

WORKSHOP CALCULATION & SCIENCE (COMMON FOR WELDER, FITTER AND MECHANIC DIESEL)

NSQF LEVEL - 5

HANDBOOK FOR CRAFTS INSTRUCTOR TRAINING SCHEME



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

Published by



National Instructional Media Institute

Post.Box.No. 3142,
Guindy, Chennai - 600032
Email : chennai-nimi@nic.in
Website: www.nimi.gov.in

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First Edition, 2024

Printed in India at

National Instructional Media Institute
Post. Box. No. 3142,
Guindy,
Chennai - 600032

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A Comprehensive Training Program
under Crafts Instructor Training Scheme (CITS)
for Instructors

**HANDBOOK ON
TECHNICAL INSTRUCTOR TRAINING
MODULES**

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NOT TO BE REPUBLISHED

अतुल कुमार तिवारी, I.A.S.

सचिव

ATUL KUMAR TIWARI, I.A.S.

Secretary



भारत सरकार
कौशल विकास एवं उद्यमिता मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT
AND ENTREPRENEURSHIP



Foreword

In today's rapidly evolving world, the role of skilled craftsmen and women is more crucial than ever. The Craft Instructor Training Scheme (CITS) stands at the forefront of this transformation, shaping the educators who will train the next generation of artisans and technicians. This book aims to provide an in-depth understanding of the subject, exploring its significance, methodologies, and impact on vocