.

$$\frac{\sin^2 \theta}{\cos^2 \theta} + \frac{\cos^2 \theta}{\cos^2 \theta} = \frac{1}{\cos^2 \theta}$$

$$\text{or } 1 + \tan^2 \theta = \sec^2 \theta$$

Using the same equation

$$\sin^2 \theta + \cos^2 \theta = 1.$$

Dividing both sides by $\sin^2 \theta$,

$$\frac{\sin^2 \theta}{\sin^2 \theta} + \frac{\cos^2 \theta}{\sin^2 \theta} = \frac{1}{\sin^2 \theta}$$

$$1 + \frac{\cos^2 \theta}{\sin^2 \theta} = \frac{1}{\sin^2 \theta}$$

$$1 + \cot^2 \theta = \operatorname{cosec}^2 \theta$$

$$1 + \tan^2 \theta = \sec^2 \theta$$

Trigonometrical Tables

| Ratio | 0° | 30° | 45° | 60° | 90° |
|-------|----|----------------------|----------------------|----------------------|-----|
| sin θ | 0 | $\frac{1}{2}$ | $\frac{1}{\sqrt{2}}$ | $\frac{\sqrt{3}}{2}$ | 1 |
| cos θ | 1 | $\frac{\sqrt{3}}{2}$ | $\frac{1}{\sqrt{2}}$ | $\frac{1}{2}$ | 0 |
| tan θ | 0 | $\frac{1}{\sqrt{3}}$ | 1 | $\sqrt{3}$ | ∞ |

When θ increases,

Sine value increases;

Cosine value decreases;

Tangent value increases to more than 1 when the angle is more than 45° ($\tan 60^\circ = 1.732$)

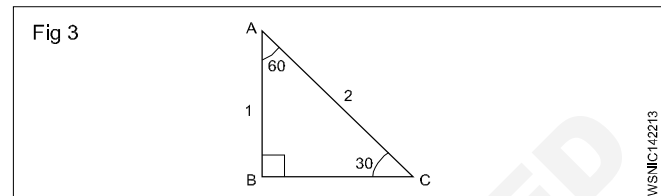
Sine of an angle = Cosine of its complementary angle

Cosine of an angle = Sine of its complementary angle

Examples

If $\sin 30^\circ = \frac{1}{2}$ find the value of $\sin 60^\circ$

By applying pythagores theorem



$$BC^2 = AC^2 - AB^2$$

$$BC^2 = 2^2 - 1^2$$

$$= 4 - 1$$

$$= 3$$

$$BC = \sqrt{3}$$

$$\sin 60^\circ = \frac{\sqrt{3}}{2}$$

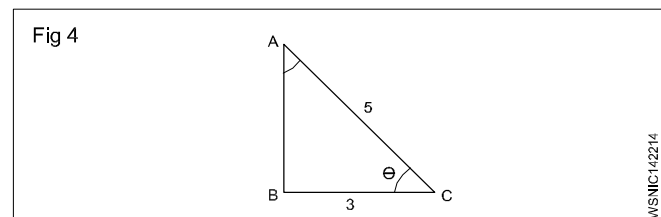
$\cos \theta = \frac{3}{5}$ Find the other trigonometrical ratios

By applying pythagores theorem

$$AB^2 = AC^2 - BC^2$$

$$= 5^2 - 3^2 = 25 - 9$$

$$= 16$$



$$AB = \sqrt{16} = 4$$

$$\text{Now } \sin \theta = \frac{4}{5}$$

$$\tan \theta = \frac{4}{3}$$

$$\operatorname{Cosec} \theta = \frac{5}{4}$$

$$\sec \theta = \frac{5}{3}$$

$$\cot \theta = \frac{3}{4}$$

Signs of trigonometrical functions for angles more than 90°

| Ratio | 90 - θ | 90 + θ | 180 - θ | 180 + θ | 270 - θ | 270 + θ | 360 - θ | - θ |
|-------|--------|---------|---------|---------|---------|---------|---------|---------|
| sin | cos | cos | sin | - sin | - cos | - cos | - sin | - sin |
| cos | sin | - sin | - cos | - cos | - sin | sin | cos | cos |
| tan | cot | - cot | - tan | tan | cot | - cot | - tan | - tan |
| cosec | sec | sec | cosec | - cosec | - sec | - sec | - cosec | - cosec |
| sec | cosec | - cosec | - sec | - sec | - cosec | cosec | sec | sec |
| cot | tan | - tan | - cot | cot | tan | - tan | - cot | - cot |

Simplify :

$$\begin{aligned} \cot \theta + \tan (180+\theta) + \tan(90-\theta) + (\tan 360 - \theta) \\ = \cot \theta + \tan \theta - \cot \theta - \tan \theta \\ = 0 \end{aligned}$$

Simplify :

$$\begin{aligned} \frac{\cos (90+\theta) \sec (-\theta) \tan (180-\theta)}{\sec (360-\theta) \sin (180+\theta) \cos (90-\theta)} \\ = \frac{(-\sin \theta) \times (\sec \theta) \times (-\tan \theta)}{(\sec \theta) \times (-\sin \theta) \times (-\sin \theta)} \\ = \frac{\tan \theta}{\sin \theta} = \frac{1}{\cos \theta} = \sec \theta \end{aligned}$$

simplify:

$$\begin{aligned} \frac{\cos (90^\circ + \theta) \sec (-\theta) \tan (180^\circ - \theta)}{\sec (360^\circ - \theta) \sin (180^\circ + \theta) \cot (90^\circ - \theta)} \\ \cos (90^\circ + \theta) = -\sin \theta \\ \sec (-\theta) = \sec \theta \\ \tan (180^\circ - \theta) = -\tan \theta \end{aligned}$$

$$\sec (360^\circ - \theta) = \sec \theta$$

$$\sin (180^\circ + \theta) = -\sin \theta$$

$$\cot (90^\circ + \theta) = -\tan \theta$$

$$\begin{aligned} \frac{\cos (90^\circ + \theta) \sec (-\theta) \tan (180^\circ - \theta)}{\sec (360^\circ - \theta) \sin (180^\circ + \theta) \cot (90^\circ - \theta)} \\ = \frac{(-\sin \theta)(\sec \theta)(\tan \theta)}{(\sec \theta)(-\sin \theta)(-\tan \theta)} \\ = 1 \end{aligned}$$

Simplify:

$$\begin{aligned} \cot \theta + \tan (180^\circ + \theta) + \tan (90^\circ + \theta) + \tan (360^\circ - \theta) \\ \tan (180^\circ - \theta) = \tan \theta \\ \tan (90^\circ + \theta) = -\cot \theta \\ \tan (360^\circ - \theta) = -\tan \theta \\ \cot \theta + \tan (180^\circ + \theta) + \tan (90^\circ + \theta) + \tan (360^\circ - \theta) \\ \cot \theta + \tan \theta - \cot \theta - \tan \theta = 0 \end{aligned}$$

Assignment

1 Given $\sin 30^\circ = 1/2$, find the value of $\tan 60^\circ$

2 If $\cos \theta = 4/5$, find the other ratios

3 If $\sin A = 3/5$, find $\cos \theta$, $\tan \theta$ & $\sec \theta$

4 If $\tan \theta = 24/7$, find $\sin \theta$ and $\cos \theta$

5 Find the value of $\cos \theta$ and $\tan \theta$, if $\sin \theta = 1/2$

6 If $\cos \theta = 5/13$, find the value of $\tan \theta$

7 If $\sin \theta = 1/2$, find the value of $\sin^2 \theta - \cos^2 \theta$

8 What is the value of

$$\frac{\sin^2 30^\circ}{\cos^2 45^\circ} + \frac{\tan 45^\circ}{\sec 60^\circ} - \frac{\sin 60^\circ}{\cot 45^\circ} - \frac{\cos 30^\circ}{\sin 90^\circ}$$

Simplify :

1 $\tan (90 + A) + (\tan 180 + A) \tan (90 + A)$

2 $\frac{\cos (90 + \theta) \cdot \sec (-\theta) \cdot \tan (180 - \theta)}{\sec (360 + \theta) \cdot \sin (180 + \theta) \cdot \cot (90 + \theta)}$

Trigonometry - Trigonometrical tables

Use of trigonometrical tables (Ref: Sin, Cos & Tan Table)

| Deg. | Minutes from 0 to 4 | | | | | | Mean difference | | | | |
|------|---------------------|----|-----|-----|-----|-----|-----------------|----|----|----|----|
| | 0' | 6' | 12' | 18' | 24' | 54' | 1' | 2' | 3' | 4' | 5' |
| 0 | | | | . | | | . | | | | |
| 1 | | | | . | | | . | | | | |
| 2 | | | | . | | | . | | | | |
| 3 | | | | . | | | . | | | | |
| . | | | | . | | | . | | | | |
| . | | | | . | | | . | | | | |
| . | | | | . | | | . | | | | |
| 26 | .. | .. | .. | x | .. | .. | .. | 5 | | | |
| . | | | | | | | | | | | |
| . | | | | | | | | | | | |
| . | | | | | | | | | | | |
| 89 | | | | | | | | | | | |

Sine value for 26°–20'

Refer to Natural sine table.

Degrees column go up to 26° down

Minutes column 18' horizontal and under this note the value which is given as 0.4431.

Under mean difference for 2' in the same horizontal line 5 is given. Add this to the extreme right number noted for 26°–18'.

$$\text{Sine } 26^\circ - 20' = 0.4431 + .0005 = 0.4436$$

Cosine value for 43°–41'

Referring to the Natural cosines table for 43°–36' it is given as 0.7242 and the mean difference for 5' minutes is given as 10.

$$\begin{aligned} \cos 43^\circ - 41' &= \text{value for } \cos 43^\circ .36' \\ &\quad - \text{the value given for} \\ \text{mean difference of } 5' &= 0.7242 - 0.0010 \\ &= 0.7232 \end{aligned}$$

When reading sine value add the mean difference value. When reading cosine value subtract the mean difference value.

Arrangement

Values of trigonometrical ratios can be taken from mathematical tables.

The left hand vertical column consists of degrees.

The top horizontal column is arranged in minutes in steps of 6' from 0' to 54'. In the extreme right horizontal columns the mean differences are written in minutes from 1' to 5' in steps of 1' to account for angles with minutes between the interval of 6'.

- The values of cosine, cosecant and cotangent decrease when the value of the angle increases.
- For sine, secant and tangent, the value increases when the angle increases.
- The value of sine and cosine will never be more than 1.
- The value of secant and cosecant will never be less than 1.
- The value of Tan and Cot ranges from 0 to ∞.

EXAMPLE

From the tables obtain the cosine of 45°20'.

$$\cos 45^\circ 18' = 0.7108$$

$$\text{mean difference for } 2' = 0.0004$$

$$\cos 45^\circ 20' = 0.7104$$

SINE TABLE

1 Sin 25° = 0.4226

2 Sin 17° 5'

$$\sin 17^\circ = 0.2924$$

$$\text{Difference } 5' = 14$$

$$\sin 17^\circ 5' = 0.2938 \quad \text{Ans}$$

3 sin 17° 45' 13"

$$\sin 17^\circ 46' = 0.3051$$

$$\sin 17^\circ 45' = 0.3048$$

$$\text{Difference } 1' = 0.0003$$

$$\begin{aligned}
 1'(\text{or}) 60'' &= 0.0003 \\
 13'' &= \frac{0.0003}{60} \times 13 \\
 &= \frac{0.0039}{60} \\
 &= \frac{0.00039}{6} \\
 &= 0.000065
 \end{aligned}$$

$$\begin{aligned}
 \sin 17^\circ 45' &= 0.3048 \\
 13'' &= 0.000065
 \end{aligned}$$

$$\sin 17^\circ 45' 13'' = 0.304865 \quad \text{Ans.}$$

4 sin 82° 14' 18"

$$\sin 82^\circ 15' = 0.9908$$

$$\sin 82^\circ 14' = 0.9908$$

$$\text{Difference } 1' = 0$$

$$1'(\text{or}) 60'' = 0$$

$$\sin 18'' = 0$$

$$\sin 82^\circ 14' = 0.9908$$

$$18'' = 0.0000$$

$$\sin 82^\circ 41' 18'' = 0.9908 \quad \text{Ans.}$$

Finding the corresponding angles when sine values are given:

1. Sin $\theta = 0.9925$

$$\theta = 83^\circ$$

2. Sin $\theta = 0.8791$

$$0.8788 = \sin 61^\circ 30'$$

$$0.0003 = 2'$$

$$0.8791 = \sin 61^\circ 32'$$

3. sin $\theta = 0.68015$

$$0.6794 = \sin 42^\circ 48'$$

$$0.0006 = 3'$$

$$0.6800 = \sin 42^\circ 51'$$

$$0.6803 = \sin 42^\circ 52'$$

$$\text{Difference } 0.0003 = 1' (\text{or}) 60''$$

$$\begin{aligned}
 0.00015 &= \frac{60}{0.0003} \times 0.00015 \\
 &= \frac{60 \times 15}{30} \\
 &= 30''
 \end{aligned}$$

$$0.6800 = \sin 42^\circ 51'$$

$$0.00015 = 30''$$

$$0.68015 = \sin 42^\circ 51' 30''$$

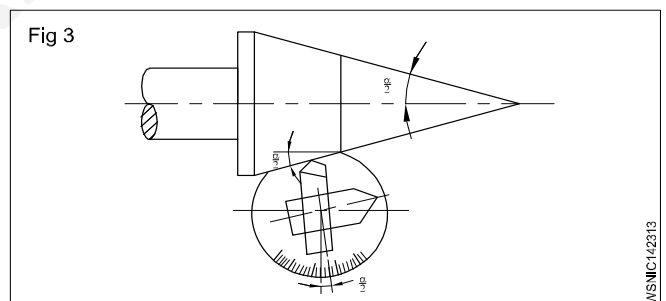
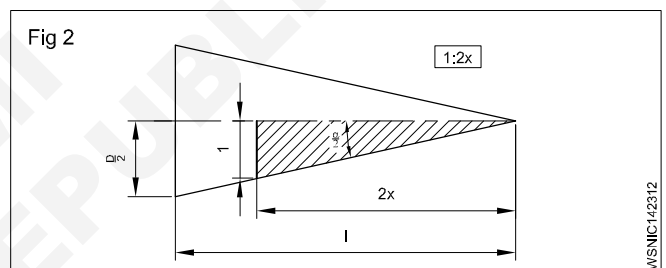
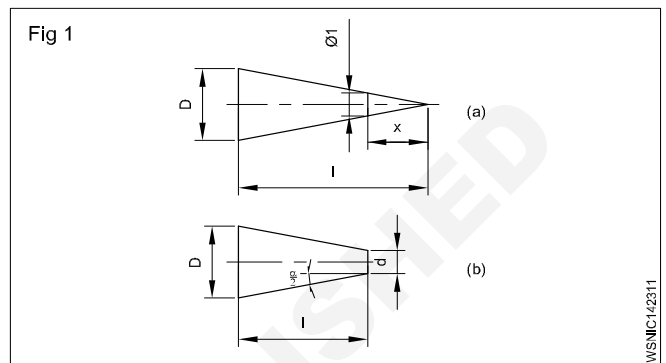
$$\theta = 42^\circ 51' 30''$$

Calculations involving tapers

D - Big diameter of the taper

d - small diameter of the taper

C - Taper Ratio - 1:x



$\frac{C}{2}$ Ratio of inclination - 1:2 x

l - length of taper

α - included angle of taper

$\frac{\alpha}{2}$ - setting angle

Taper ratio = Ratio of inclination (for wedges).

Taper ratio

The ratio between the difference in diameter to the length of the taper is known as taper ratio. D is the difference in larger diameter shown in the sketch as the small diameter of taper is 0. Taper ratio is $D : l$. In the sectioned portion the difference in diameter is 1 and the length of taper is shown as x .

$C = D : d = 1 : x$ as per Fig 1 (a), $C = \frac{D-d}{l}$ as per Fig 1 (b)

Ratio of inclination

Taking half of the taper, $\frac{D}{2}$ is the difference in diameter for a taper length of l , if $d = 0$.

$$\therefore \frac{C}{2} = \frac{D}{2l} \quad \text{if the small diameter is 0}$$

$$\text{or } \frac{C}{2} = \frac{D-d}{2l}$$

1 Ratio of inclination = $\frac{1}{2}$ of the taper ratio.

Setting angle

One of the methods of turning taper is by swivelling the compound slide to an angle known as setting angle and feeding the tool at an angle to the axis of work.

$$\tan \frac{\alpha}{2} = \frac{C}{2} = \frac{D-d}{2l}$$

$$\tan \frac{\alpha}{2} = \frac{\text{taper ratio}}{2}$$

$$= \frac{\text{difference in diameter}}{2 \times \text{taper length}}$$

NOTE: $\frac{\alpha}{2}$ is the setting angle which is equal to half of the included angle of the taper.

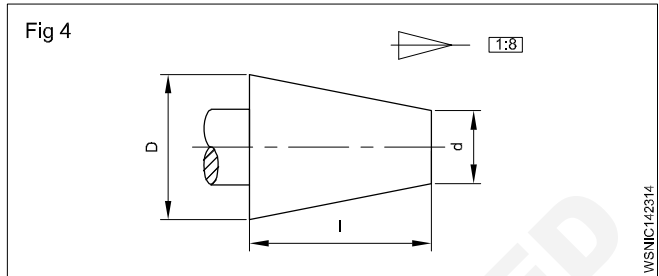
Taper Ratio $C = 1 : x$ or $D : l$ or $(D-d) : l$

Ratio of inclination $\frac{C}{2} = 1 : 2x = \frac{D}{2} : l$ or $\left(\frac{D-d}{2}\right) : l$

Setting angle determination is by the formula

$$\tan \frac{\alpha}{2} = \frac{D-d}{2l} = \frac{C}{2}$$

Fig 4



EXAMPLE

A pivot in the form of a frustum of a cone has a taper ratio 1:8. If the small diameter is 30 mm and length of taper is 80 mm, find its large diameter.

$$C = 1:8 = \frac{1}{8}$$

$$\therefore \frac{D-d}{l} = \frac{1}{8}$$

$$\therefore D - d = \frac{1}{8} \times 80 = 10 \text{ mm.}$$

$$D - 30 \text{ mm} = 10 \text{ mm}$$

$$D = 10 \text{ mm} + 30 \text{ mm} = 40 \text{ mm}$$

$$\text{Large diameter } D = 40 \text{ mm}$$

Cos Table

1 Cos 38°

$$\cos 38^\circ = 0.7880$$

2 Cos 83°12'

$$\cos 83^\circ 12' = 0.1184$$

3 Cos 26°40'

$$\cos 26^\circ 36' = 0.8942$$

$$4' = 5(-)$$

$$\cos 26^\circ 40' = 0.8937$$

4 Cos 31°20'

$$\cos 31^\circ 18' = 0.8545$$

$$2' = 3(-)$$

$$\cos 31^\circ 20' = 0.8542$$

Find the corresponding angles when cos values are given:

1 **Cos θ = 0.5150**

$$\theta = 59^\circ$$

2 **Cos θ = 0.0192**

$$\theta = 88^\circ 54'$$

3 **Cos θ = 0.9682**

$$0.9686 = \cos 14^\circ 24'$$

$$(-) 4 = 5'$$

$$0.9682 = \cos 14^\circ 29'$$

$$\theta = 14^\circ 29'$$

$$4 \quad \text{Cos } \theta = 0.8476$$

$$0.8480 = \cos 32^\circ 0'$$

$$(-) 0.0003 = \quad \quad 2'$$

$$0.8477 = \cos 32^\circ 2'$$

$$0.8475 = \cos 32^\circ 3'$$

$$0.0002 = 1' \text{ (or) } 60''$$

$$0.0001 = \frac{\quad}{0.0002} \times 0.0001$$

$$= \frac{\quad}{60} \times 1$$

$$= \frac{\quad}{2}$$

$$= 30''$$

$$0.8477 = \text{Cos } 32^\circ 2'$$

$$(-) 0.0001 = \quad \quad 30'' (+)$$

$$\mathbf{0.8476 = \text{Cos } 32^\circ 2' 30''}$$

tan Table

1 tan 35° 37'

$$\tan 35^\circ 36' = 0.7159$$

$$1' = 0.0004$$

$$\tan 35^\circ 37' = 0.7163$$

2 tan 50° 5'

$$\tan 50^\circ 0' = 1.1918$$

$$5' = 0.0036$$

$$\tan 50^\circ 5' = 1.1954$$

Find the corresponding angles when tan values are given

$$1 \quad \tan \theta = 0.3972$$

$$0.3959 = \tan 21^\circ 36'$$

$$0.0013 = \quad \quad 4'$$

$$0.3972 = \tan 21^\circ 40'$$

$$2 \quad \tan \theta = 1.0065$$

$$1.0035 = \tan 45^\circ 6'$$

$$0.0030 = \quad \quad 5'$$

$$1.0065 = \tan 45^\circ 11'$$

Problems Related with Trigonometrical tables

1 A 250 mm Sine bar is used to measure an angle. If the difference in height is 5 cm, find the angle.

$$\text{Sin } \theta = \frac{\text{Opp.side}}{\text{Hyp.}} = \frac{h}{l}$$

$$= \frac{5 \text{ cm}}{250 \text{ mm}}$$

$$= \frac{50 \text{ mm}}{250 \text{ mm}}$$

$$= 0.2000$$

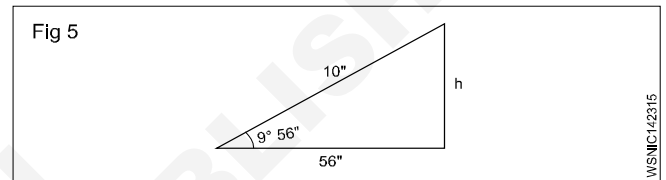
$$\theta = 11^\circ 32'$$

2 Find the height of the slip gauge if a Sine bar with plugs of 10" centre is set up to inspect a taper having an included angle of 9° 56".

$$\text{Sin } \theta = \frac{\text{Opp.side}}{\text{Hyp.}} = \frac{h}{l}$$

$$\text{Sin } 9^\circ 56'' = \frac{h}{10}$$

$$\therefore h = 10 \times \text{sin } 9^\circ 56''$$



$$\text{Sin } 9^\circ 0'' = 0.1564$$

$$\text{Sin } 9^\circ 1'' = 0.1567$$

$$1' \text{ (or) } 60'' = 0.0003$$

$$56'' = \frac{0.0003}{60} \times 56$$

$$= \frac{0.0168}{60}$$

$$= \frac{0.00168}{6}$$

$$= 0.00028$$

$$\text{sin } 9^\circ 0' 00'' = 0.1564$$

$$56'' = 0.00028$$

$$\text{sin } 9^\circ 0' 56'' = 0.15668$$

$$h = 10 \times \text{sin } 9^\circ 56''$$

$$= 10 \times 0.15668$$

$$= 1.5668 \text{ cm}$$

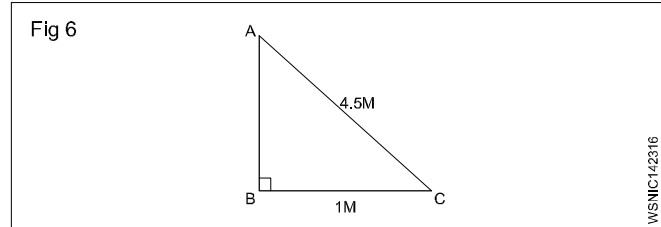
Height of slip gauge = 1.5668"

3 Find the angle which the ladder makes with the ground if the foot of a 4.5 m long ladder is placed at 1 m away from the wall.

In Right angled D

$$\text{Cos } C = \frac{BC}{AC}$$

$$\begin{aligned} \cos \theta &= \frac{1 \text{ m}}{4.5 \text{ m}} = 0.2222 \\ \cos &= 0.2222 \\ 0.2233 &= \cos 77^\circ 6' \\ (-) \quad 0.0011 &= \quad \quad \quad 4' (+) \\ \hline 0.2222 &= \cos 77^\circ 10' \\ \hline \theta &= 77^\circ 10' \end{aligned}$$



Assignment

I Find the values of the given angles

- 1 $\sin 65^\circ$
- 2 $\sin 42^\circ 23'$
- 3 $\sin 66^\circ 35' 32''$
- 4 $\sin 7^\circ 15' 41''$
- 5 $\sin 27^\circ 27''$
- 6 $\cos 26^\circ 40'$
- 7 $\cos 47^\circ 39'$
- 8 $\cos 79^\circ 31' 53''$
- 9 $\tan 28^\circ 45'$
- 10 $\tan 67^\circ 27' 36''$

II Find corresponding angles for given values

- 1 $\sin \theta = 0.3062$
- 2 $\sin \theta = 0.6002$
- 3 $\sin \theta = 0.22453$
- 4 $\sin \theta = 0.04802$
- 5 $\cos \theta = 0.6446$

- 6 $\cos \theta = 0.8926$
- 7 $\cos \theta = 0.11773$
- 8 $\cos \theta = 0.21646$
- 9 $\tan \theta = 0.3411$
- 10 $\tan \theta = 2.3868$

III

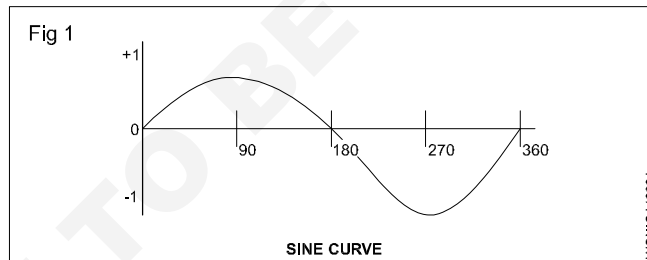
- 1 Calculate its base, if the slant height of a cone is 12.25 cm and the vertex angle is 110° .
- 2 A ladder 2.5 m long makes an angle of 60° with the ground. Find the height of the wall where the ladder touches the wall.
- 3 A sine bar of 200 mm is to be set at an angle of $15^\circ 15' 3''$. Select the slip gauge block to built up the required height.
- 4 In a right angled triangle ABC, $\angle C = 90^\circ$, If $AB = 50 \text{ mm}$ and $\angle B = 75^\circ$, Find the remaining sides.
- 5 Calculate the required length of the bar for this point if a centre point having an included angle of 60° is to be turned at the end of a 50 mm dia bar.

Natural Sines

| ° | 0' | 6' | 12' | 18' | 24' | 30' | 36' | 42' | 48' | 54' | 1' | 2' | 3' | 4' | 5' |
|----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|----|----|----|----|----|
| | 0.0° | 0.1° | 0.2° | 0.3° | 0.4° | 0.5° | 0.6° | 0.7° | 0.8° | 0.9° | | | | | |
| 0 | 0.0000 | 0.0017 | 0.0035 | 0.0052 | 0.0070 | 0.0087 | 0.0105 | 0.0122 | 0.0140 | 0.0157 | 3 | 6 | 9 | 12 | 15 |
| 1 | 0.0175 | 0.0192 | 0.0209 | 0.0227 | 0.0244 | 0.0262 | 0.0279 | 0.0297 | 0.0314 | 0.0332 | 3 | 6 | 9 | 12 | 15 |
| 2 | 0.0349 | 0.0366 | 0.0384 | 0.0401 | 0.0419 | 0.0436 | 0.0454 | 0.0471 | 0.0488 | 0.0506 | 3 | 6 | 9 | 12 | 15 |
| 3 | 0.0523 | 0.0541 | 0.0558 | 0.0576 | 0.0593 | 0.0610 | 0.0628 | 0.0645 | 0.0663 | 0.0680 | 3 | 6 | 9 | 12 | 15 |
| 4 | 0.0698 | 0.0715 | 0.0732 | 0.0750 | 0.0767 | 0.0785 | 0.0802 | 0.0819 | 0.0837 | 0.0854 | 3 | 6 | 9 | 12 | 14 |
| 5 | 0.0872 | 0.0899 | 0.0906 | 0.0924 | 0.0941 | 0.0958 | 0.0976 | 0.0993 | 0.1011 | 0.1028 | 3 | 6 | 9 | 12 | 14 |
| 6 | 0.1045 | 0.1063 | 0.1080 | 0.1097 | 0.1115 | 0.1132 | 0.1149 | 0.1167 | 0.1184 | 0.1201 | 3 | 6 | 9 | 12 | 14 |
| 7 | 0.1219 | 0.1236 | 0.1253 | 0.1271 | 0.1288 | 0.1305 | 0.1323 | 0.1340 | 0.1357 | 0.1374 | 3 | 6 | 9 | 12 | 14 |
| 8 | 0.1392 | 0.1409 | 0.1426 | 0.1444 | 0.1461 | 0.1478 | 0.1495 | 0.1513 | 0.1530 | 0.1547 | 3 | 6 | 9 | 11 | 14 |
| 9 | 0.1564 | 0.1582 | 0.1599 | 0.1616 | 0.1633 | 0.1650 | 0.1668 | 0.1685 | 0.1702 | 0.1719 | 3 | 6 | 9 | 11 | 14 |
| 10 | 0.1736 | 0.1754 | 0.1771 | 0.1788 | 0.1805 | 0.1822 | 0.1840 | 0.1857 | 0.1874 | 0.1891 | 3 | 6 | 9 | 11 | 14 |
| 11 | 0.1908 | 0.1925 | 0.1942 | 0.1959 | 0.1977 | 0.1994 | 0.2011 | 0.2028 | 0.2045 | 0.2062 | 3 | 6 | 9 | 12 | 14 |
| 12 | 0.2079 | 0.2096 | 0.2113 | 0.2130 | 0.2147 | 0.2164 | 0.2181 | 0.2198 | 0.2215 | 0.2232 | 3 | 6 | 9 | 11 | 14 |
| 13 | 0.2250 | 0.2267 | 0.2284 | 0.2300 | 0.2317 | 0.2334 | 0.2351 | 0.2368 | 0.2385 | 0.2402 | 3 | 6 | 8 | 11 | 14 |
| 14 | 0.2419 | 0.2436 | 0.2453 | 0.2470 | 0.2487 | 0.2504 | 0.2521 | 0.2538 | 0.2554 | 0.2571 | 3 | 6 | 8 | 11 | 14 |
| 15 | 0.2558 | 0.2605 | 0.2622 | 0.2639 | 0.2656 | 0.2672 | 0.2689 | 0.2706 | 0.2723 | 0.2740 | 3 | 6 | 8 | 11 | 14 |
| 16 | 0.2756 | 0.2773 | 0.2790 | 0.2807 | 0.2823 | 0.2840 | 0.2857 | 0.2874 | 0.2890 | 0.2907 | 3 | 6 | 8 | 11 | 14 |
| 17 | 0.2924 | 0.2940 | 0.2957 | 0.2974 | 0.2990 | 0.3007 | 0.3024 | 0.3040 | 0.3057 | 0.3074 | 3 | 6 | 8 | 11 | 14 |
| 18 | 0.3090 | 0.3107 | 0.3123 | 0.3140 | 0.3156 | 0.3173 | 0.3190 | 0.3206 | 0.3223 | 0.3239 | 3 | 6 | 8 | 11 | 14 |
| 19 | 0.3256 | 0.3272 | 0.3289 | 0.3305 | 0.3322 | 0.3338 | 0.3355 | 0.3371 | 0.3387 | 0.3404 | 3 | 5 | 8 | 11 | 14 |
| 20 | 0.3420 | 0.3437 | 0.3453 | 0.3469 | 0.3486 | 0.3502 | 0.3518 | 0.3535 | 0.3551 | 0.3567 | 3 | 5 | 8 | 11 | 14 |
| 21 | 0.3584 | 0.3600 | 0.3616 | 0.3633 | 0.3649 | 0.3665 | 0.3681 | 0.3697 | 0.3714 | 0.3730 | 3 | 5 | 8 | 11 | 14 |
| 22 | 0.3746 | 0.3762 | 0.3778 | 0.3795 | 0.3811 | 0.3827 | 0.3843 | 0.3859 | 0.3875 | 0.3891 | 3 | 5 | 8 | 11 | 13 |
| 23 | 0.3907 | 0.3923 | 0.3939 | 0.3955 | 0.3971 | 0.3987 | 0.4003 | 0.4019 | 0.4035 | 0.4051 | 3 | 5 | 8 | 11 | 13 |
| 24 | 0.4067 | 0.4083 | 0.4099 | 0.4115 | 0.4131 | 0.4147 | 0.4163 | 0.4179 | 0.4195 | 0.4210 | 3 | 5 | 8 | 11 | 13 |
| 25 | 0.4226 | 0.4242 | 0.4258 | 0.4274 | 0.4289 | 0.4305 | 0.4321 | 0.4337 | 0.4352 | 0.4368 | 3 | 5 | 8 | 11 | 13 |
| 26 | 0.4384 | 0.4399 | 0.4415 | 0.4431 | 0.4446 | 0.4462 | 0.4478 | 0.4493 | 0.4509 | 0.4524 | 3 | 5 | 8 | 10 | 13 |
| 27 | 0.4540 | 0.4555 | 0.4571 | 0.4586 | 0.4602 | 0.4617 | 0.4633 | 0.4648 | 0.4664 | 0.4679 | 3 | 5 | 8 | 10 | 13 |
| 28 | 0.4695 | 0.4710 | 0.4726 | 0.4741 | 0.4756 | 0.4772 | 0.4787 | 0.4802 | 0.4818 | 0.4833 | 3 | 5 | 8 | 10 | 13 |
| 29 | 0.4848 | 0.4863 | 0.4879 | 0.4894 | 0.4909 | 0.4924 | 0.4939 | 0.4955 | 0.4970 | 0.4985 | 3 | 5 | 8 | 10 | 13 |
| 30 | 0.500 | 0.5015 | 0.5030 | 0.5045 | 0.5060 | 0.5075 | 0.5090 | 0.5105 | 0.5120 | 0.5135 | 3 | 5 | 8 | 10 | 13 |
| 31 | 0.5150 | 0.5165 | 0.5180 | 0.5195 | 0.5210 | 0.5225 | 0.5240 | 0.5255 | 0.5270 | 0.5284 | 2 | 5 | 7 | 10 | 12 |
| 32 | 0.5299 | 0.5314 | 0.5329 | 0.5344 | 0.5358 | 0.5373 | 0.5388 | 0.5402 | 0.5417 | 0.5432 | 2 | 5 | 7 | 10 | 12 |
| 33 | 0.5446 | 0.5461 | 0.5476 | 0.5490 | 0.5505 | 0.5519 | 0.5534 | 0.5548 | 0.5563 | 0.5577 | 2 | 5 | 7 | 10 | 12 |
| 34 | 0.5592 | 0.5606 | 0.5621 | 0.5635 | 0.5650 | 0.5664 | 0.5678 | 0.5693 | 0.5707 | 0.5721 | 2 | 5 | 7 | 10 | 12 |
| 35 | 0.5736 | 0.5750 | 0.5764 | 0.5779 | 0.5793 | 0.5807 | 0.5821 | 0.5835 | 0.5850 | 0.5864 | 2 | 5 | 7 | 9 | 12 |
| 36 | 0.5878 | 0.5892 | 0.5906 | 0.5920 | 0.5934 | 0.5948 | 0.5962 | 0.5976 | 0.5990 | 0.6004 | 2 | 5 | 7 | 9 | 12 |
| 37 | 0.6018 | 0.6032 | 0.6046 | 0.6060 | 0.6074 | 0.6088 | 0.6101 | 0.6115 | 0.6129 | 0.6143 | 2 | 5 | 7 | 9 | 12 |
| 38 | 0.6157 | 0.6170 | 0.6184 | 0.6198 | 0.6211 | 0.6225 | 0.6239 | 0.6252 | 0.6266 | 0.6280 | 2 | 5 | 7 | 9 | 11 |
| 39 | 0.6293 | 0.6307 | 0.6320 | 0.6334 | 0.6347 | 0.6361 | 0.6374 | 0.6388 | 0.6401 | 0.6414 | 2 | 4 | 7 | 9 | 11 |
| 40 | 0.6428 | 0.6441 | 0.6455 | 0.6468 | 0.6481 | 0.6494 | 0.6508 | 0.6521 | 0.6534 | 0.6547 | 2 | 4 | 7 | 9 | 11 |
| 41 | 0.6561 | 0.6574 | 0.6587 | 0.6600 | 0.6613 | 0.6626 | 0.6639 | 0.6652 | 0.6665 | 0.6678 | 2 | 4 | 7 | 9 | 11 |
| 42 | 0.6691 | 0.6704 | 0.6717 | 0.6730 | 0.6743 | 0.6756 | 0.6769 | 0.6782 | 0.6794 | 0.6807 | 2 | 4 | 6 | 9 | 11 |
| 43 | 0.6820 | 0.6833 | 0.6845 | 0.6858 | 0.6871 | 0.6884 | 0.6896 | 0.6909 | 0.6921 | 0.6934 | 2 | 4 | 6 | 8 | 11 |
| 44 | 0.6947 | 0.6959 | 0.6972 | 0.6984 | 0.6997 | 0.7009 | 0.7022 | 0.7034 | 0.7046 | 0.7059 | 2 | 4 | 6 | 8 | 10 |
| 45 | 0.7071 | 0.7083 | 0.7096 | 0.7108 | 0.7120 | 0.7133 | 0.7145 | 0.7157 | 0.7169 | 0.7181 | 2 | 4 | 6 | 8 | 10 |
| 46 | 0.7193 | 0.7206 | 0.7218 | 0.7230 | 0.7242 | 0.7254 | 0.7266 | 0.7278 | 0.7290 | 0.7302 | 2 | 4 | 6 | 8 | 10 |
| 47 | 0.7314 | 0.7325 | 0.7337 | 0.7349 | 0.7361 | 0.7373 | 0.7385 | 0.7396 | 0.7408 | 0.7420 | 2 | 4 | 6 | 8 | 10 |
| 48 | 0.7431 | 0.7443 | 0.7455 | 0.7466 | 0.7478 | 0.7490 | 0.7501 | 0.7513 | 0.7524 | 0.7536 | 2 | 4 | 6 | 8 | 10 |
| 49 | 0.7547 | 0.7558 | 0.7570 | 0.7581 | 0.7593 | 0.7604 | 0.7615 | 0.7627 | 0.7638 | 0.7649 | 2 | 4 | 6 | 8 | 9 |
| 50 | 0.7660 | 0.7672 | 0.7683 | 0.7694 | 0.7705 | 0.7716 | 0.7727 | 0.7738 | 0.7749 | 0.7760 | 2 | 4 | 6 | 7 | 9 |
| 51 | 0.7771 | 0.7782 | 0.7793 | 0.7804 | 0.7815 | 0.7826 | 0.7837 | 0.7848 | 0.7859 | 0.7869 | 2 | 4 | 5 | 7 | 9 |
| 52 | 0.7880 | 0.7891 | 0.7902 | 0.7912 | 0.7923 | 0.7934 | 0.7944 | 0.7955 | 0.7965 | 0.7976 | 2 | 4 | 5 | 7 | 9 |
| 53 | 0.7986 | 0.7997 | 0.8007 | 0.8018 | 0.8028 | 0.8039 | 0.8049 | 0.8059 | 0.8070 | 0.8080 | 2 | 3 | 5 | 7 | 9 |
| 54 | 0.8090 | 0.8100 | 0.8111 | 0.8121 | 0.8131 | 0.8141 | 0.8151 | 0.8161 | 0.8171 | 0.8181 | 2 | 3 | 5 | 7 | 8 |
| 55 | 0.8192 | 0.8202 | 0.8211 | 0.8221 | 0.8231 | 0.8241 | 0.8251 | 0.8261 | 0.8271 | 0.8281 | 2 | 3 | 5 | 7 | 8 |
| 56 | 0.8290 | 0.8300 | 0.8310 | 0.8320 | 0.8329 | 0.8339 | 0.8348 | 0.8358 | 0.8368 | 0.8377 | 2 | 3 | 5 | 6 | 8 |
| 57 | 0.8387 | 0.8396 | 0.8406 | 0.8415 | 0.8425 | 0.8434 | 0.8443 | 0.8453 | 0.8462 | 0.8471 | 2 | 3 | 5 | 6 | 8 |
| 58 | 0.8480 | 0.8490 | 0.8499 | 0.8508 | 0.8517 | 0.8526 | 0.8536 | 0.8545 | 0.8554 | 0.8563 | 2 | 3 | 5 | 6 | 8 |
| 59 | 0.8572 | 0.8581 | 0.8590 | 0.8599 | 0.8607 | 0.8616 | 0.8625 | 0.8634 | 0.8643 | 0.8652 | 1 | 3 | 4 | 6 | 7 |

Natural Sines

| ° | 0' | 6' | 12' | 18' | 24' | 30' | 36' | 42' | 48' | 54' | 1' | 2' | 3' | 4' | 5' |
|----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|----|----|----|----|----|
| | 0.0° | 0.1° | 0.2° | 0.3° | 0.4° | 0.5° | 0.6° | 0.7° | 0.8° | 0.9° | | | | | |
| 60 | 0.8660 | 0.8669 | 0.8678 | 0.8686 | 0.8695 | 0.8704 | 0.8712 | 0.8721 | 0.8729 | 0.8738 | 1 | 3 | 4 | 6 | 7 |
| 61 | 0.8746 | 0.8755 | 0.8763 | 0.8771 | 0.8780 | 0.8788 | 0.8796 | 0.8805 | 0.8813 | 0.8821 | 1 | 3 | 4 | 6 | 7 |
| 62 | 0.8829 | 0.8838 | 0.8846 | 0.8854 | 0.8862 | 0.8870 | 0.8878 | 0.8886 | 0.8894 | 0.8902 | 1 | 3 | 4 | 5 | 7 |
| 63 | 0.8910 | 0.8918 | 0.8926 | 0.8934 | 0.8942 | 0.8949 | 0.8957 | 0.8965 | 0.8973 | 0.8980 | 1 | 3 | 4 | 5 | 6 |
| 64 | 0.8988 | 0.8996 | 0.9003 | 0.9011 | 0.9018 | 0.9026 | 0.9033 | 0.9041 | 0.9048 | 0.9056 | 1 | 3 | 4 | 5 | 6 |
| 65 | 0.9063 | 0.9070 | 0.9078 | 0.9085 | 0.9092 | 0.9100 | 0.9107 | 0.9114 | 0.9121 | 0.9128 | 1 | 2 | 4 | 5 | 6 |
| 66 | 0.9135 | 0.9143 | 0.9150 | 0.9157 | 0.9164 | 0.9171 | 0.9178 | 0.9184 | 0.9191 | 0.9198 | 1 | 2 | 3 | 5 | 6 |
| 67 | 0.9205 | 0.9212 | 0.9219 | 0.9225 | 0.9232 | 0.9239 | 0.9245 | 0.9252 | 0.9259 | 0.9265 | 1 | 2 | 3 | 4 | 6 |
| 68 | 0.9272 | 0.9278 | 0.9285 | 0.9291 | 0.9298 | 0.9304 | 0.9311 | 0.9317 | 0.9323 | 0.9330 | 1 | 2 | 3 | 4 | 5 |
| 69 | 0.9336 | 0.9342 | 0.9348 | 0.9354 | 0.9361 | 0.9367 | 0.9373 | 0.9379 | 0.9385 | 0.9391 | 1 | 2 | 3 | 4 | 5 |
| 70 | 0.9397 | 0.9403 | 0.9409 | 0.9415 | 0.9421 | 0.9426 | 0.9432 | 0.9438 | 0.9444 | 0.9449 | 1 | 2 | 3 | 4 | 5 |
| 71 | 0.9455 | 0.9461 | 0.9466 | 0.9472 | 0.9478 | 0.9483 | 0.9489 | 0.9494 | 0.9500 | 0.9505 | 1 | 2 | 3 | 4 | 5 |
| 72 | 0.9511 | 0.9516 | 0.9521 | 0.9527 | 0.9532 | 0.9537 | 0.9542 | 0.9548 | 0.9553 | 0.9558 | 1 | 2 | 3 | 3 | 4 |
| 73 | 0.9563 | 0.9568 | 0.9573 | 0.9578 | 0.9583 | 0.9588 | 0.9593 | 0.9598 | 0.9603 | 0.9608 | 1 | 2 | 2 | 3 | 4 |
| 74 | 0.9613 | 0.9617 | 0.9622 | 0.9627 | 0.9632 | 0.9636 | 0.9641 | 0.9646 | 0.9650 | 0.9655 | 1 | 2 | 2 | 3 | 4 |
| 75 | 0.9659 | 0.9664 | 0.9668 | 0.9673 | 0.9677 | 0.9681 | 0.9686 | 0.9690 | 0.9694 | 0.9699 | 1 | 1 | 2 | 3 | 4 |
| 76 | 0.9703 | 0.9707 | 0.9711 | 0.9715 | 0.9720 | 0.9724 | 0.9728 | 0.9732 | 0.9736 | 0.9740 | 1 | 1 | 2 | 3 | 3 |
| 77 | 0.9744 | 0.9748 | 0.9751 | 0.9755 | 0.9759 | 0.9763 | 0.9767 | 0.9770 | 0.9774 | 0.9778 | 1 | 1 | 2 | 2 | 3 |
| 78 | 0.9781 | 0.9785 | 0.9789 | 0.9792 | 0.9796 | 0.9799 | 0.9803 | 0.9806 | 0.9810 | 0.9813 | 1 | 1 | 2 | 2 | 3 |
| 79 | 0.9816 | 0.9820 | 0.9823 | 0.9826 | 0.9829 | 0.9833 | 0.9836 | 0.9839 | 0.9842 | 0.9845 | 1 | 1 | 2 | 2 | 3 |
| 80 | 0.9848 | 0.9851 | 0.9854 | 0.9857 | 0.9860 | 0.9863 | 0.9866 | 0.9869 | 0.9871 | 0.9874 | 0 | 1 | 1 | 2 | 2 |
| 81 | 0.9877 | 0.9880 | 0.9882 | 0.9885 | 0.9888 | 0.9890 | 0.9893 | 0.9895 | 0.9898 | 0.9900 | 0 | 1 | 1 | 2 | 2 |
| 82 | 0.9903 | 0.9905 | 0.9907 | 0.9910 | 0.9912 | 0.9914 | 0.9917 | 0.9919 | 0.9921 | 0.9923 | 0 | 1 | 1 | 1 | 2 |
| 83 | 0.9925 | 0.9928 | 0.9930 | 0.9932 | 0.9934 | 0.9936 | 0.9938 | 0.9940 | 0.9942 | 0.9943 | 0 | 1 | 1 | 1 | 2 |
| 84 | 0.9945 | 0.9947 | 0.9949 | 0.9951 | 0.9952 | 0.9954 | 0.9956 | 0.9957 | 0.9959 | 0.9960 | 0 | 1 | 1 | 1 | 1 |
| 85 | 0.9962 | 0.9963 | 0.9965 | 0.9966 | 0.9968 | 0.9969 | 0.9971 | 0.9972 | 0.9973 | 0.9974 | 0 | 0 | 1 | 1 | 1 |
| 86 | 0.9976 | 0.9977 | 0.9978 | 0.9979 | 0.9980 | 0.9981 | 0.9982 | 0.9983 | 0.9984 | 0.9985 | 0 | 0 | 1 | 1 | 1 |
| 87 | 0.9986 | 0.9987 | 0.9988 | 0.9989 | 0.9990 | 0.9990 | 0.9991 | 0.9992 | 0.9993 | 0.9993 | 0 | 0 | 0 | 1 | 1 |
| 88 | 0.9994 | 0.9995 | 0.9995 | 0.9996 | 0.9996 | 0.9997 | 0.9997 | 0.9997 | 0.9998 | 0.9998 | 0 | 0 | 0 | 0 | 0 |
| 89 | 0.9998 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0 | 0 | 0 | 0 | 0 |
| 90 | 1.0000 | | | | | | | | | | | | | | |



| Quadrant | Angle | sin A = | Examples |
|----------|--------------|----------------|---|
| First | 0 to 90° | sin A | sin 34°38' = 0.5683 |
| Second | 90° to 180° | sin(180° - A) | sin 145°22' = sin(180° - 145° 22') = sin 34°38' = 0.5683 |
| Third | 180° to 270° | -sin(A - 180°) | sin 214°38' = -sin(214°38' - 180°) = -sin 34°38' = -0.5683 |
| Fourth | 270° to 360° | -sin(360° - A) | sin 325°22' = -sin(360° - 325°22') = -sin 34°38' = -0.5683 |

Natural Cosines

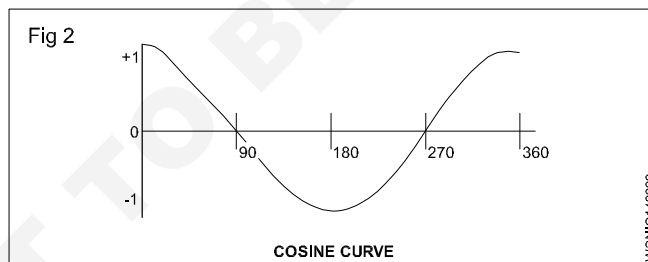
Numbers in different columns to be subtracted, not added

| ° | 0' 0.0° | 6' 0.1° | 12' 0.2° | 18' 0.3° | 24' 0.4° | 30' 0.5° | 36' 0.6° | 42' 0.7° | 48' 0.8° | 54' 0.9° | 1' | 2' | 3' | 4' | 5' |
|----|------------|------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|----|----|----|----|----|
| 0 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 1.0000 | 0.9999 | 0.9999 | 0.9999 | 0.9999 | 0 | 0 | 0 | 0 | 0 |
| 1 | 0.9998 | 0.9998 | 0.9998 | 0.9997 | 0.9997 | 0.9997 | 0.9996 | 0.9996 | 0.9995 | 0.9995 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0.9994 | 0.9993 | 0.9993 | 0.9992 | 0.9991 | 0.9990 | 0.9990 | 0.9989 | 0.9988 | 0.9987 | 0 | 0 | 0 | 1 | 1 |
| 3 | 0.9986 | 0.9985 | 0.9984 | 0.9983 | 0.9982 | 0.9981 | 0.9980 | 0.9979 | 0.9978 | 0.9977 | 0 | 0 | 1 | 1 | 1 |
| 4 | 0.9976 | 0.9974 | 0.9973 | 0.9972 | 0.9971 | 0.9969 | 0.9968 | 0.9966 | 0.9965 | 0.9963 | 0 | 0 | 1 | 1 | 1 |
| 5 | 0.9962 | 0.9960 | 0.9959 | 0.9957 | 0.9956 | 0.9954 | 0.9952 | 0.9951 | 0.9949 | 0.9947 | 0 | 1 | 1 | 1 | 1 |
| 6 | 0.9945 | 0.9943 | 0.9942 | 0.9940 | 0.9938 | 0.9936 | 0.9934 | 0.9932 | 0.9930 | 0.9928 | 0 | 1 | 1 | 1 | 2 |
| 7 | 0.9925 | 0.9923 | 0.9921 | 0.9919 | 0.9917 | 0.9914 | 0.9912 | 0.9910 | 0.9907 | 0.9905 | 0 | 1 | 1 | 1 | 2 |
| 8 | 0.9903 | 0.9900 | 0.9898 | 0.9895 | 0.9893 | 0.9890 | 0.9888 | 0.9885 | 0.9882 | 0.9880 | 0 | 1 | 1 | 2 | 2 |
| 9 | 0.9877 | 0.9874 | 0.9871 | 0.9869 | 0.9866 | 0.9863 | 0.9860 | 0.9857 | 0.9854 | 0.9851 | 0 | 1 | 1 | 2 | 2 |
| 10 | 0.9848 | 0.9845 | 0.9842 | 0.9839 | 0.9836 | 0.9833 | 0.9829 | 0.9826 | 0.9823 | 0.9820 | 1 | 1 | 2 | 2 | 3 |
| 11 | 0.9816 | 0.9813 | 0.9810 | 0.9806 | 0.9803 | 0.9799 | 0.9796 | 0.9792 | 0.9789 | 0.9785 | 1 | 1 | 2 | 2 | 3 |
| 12 | 0.9781 | 0.9778 | 0.9774 | 0.9770 | 0.9767 | 0.9763 | 0.9759 | 0.9755 | 0.9751 | 0.9748 | 1 | 1 | 2 | 2 | 3 |
| 13 | 0.9744 | 0.9740 | 0.9736 | 0.9732 | 0.9728 | 0.9724 | 0.9720 | 0.9715 | 0.9711 | 0.9707 | 1 | 1 | 2 | 3 | 3 |
| 14 | 0.9703 | 0.9699 | 0.9694 | 0.9690 | 0.9686 | 0.9681 | 0.9677 | 0.9673 | 0.9668 | 0.9664 | 1 | 1 | 2 | 3 | 4 |
| 15 | 0.9659 | 0.9655 | 0.9650 | 0.9646 | 0.9641 | 0.9636 | 0.9632 | 0.9627 | 0.9622 | 0.9617 | 1 | 2 | 2 | 3 | 4 |
| 16 | 0.9613 | 0.9608 | 0.9603 | 0.9598 | 0.9593 | 0.9588 | 0.9583 | 0.9578 | 0.9573 | 0.9568 | 1 | 2 | 2 | 3 | 4 |
| 17 | 0.9563 | 0.9558 | 0.9553 | 0.9548 | 0.9542 | 0.9537 | 0.9532 | 0.9527 | 0.9521 | 0.9516 | 1 | 2 | 3 | 3 | 4 |
| 18 | 0.9511 | 0.9505 | 0.9500 | 0.9494 | 0.9489 | 0.9483 | 0.9478 | 0.9472 | 0.9466 | 0.9461 | 1 | 2 | 3 | 4 | 5 |
| 19 | 0.9455 | 0.9449 | 0.9444 | 0.9438 | 0.9432 | 0.9426 | 0.9421 | 0.9415 | 0.9409 | 0.9403 | 1 | 2 | 3 | 4 | 5 |
| 20 | 0.9397 | 0.9391 | 0.9385 | 0.9379 | 0.9373 | 0.9367 | 0.9361 | 0.9354 | 0.9348 | 0.9342 | 1 | 2 | 3 | 4 | 5 |
| 21 | 0.9336 | 0.9330 | 0.9323 | 0.9317 | 0.9311 | 0.9304 | 0.9298 | 0.9291 | 0.9285 | 0.9278 | 1 | 2 | 3 | 4 | 5 |
| 22 | 0.9272 | 0.9265 | 0.9259 | 0.9252 | 0.9245 | 0.9239 | 0.9232 | 0.9225 | 0.9219 | 0.9212 | 1 | 2 | 3 | 4 | 6 |
| 23 | 0.9205 | 0.9198 | 0.9191 | 0.9184 | 0.9178 | 0.9171 | 0.9164 | 0.9157 | 0.9150 | 0.9143 | 1 | 2 | 3 | 5 | 6 |
| 24 | 0.9135 | 0.9128 | 0.9121 | 0.9114 | 0.9107 | 0.9100 | 0.9092 | 0.9085 | 0.9078 | 0.9070 | 1 | 2 | 4 | 5 | 6 |
| 25 | 0.9063 | 0.9056 | 0.9048 | 0.9041 | 0.9033 | 0.9026 | 0.9018 | 0.9011 | 0.9003 | 0.8996 | 1 | 3 | 4 | 5 | 6 |
| 26 | 0.8988 | 0.8980 | 0.8973 | 0.8965 | 0.8957 | 0.8949 | 0.8942 | 0.8934 | 0.8926 | 0.8918 | 1 | 3 | 4 | 5 | 6 |
| 27 | 0.8910 | 0.8902 | 0.8894 | 0.8886 | 0.8878 | 0.8870 | 0.8862 | 0.8854 | 0.8846 | 0.8838 | 1 | 3 | 4 | 5 | 7 |
| 28 | 0.8829 | 0.8821 | 0.8813 | 0.8805 | 0.8796 | 0.8788 | 0.8780 | 0.8771 | 0.8763 | 0.8755 | 1 | 3 | 4 | 6 | 7 |
| 29 | 0.8746 | 0.8738 | 0.8729 | 0.8721 | 0.8712 | 0.8704 | 0.8695 | 0.8686 | 0.8678 | 0.8669 | 1 | 3 | 4 | 6 | 7 |
| 30 | 0.8660 | 0.8652 | 0.8643 | 0.8634 | 0.8625 | 0.8616 | 0.8607 | 0.8599 | 0.8590 | 0.8581 | 1 | 3 | 4 | 6 | 7 |
| 31 | 0.8572 | 0.8563 | 0.8554 | 0.8545 | 0.8536 | 0.8526 | 0.8517 | 0.8508 | 0.8499 | 0.8490 | 2 | 3 | 5 | 6 | 8 |
| 32 | 0.8480 | 0.8471 | 0.8462 | 0.8453 | 0.8443 | 0.8434 | 0.8425 | 0.8415 | 0.8406 | 0.8396 | 2 | 3 | 5 | 6 | 8 |
| 33 | 0.8387 | 0.8377 | 0.8368 | 0.8358 | 0.8348 | 0.8339 | 0.8329 | 0.8320 | 0.8310 | 0.8300 | 2 | 3 | 5 | 6 | 8 |
| 34 | 0.8290 | 0.8281 | 0.8271 | 0.8261 | 0.8251 | 0.8241 | 0.8231 | 0.8221 | 0.8211 | 0.8202 | 2 | 3 | 5 | 7 | 8 |
| 35 | 0.8192 | 0.8181 | 0.8171 | 0.8161 | 0.8151 | 0.8141 | 0.8131 | 0.8121 | 0.8111 | 0.8100 | 2 | 3 | 5 | 7 | 8 |
| 36 | 0.8090 | 0.8080 | 0.8070 | 0.8059 | 0.8049 | 0.8039 | 0.8028 | 0.8018 | 0.8007 | 0.7997 | 2 | 3 | 5 | 7 | 9 |
| 37 | 0.7986 | 0.7976 | 0.7965 | 0.7955 | 0.7944 | 0.7934 | 0.7923 | 0.7912 | 0.7902 | 0.7891 | 2 | 4 | 5 | 7 | 9 |
| 38 | 0.7880 | 0.7869 | 0.7859 | 0.7848 | 0.7837 | 0.7826 | 0.7815 | 0.7804 | 0.7793 | 0.7782 | 2 | 4 | 5 | 7 | 9 |
| 39 | 0.7771 | 0.7760 | 0.7749 | 0.7738 | 0.7727 | 0.7716 | 0.7705 | 0.7694 | 0.7683 | 0.7672 | 2 | 4 | 6 | 7 | 9 |
| 40 | 0.7660 | 0.7649 | 0.7638 | 0.7627 | 0.7615 | 0.7604 | 0.7593 | 0.7581 | 0.7570 | 0.7559 | 2 | 4 | 6 | 8 | 9 |
| 41 | 0.7547 | 0.7536 | 0.7524 | 0.7513 | 0.7501 | 0.7490 | 0.7478 | 0.7466 | 0.7455 | 0.7443 | 2 | 4 | 6 | 8 | 10 |
| 42 | 0.7431 | 0.7420 | 0.7408 | 0.7396 | 0.7385 | 0.7373 | 0.7361 | 0.7349 | 0.7337 | 0.7325 | 2 | 4 | 6 | 8 | 10 |
| 43 | 0.7314 | 0.7302 | 0.7290 | 0.7278 | 0.7266 | 0.7254 | 0.7242 | 0.7230 | 0.7218 | 0.7206 | 2 | 4 | 6 | 8 | 10 |
| 44 | 0.7193 | 0.7181 | 0.7169 | 0.7157 | 0.7145 | 0.7133 | 0.7120 | 0.7108 | 0.7096 | 0.7083 | 2 | 4 | 6 | 8 | 10 |
| 45 | 0.7071 | 0.7059 | 0.7046 | 0.7034 | 0.7022 | 0.7009 | 0.6997 | 0.6984 | 0.6972 | 0.6959 | 2 | 4 | 6 | 8 | 10 |
| 46 | 0.6947 | 0.6934 | 0.6921 | 0.6909 | 0.6896 | 0.6884 | 0.6871 | 0.6858 | 0.6845 | 0.6833 | 2 | 4 | 6 | 8 | 11 |
| 47 | 0.6820 | 0.6807 | 0.6794 | 0.6782 | 0.6769 | 0.6756 | 0.6743 | 0.6730 | 0.6717 | 0.6704 | 2 | 4 | 6 | 9 | 11 |
| 48 | 0.6691 | 0.6678 | 0.6665 | 0.6652 | 0.6639 | 0.6626 | 0.6613 | 0.6600 | 0.6587 | 0.6574 | 2 | 4 | 7 | 9 | 11 |
| 49 | 0.6561 | 0.6547 | 0.6534 | 0.6521 | 0.6508 | 0.6494 | 0.6481 | 0.6468 | 0.6455 | 0.6441 | 2 | 4 | 7 | 9 | 11 |
| 50 | 0.6428 | 0.6414 | 0.6401 | 0.6388 | 0.6374 | 0.6361 | 0.6347 | 0.6334 | 0.6320 | 0.6307 | 2 | 4 | 7 | 9 | 11 |
| 51 | 0.6293 | 0.6280 | 0.6266 | 0.6252 | 0.6239 | 0.6225 | 0.6211 | 0.6198 | 0.6184 | 0.6170 | 2 | 5 | 7 | 9 | 11 |
| 52 | 0.6157 | 0.6143 | 0.6129 | 0.6115 | 0.6101 | 0.6088 | 0.6074 | 0.6060 | 0.6046 | 0.6032 | 2 | 5 | 7 | 9 | 12 |
| 53 | 0.6018 | 0.6004 | 0.5990 | 0.5976 | 0.5962 | 0.5948 | 0.5934 | 0.5920 | 0.5906 | 0.5892 | 2 | 5 | 7 | 9 | 12 |
| 54 | 0.5878 | 0.5864 | 0.5850 | 0.5835 | 0.5821 | 0.5807 | 0.5793 | 0.5779 | 0.5764 | 0.5750 | 2 | 5 | 7 | 9 | 12 |
| 55 | 0.5736 | 0.5721 | 0.5707 | 0.5693 | 0.5678 | 0.5664 | 0.5650 | 0.5635 | 0.5621 | 0.5606 | 2 | 5 | 7 | 10 | 12 |
| 56 | 0.5592 | 0.5577 | 0.5563 | 0.5548 | 0.5534 | 0.5519 | 0.5505 | 0.5490 | 0.5476 | 0.5461 | 2 | 5 | 7 | 10 | 12 |
| 57 | 0.5446 | 0.5432 | 0.5417 | 0.5402 | 0.5388 | 0.5373 | 0.5358 | 0.5344 | 0.5329 | 0.5314 | 2 | 5 | 7 | 10 | 12 |
| 58 | 0.5299 | 0.5284 | 0.5270 | 0.5255 | 0.5240 | 0.5225 | 0.5210 | 0.5195 | 0.5180 | 0.5165 | 2 | 5 | 7 | 10 | 12 |
| 59 | 0.5150 | 0.5135 | 0.5120 | 0.5105 | 0.5090 | 0.5075 | 0.5060 | 0.5045 | 0.5030 | 0.5015 | 3 | 5 | 8 | 10 | 13 |

Natural Cosines

Numbers in different columns to be subtracted, not added

| ° | 0' | 6' | 12' | 18' | 24' | 30' | 36' | 42' | 48' | 54' | 1' | 2' | 3' | 4' | 5' |
|----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|----|----|----|----|----|
| | 0.0° | 0.1° | 0.2° | 0.3° | 0.4° | 0.5° | 0.6° | 0.7° | 0.8° | 0.9° | | | | | |
| 60 | 0.5000 | 0.4985 | 0.4970 | 0.4955 | 0.4939 | 0.4924 | 0.4909 | 0.4894 | 0.4879 | 0.4863 | 3 | 5 | 8 | 10 | 13 |
| 61 | 0.4848 | 0.4833 | 0.4818 | 0.4802 | 0.4787 | 0.4772 | 0.4756 | 0.4741 | 0.4726 | 0.4710 | 3 | 5 | 8 | 10 | 13 |
| 62 | 0.4695 | 0.4679 | 0.4664 | 0.4648 | 0.4633 | 0.4617 | 0.4602 | 0.4586 | 0.4571 | 0.4555 | 3 | 5 | 8 | 10 | 13 |
| 63 | 0.4540 | 0.4524 | 0.4509 | 0.4493 | 0.4478 | 0.4462 | 0.4446 | 0.4431 | 0.4415 | 0.4399 | 3 | 5 | 8 | 10 | 13 |
| 64 | 0.4384 | 0.4368 | 0.4352 | 0.4337 | 0.4321 | 0.4305 | 0.4289 | 0.4274 | 0.4258 | 0.4242 | 3 | 5 | 8 | 11 | 13 |
| 65 | 0.4226 | 0.4210 | 0.4195 | 0.4179 | 0.4163 | 0.4147 | 0.4131 | 0.4115 | 0.4099 | 0.4083 | 3 | 5 | 8 | 11 | 13 |
| 66 | 0.4067 | 0.4051 | 0.4035 | 0.4019 | 0.4003 | 0.3987 | 0.3971 | 0.3955 | 0.3939 | 0.3923 | 3 | 5 | 8 | 11 | 13 |
| 67 | 0.3907 | 0.3891 | 0.3875 | 0.3859 | 0.3843 | 0.3827 | 0.3811 | 0.3795 | 0.3778 | 0.3762 | 3 | 5 | 8 | 11 | 13 |
| 68 | 0.3746 | 0.3730 | 0.3714 | 0.3697 | 0.3681 | 0.3665 | 0.3649 | 0.3633 | 0.3616 | 0.3600 | 3 | 5 | 8 | 11 | 14 |
| 69 | 0.3584 | 0.3567 | 0.3551 | 0.3535 | 0.3518 | 0.3502 | 0.3486 | 0.3469 | 0.3453 | 0.3437 | 3 | 5 | 8 | 11 | 14 |
| 70 | 0.3420 | 0.3404 | 0.3387 | 0.3371 | 0.3355 | 0.3338 | 0.3322 | 0.3305 | 0.3289 | 0.3272 | 3 | 5 | 8 | 11 | 14 |
| 71 | 0.3256 | 0.3239 | 0.3223 | 0.3206 | 0.3190 | 0.3173 | 0.3156 | 0.3140 | 0.3123 | 0.3107 | 3 | 6 | 8 | 11 | 14 |
| 72 | 0.3090 | 0.3074 | 0.3057 | 0.3040 | 0.3024 | 0.3007 | 0.2990 | 0.2974 | 0.2957 | 0.2940 | 3 | 6 | 8 | 11 | 14 |
| 73 | 0.2924 | 0.2907 | 0.2890 | 0.2874 | 0.2857 | 0.2840 | 0.2823 | 0.2807 | 0.2790 | 0.2773 | 3 | 6 | 8 | 11 | 14 |
| 74 | 0.2756 | 0.2740 | 0.2723 | 0.2706 | 0.2689 | 0.2672 | 0.2656 | 0.2639 | 0.2622 | 0.2605 | 3 | 6 | 8 | 11 | 14 |
| 75 | 0.2588 | 0.2571 | 0.2554 | 0.2538 | 0.2521 | 0.2504 | 0.2487 | 0.2470 | 0.2453 | 0.2436 | 3 | 6 | 8 | 11 | 14 |
| 76 | 0.2419 | 0.2402 | 0.2385 | 0.2368 | 0.2351 | 0.2334 | 0.2317 | 0.2300 | 0.2284 | 0.2267 | 3 | 6 | 8 | 11 | 14 |
| 77 | 0.2250 | 0.2233 | 0.2215 | 0.2198 | 0.2181 | 0.2164 | 0.2147 | 0.2130 | 0.2113 | 0.2096 | 3 | 6 | 9 | 11 | 14 |
| 78 | 0.2079 | 0.2062 | 0.2045 | 0.2028 | 0.2011 | 0.1994 | 0.1977 | 0.1959 | 0.1942 | 0.1925 | 3 | 6 | 9 | 11 | 14 |
| 79 | 0.1908 | 0.1891 | 0.1874 | 0.1857 | 0.1840 | 0.1822 | 0.1805 | 0.1788 | 0.1771 | 0.1754 | 3 | 6 | 9 | 11 | 14 |
| 80 | 0.1736 | 0.1719 | 0.1702 | 0.1685 | 0.1668 | 0.1650 | 0.1633 | 0.1616 | 0.1599 | 0.1582 | 3 | 6 | 9 | 11 | 14 |
| 81 | 0.1564 | 0.1547 | 0.1530 | 0.1513 | 0.1495 | 0.1478 | 0.1461 | 0.1444 | 0.1426 | 0.1409 | 3 | 6 | 9 | 11 | 14 |
| 82 | 0.1392 | 0.1374 | 0.1357 | 0.1340 | 0.1323 | 0.1305 | 0.1288 | 0.1271 | 0.1253 | 0.1236 | 3 | 6 | 9 | 12 | 14 |
| 83 | 0.1219 | 0.1201 | 0.1184 | 0.1167 | 0.1149 | 0.1132 | 0.1115 | 0.1097 | 0.1080 | 0.1063 | 3 | 6 | 9 | 12 | 14 |
| 84 | 0.1045 | 0.1028 | 0.1011 | 0.0993 | 0.0976 | 0.0958 | 0.0941 | 0.0924 | 0.0906 | 0.0889 | 3 | 6 | 9 | 12 | 14 |
| 85 | 0.0872 | 0.0854 | 0.0837 | 0.0819 | 0.0802 | 0.0785 | 0.0767 | 0.0750 | 0.0732 | 0.0715 | 3 | 6 | 9 | 12 | 14 |
| 86 | 0.0698 | 0.0680 | 0.0663 | 0.0645 | 0.0628 | 0.0610 | 0.0593 | 0.0576 | 0.0558 | 0.0541 | 3 | 6 | 9 | 12 | 15 |
| 87 | 0.0523 | 0.0506 | 0.0488 | 0.0471 | 0.0454 | 0.0436 | 0.0419 | 0.0401 | 0.0384 | 0.0366 | 3 | 6 | 9 | 12 | 15 |
| 88 | 0.0349 | 0.0332 | 0.0314 | 0.0297 | 0.0279 | 0.0262 | 0.0244 | 0.0227 | 0.0209 | 0.0192 | 3 | 6 | 9 | 12 | 15 |
| 89 | 0.0175 | 0.0157 | 0.0140 | 0.0122 | 0.0105 | 0.0087 | 0.0070 | 0.0052 | 0.0035 | 0.0017 | 3 | 6 | 9 | 12 | 15 |
| 90 | 0.0000 | | | | | | | | | | | | | | |



| Quadrant | Angle | cos A = | Examples |
|----------|--------------|----------------|---|
| First | 0 to 90° | cos A | cos 33°26' = 0.8345 |
| Second | 90° to 180° | -cos(180° - A) | sin 146°34' = -cos(180° - 146°34') = -cos 33°26' = -0.8345 |
| Third | 180° to 270° | cos(A - 180°) | cos 213°26' = -cos(213°26' - 180°) = -cos 33°26' = -0.8345 |
| Fourth | 270° to 360° | cos(360° - A) | cos 326°34' = cos(360° - 326°34') = cos 33°26' = 0.8345 |

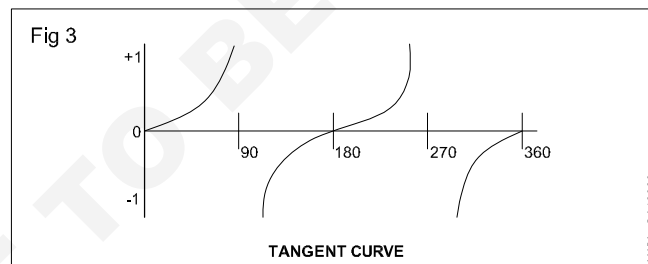
Natural Tangents

| ° | 0' | 6' | 12' | 18' | 24' | 30' | 36' | 42' | 48' | 54' | 1' | 2' | 3' | 4' | 5' |
|----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|----|----|----|----|----|
| | 0.0° | 0.1° | 0.2° | 0.3° | 0.4° | 0.5° | 0.6° | 0.7° | 0.8° | 0.9° | | | | | |
| 0 | 0.0000 | 0.0017 | 0.0035 | 0.0052 | 0.0070 | 0.0087 | 0.0105 | 0.0122 | 0.0140 | 0.0157 | 3 | 6 | 9 | 12 | 15 |
| 1 | 0.0175 | 0.0192 | 0.0209 | 0.0227 | 0.0244 | 0.0262 | 0.0279 | 0.0297 | 0.0314 | 0.0332 | 3 | 6 | 9 | 12 | 15 |
| 2 | 0.0349 | 0.0367 | 0.0384 | 0.0402 | 0.0419 | 0.0437 | 0.0454 | 0.0472 | 0.0489 | 0.0507 | 3 | 6 | 9 | 12 | 15 |
| 3 | 0.0524 | 0.0542 | 0.0559 | 0.0577 | 0.0594 | 0.0612 | 0.0629 | 0.0647 | 0.0664 | 0.0682 | 3 | 6 | 9 | 12 | 15 |
| 4 | 0.0699 | 0.0717 | 0.0734 | 0.0752 | 0.0769 | 0.0787 | 0.0805 | 0.0822 | 0.0840 | 0.0857 | 3 | 6 | 9 | 12 | 15 |
| 5 | 0.0875 | 0.0892 | 0.0910 | 0.0928 | 0.0945 | 0.0963 | 0.0981 | 0.0998 | 0.1016 | 0.1033 | 3 | 6 | 9 | 12 | 15 |
| 6 | 0.1051 | 0.1069 | 0.1086 | 0.1104 | 0.1122 | 0.1139 | 0.1157 | 0.1175 | 0.1192 | 0.1210 | 3 | 6 | 9 | 12 | 15 |
| 7 | 0.1228 | 0.1246 | 0.1263 | 0.1281 | 0.1299 | 0.1317 | 0.1334 | 0.1352 | 0.1370 | 0.1388 | 3 | 6 | 9 | 12 | 15 |
| 8 | 0.1405 | 0.1423 | 0.1441 | 0.1459 | 0.1477 | 0.1495 | 0.1512 | 0.1530 | 0.1548 | 0.1566 | 3 | 6 | 9 | 12 | 15 |
| 9 | 0.1584 | 0.1602 | 0.1620 | 0.1638 | 0.1655 | 0.1673 | 0.1691 | 0.1709 | 0.1727 | 0.1745 | 3 | 6 | 9 | 12 | 15 |
| 10 | 0.1763 | 0.1781 | 0.1799 | 0.1817 | 0.1835 | 0.1853 | 0.1871 | 0.1890 | 0.1908 | 0.1926 | 3 | 6 | 9 | 12 | 15 |
| 11 | 0.1944 | 0.1962 | 0.1980 | 0.1998 | 0.2016 | 0.2035 | 0.2053 | 0.2071 | 0.2089 | 0.2107 | 3 | 6 | 9 | 12 | 15 |
| 12 | 0.2126 | 0.2144 | 0.2162 | 0.2180 | 0.2199 | 0.2217 | 0.2235 | 0.2254 | 0.2272 | 0.2290 | 3 | 6 | 9 | 12 | 15 |
| 13 | 0.2309 | 0.2327 | 0.2345 | 0.2364 | 0.2382 | 0.2401 | 0.2419 | 0.2438 | 0.2456 | 0.2475 | 3 | 6 | 9 | 12 | 15 |
| 14 | 0.2493 | 0.2512 | 0.2530 | 0.2549 | 0.2568 | 0.2586 | 0.2605 | 0.2623 | 0.2642 | 0.2661 | 3 | 6 | 9 | 12 | 16 |
| 15 | 0.2679 | 0.2698 | 0.2717 | 0.2736 | 0.2754 | 0.2773 | 0.2792 | 0.2811 | 0.2830 | 0.2849 | 3 | 6 | 9 | 13 | 16 |
| 16 | 0.2867 | 0.2886 | 0.2905 | 0.2924 | 0.2943 | 0.2962 | 0.2981 | 0.3000 | 0.3019 | 0.3038 | 3 | 6 | 9 | 13 | 16 |
| 17 | 0.3057 | 0.3076 | 0.3096 | 0.3115 | 0.3134 | 0.3153 | 0.3172 | 0.3191 | 0.3211 | 0.3230 | 3 | 6 | 10 | 13 | 16 |
| 18 | 0.3249 | 0.3269 | 0.3288 | 0.3307 | 0.3327 | 0.3346 | 0.3365 | 0.3385 | 0.3404 | 0.3424 | 3 | 6 | 10 | 13 | 16 |
| 19 | 0.3443 | 0.3463 | 0.3482 | 0.3502 | 0.3522 | 0.3541 | 0.3561 | 0.3581 | 0.3600 | 0.3620 | 3 | 7 | 10 | 13 | 16 |
| 20 | 0.3640 | 0.3659 | 0.3679 | 0.3699 | 0.3719 | 0.3739 | 0.3759 | 0.3779 | 0.3799 | 0.3819 | 3 | 7 | 10 | 13 | 17 |
| 21 | 0.3839 | 0.3859 | 0.3879 | 0.3899 | 0.3919 | 0.3939 | 0.3959 | 0.3979 | 0.4000 | 0.4020 | 3 | 7 | 10 | 13 | 17 |
| 22 | 0.4040 | 0.4061 | 0.4081 | 0.4101 | 0.4122 | 0.4142 | 0.4163 | 0.4183 | 0.4204 | 0.4224 | 3 | 7 | 10 | 14 | 17 |
| 23 | 0.4245 | 0.4265 | 0.4286 | 0.4307 | 0.4327 | 0.4348 | 0.4369 | 0.4390 | 0.4411 | 0.4431 | 3 | 7 | 10 | 14 | 17 |
| 24 | 0.4452 | 0.4473 | 0.4494 | 0.4515 | 0.4536 | 0.4557 | 0.4578 | 0.4599 | 0.4621 | 0.4642 | 4 | 7 | 11 | 14 | 18 |
| 25 | 0.4663 | 0.4684 | 0.4706 | 0.4727 | 0.4748 | 0.4770 | 0.4791 | 0.4813 | 0.4834 | 0.4856 | 4 | 7 | 11 | 14 | 18 |
| 26 | 0.4877 | 0.4899 | 0.4921 | 0.4942 | 0.4964 | 0.4986 | 0.5008 | 0.5029 | 0.5051 | 0.5073 | 4 | 7 | 11 | 15 | 18 |
| 27 | 0.5095 | 0.5117 | 0.5139 | 0.5161 | 0.5184 | 0.5206 | 0.5228 | 0.5250 | 0.5272 | 0.5295 | 4 | 7 | 11 | 15 | 18 |
| 28 | 0.5317 | 0.5340 | 0.5362 | 0.5384 | 0.5407 | 0.5430 | 0.5452 | 0.5475 | 0.5498 | 0.5520 | 4 | 8 | 11 | 15 | 19 |
| 29 | 0.5543 | 0.5566 | 0.5589 | 0.5612 | 0.5635 | 0.5658 | 0.5681 | 0.5704 | 0.5727 | 0.5750 | 4 | 8 | 12 | 15 | 19 |
| 30 | 0.5774 | 0.5797 | 0.5820 | 0.5844 | 0.5867 | 0.5890 | 0.5914 | 0.5938 | 0.5961 | 0.5985 | 4 | 8 | 12 | 16 | 20 |
| 31 | 0.6009 | 0.6032 | 0.6056 | 0.6080 | 0.6104 | 0.6128 | 0.6152 | 0.6176 | 0.6200 | 0.6224 | 4 | 8 | 12 | 16 | 20 |
| 32 | 0.6249 | 0.6273 | 0.6297 | 0.6322 | 0.6346 | 0.6371 | 0.6395 | 0.6420 | 0.6445 | 0.6469 | 4 | 8 | 12 | 16 | 20 |
| 33 | 0.6494 | 0.6519 | 0.6544 | 0.6569 | 0.6594 | 0.6619 | 0.6644 | 0.6669 | 0.6694 | 0.6720 | 4 | 8 | 13 | 17 | 21 |
| 34 | 0.6745 | 0.6771 | 0.6796 | 0.6822 | 0.6847 | 0.6873 | 0.6899 | 0.6924 | 0.6950 | 0.6976 | 4 | 9 | 13 | 17 | 21 |
| 35 | 0.7002 | 0.7028 | 0.7054 | 0.7080 | 0.7107 | 0.7133 | 0.7159 | 0.7186 | 0.7212 | 0.7239 | 4 | 9 | 13 | 17 | 22 |
| 36 | 0.7265 | 0.7292 | 0.7319 | 0.7346 | 0.7373 | 0.7400 | 0.7427 | 0.7454 | 0.7481 | 0.7508 | 5 | 9 | 14 | 18 | 23 |
| 37 | 0.7536 | 0.7563 | 0.7590 | 0.7618 | 0.7646 | 0.7673 | 0.7701 | 0.7729 | 0.7757 | 0.7785 | 5 | 9 | 14 | 18 | 23 |
| 38 | 0.7813 | 0.7841 | 0.7869 | 0.7898 | 0.7926 | 0.7954 | 0.7983 | 0.8012 | 0.8040 | 0.8069 | 5 | 9 | 14 | 19 | 24 |
| 39 | 0.8098 | 0.8127 | 0.8156 | 0.8185 | 0.8214 | 0.8243 | 0.8273 | 0.8302 | 0.8332 | 0.8361 | 5 | 10 | 15 | 20 | 24 |
| 40 | 0.8391 | 0.8421 | 0.8451 | 0.8481 | 0.8511 | 0.8541 | 0.8571 | 0.8601 | 0.8632 | 0.8662 | 5 | 10 | 15 | 20 | 25 |
| 41 | 0.8693 | 0.8724 | 0.8754 | 0.8785 | 0.8816 | 0.8847 | 0.8878 | 0.8910 | 0.8941 | 0.8972 | 5 | 10 | 16 | 21 | 26 |
| 42 | 0.9004 | 0.9036 | 0.9067 | 0.9099 | 0.9131 | 0.9163 | 0.9195 | 0.9228 | 0.9260 | 0.9293 | 5 | 11 | 16 | 21 | 27 |
| 43 | 0.9325 | 0.9358 | 0.9391 | 0.9424 | 0.9457 | 0.9490 | 0.9523 | 0.9556 | 0.9590 | 0.9623 | 6 | 11 | 17 | 22 | 28 |
| 44 | 0.9657 | 0.9691 | 0.9725 | 0.9759 | 0.9793 | 0.9827 | 0.9861 | 0.9896 | 0.9930 | 0.9965 | 6 | 11 | 17 | 23 | 28 |
| 45 | 1.0000 | 1.0035 | 1.0070 | 1.0105 | 1.0141 | 1.0176 | 1.0212 | 1.0247 | 1.0283 | 1.0319 | 6 | 12 | 18 | 24 | 30 |
| 46 | 1.0355 | 1.0392 | 1.0428 | 1.0464 | 1.0501 | 1.0538 | 1.0575 | 1.0612 | 1.0649 | 1.0686 | 6 | 12 | 18 | 25 | 31 |
| 47 | 1.0724 | 1.0761 | 1.0799 | 1.0837 | 1.0875 | 1.0913 | 1.0951 | 1.0990 | 1.1028 | 1.1067 | 6 | 13 | 19 | 25 | 32 |
| 48 | 1.1106 | 1.1145 | 1.1184 | 1.1224 | 1.1263 | 1.1303 | 1.1343 | 1.1383 | 1.1423 | 1.1463 | 7 | 13 | 20 | 27 | 33 |
| 49 | 1.1504 | 1.1544 | 1.1585 | 1.1626 | 1.1667 | 1.1708 | 1.1750 | 1.1792 | 1.1833 | 1.1875 | 7 | 14 | 21 | 28 | 34 |
| 50 | 1.1918 | 1.1960 | 1.2002 | 1.2045 | 1.2088 | 1.2131 | 1.2174 | 1.2218 | 1.2261 | 1.2305 | 7 | 14 | 22 | 29 | 36 |
| 51 | 1.2349 | 1.2393 | 1.2437 | 1.2482 | 1.2527 | 1.2572 | 1.2617 | 1.2662 | 1.2708 | 1.2753 | 8 | 15 | 23 | 30 | 38 |
| 52 | 1.2799 | 1.2846 | 1.2892 | 1.2938 | 1.2985 | 1.3032 | 1.3079 | 1.3127 | 1.3175 | 1.3222 | 8 | 16 | 24 | 31 | 39 |
| 53 | 1.3270 | 1.3319 | 1.3367 | 1.3416 | 1.3465 | 1.3514 | 1.3564 | 1.3613 | 1.3663 | 1.3713 | 8 | 16 | 25 | 33 | 41 |
| 54 | 1.3764 | 1.3814 | 1.3865 | 1.3916 | 1.3968 | 1.4019 | 1.4071 | 1.4124 | 1.4176 | 1.4229 | 9 | 17 | 26 | 34 | 43 |
| 55 | 1.4281 | 1.4335 | 1.4388 | 1.4442 | 1.4496 | 1.4550 | 1.4605 | 1.4659 | 1.4715 | 1.4770 | 9 | 18 | 27 | 36 | 45 |
| 56 | 1.4826 | 1.4882 | 1.4938 | 1.4994 | 1.5051 | 1.5108 | 1.5166 | 1.5224 | 1.5282 | 1.5340 | 10 | 19 | 29 | 38 | 48 |
| 57 | 1.5399 | 1.5458 | 1.5517 | 1.5577 | 1.5637 | 1.5697 | 1.5757 | 1.5818 | 1.5880 | 1.5941 | 10 | 20 | 30 | 40 | 50 |
| 58 | 1.6003 | 1.6066 | 1.6128 | 1.6191 | 1.6255 | 1.6319 | 1.6383 | 1.6447 | 1.6512 | 1.6577 | 11 | 21 | 32 | 43 | 53 |
| 59 | 1.6643 | 1.6709 | 1.6775 | 1.6842 | 1.6909 | 1.6977 | 1.7045 | 1.7113 | 1.7182 | 1.7251 | 11 | 23 | 34 | 45 | 56 |

Natural Tangents

| ° | 0' | 6' | 12' | 18' | 24' | 30' | 36' | 42' | 48' | 54' | 1' | 2' | 3' | 4' | 5' |
|----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|----|-----|-----|-----|-----|
| | 0.0° | 0.1° | 0.2° | 0.3° | 0.4° | 0.5° | 0.6° | 0.7° | 0.8° | 0.9° | | | | | |
| 60 | 1.7321 | 1.7391 | 1.7461 | 1.7532 | 1.7603 | 1.7675 | 1.7747 | 1.7820 | 1.7893 | 1.7966 | 12 | 24 | 36 | 48 | 60 |
| 61 | 1.8040 | 1.8115 | 1.8190 | 1.8265 | 1.8341 | 1.8418 | 1.8495 | 1.8572 | 1.8650 | 1.8728 | 13 | 26 | 38 | 51 | 64 |
| 62 | 1.8807 | 1.8887 | 1.8967 | 1.9047 | 1.9128 | 1.9210 | 1.9292 | 1.9375 | 1.9458 | 1.9542 | 14 | 27 | 41 | 55 | 68 |
| 63 | 1.9626 | 1.9711 | 1.9797 | 1.9883 | 1.9970 | 2.0057 | 2.0145 | 2.0233 | 2.0323 | 2.0413 | 15 | 29 | 44 | 58 | 73 |
| 64 | 2.0503 | 2.0594 | 2.0686 | 2.0778 | 2.0872 | 2.0965 | 2.1060 | 2.1155 | 2.1251 | 2.1348 | 16 | 31 | 47 | 63 | 78 |
| 65 | 2.1445 | 2.1543 | 2.1642 | 2.1742 | 2.1842 | 2.1943 | 2.2045 | 2.2148 | 2.2251 | 2.2355 | 17 | 34 | 51 | 68 | 85 |
| 66 | 2.2460 | 2.2566 | 2.2673 | 2.2781 | 2.2889 | 2.2998 | 2.3109 | 2.3220 | 2.3332 | 2.3445 | 18 | 37 | 55 | 73 | 92 |
| 67 | 2.3559 | 2.3673 | 2.3789 | 2.3906 | 2.4023 | 2.4142 | 2.4262 | 2.4383 | 2.4504 | 2.4627 | 20 | 40 | 60 | 79 | 99 |
| 68 | 2.4751 | 2.4876 | 2.5002 | 2.5129 | 2.5257 | 2.5386 | 2.5517 | 2.5649 | 2.5782 | 2.5916 | 22 | 43 | 65 | 87 | 108 |
| 69 | 2.6051 | 2.6187 | 2.6325 | 2.6464 | 2.6605 | 2.6746 | 2.6889 | 2.7034 | 2.7179 | 2.7326 | 24 | 47 | 71 | 95 | 119 |
| 70 | 2.7475 | 2.7625 | 2.7776 | 2.7929 | 2.8083 | 2.8239 | 2.8397 | 2.8556 | 2.8716 | 2.8878 | 26 | 52 | 78 | 104 | 131 |
| 71 | 2.9042 | 2.9208 | 2.9375 | 2.9544 | 2.9714 | 2.9887 | 3.0061 | 3.0237 | 3.0415 | 3.0595 | 29 | 58 | 87 | 116 | 145 |
| 72 | 3.0777 | 3.0961 | 3.1146 | 3.1334 | 3.1524 | 3.1716 | 3.1910 | 3.2106 | 3.2305 | 3.2506 | 32 | 64 | 96 | 129 | 161 |
| 73 | 3.2709 | 3.2914 | 3.3122 | 3.3332 | 3.3544 | 3.3759 | 3.3977 | 3.4197 | 3.4420 | 3.4646 | 36 | 72 | 108 | 144 | 180 |
| 74 | 3.4874 | 3.5105 | 3.5339 | 3.5576 | 3.5816 | 3.6059 | 3.6305 | 3.6554 | 3.6806 | 3.7062 | 41 | 81 | 122 | 163 | 204 |
| 75 | 3.7321 | 3.7583 | 3.7848 | 3.8118 | 3.8391 | 3.8667 | 3.8947 | 3.9232 | 3.9520 | 3.9812 | 46 | 93 | 139 | 186 | 232 |
| 76 | 4.0108 | 4.0408 | 4.0713 | 4.1022 | 4.1335 | 4.1653 | 4.1976 | 4.2303 | 4.2635 | 4.2972 | 53 | 107 | 160 | 213 | 267 |
| 77 | 4.3315 | 4.3662 | 4.4015 | 4.4374 | 4.4737 | 4.5107 | 4.5483 | 4.5864 | 4.6252 | 4.6646 | | | | | |
| 78 | 4.7046 | 4.7453 | 4.7867 | 4.8288 | 4.8716 | 4.9152 | 4.9594 | 5.0045 | 5.0504 | 5.0970 | | | | | |
| 79 | 5.1446 | 5.1929 | 5.2422 | 5.2924 | 5.3435 | 5.3955 | 5.4486 | 5.5026 | 5.5578 | 5.6140 | | | | | |
| 80 | 5.6713 | 5.7297 | 5.7894 | 5.8502 | 5.9124 | 5.9758 | 6.0405 | 6.1066 | 6.1742 | 6.2432 | | | | | |
| 81 | 6.3138 | 6.3859 | 6.4596 | 6.5350 | 6.6122 | 6.6912 | 6.7720 | 6.8548 | 6.9395 | 7.0264 | | | | | |
| 82 | 7.1154 | 7.2066 | 7.3002 | 7.3962 | 7.4947 | 7.5958 | 7.6996 | 7.8062 | 7.9158 | 8.0285 | | | | | |
| 83 | 8.1443 | 8.2636 | 8.3863 | 8.5126 | 8.6427 | 8.7769 | 8.9152 | 9.0579 | 9.2052 | 9.3572 | | | | | |
| 84 | 9.5144 | 9.677 | 9.845 | 10.02 | 10.20 | 10.39 | 10.58 | 10.78 | 10.99 | 11.20 | | | | | |
| 85 | 11.43 | 11.66 | 11.91 | 12.16 | 12.43 | 12.71 | 13.00 | 13.30 | 13.62 | 13.95 | | | | | |
| 86 | 14.30 | 14.67 | 15.06 | 15.46 | 15.89 | 16.35 | 16.83 | 17.34 | 17.89 | 18.46 | | | | | |
| 87 | 19.08 | 19.74 | 20.45 | 21.20 | 22.02 | 22.90 | 23.86 | 24.90 | 26.03 | 27.27 | | | | | |
| 88 | 28.64 | 30.14 | 31.82 | 33.69 | 35.80 | 38.19 | 40.92 | 44.07 | 47.74 | 52.08 | | | | | |
| 89 | 57.29 | 63.66 | 71.62 | 81.85 | 95.49 | 114.6 | 143.2 | 191.0 | 286.5 | 573.0 | | | | | |
| 90 | x | | | | | | | | | | | | | | |

DIFFERENCES
UNTRUSTWORTHY
HERE



| Quadrant | Angle | $\tan A =$ | Examples |
|----------|--------------|------------------------|---|
| First | 0 to 90° | $\tan A$ | $\tan 56^\circ 17' = 1.4986$ |
| Second | 90° to 180° | $-\tan(180^\circ - A)$ | $\tan 123^\circ 43' = -\tan(180^\circ - 123^\circ 43')$ $= -\tan 56^\circ 17' = -1.4986$ |
| Third | 180° to 270° | $\tan(A - 180^\circ)$ | $\tan 236^\circ 17' = \tan(236^\circ 17' - 180^\circ)$ $= \tan 56^\circ 17' = 1.4986$ |
| Fourth | 270° to 360° | $-\tan(360^\circ - A)$ | $\tan 303^\circ 43' = -\tan(360^\circ - 303^\circ 43')$ $= -\tan 56^\circ 17' = -1.4986$ |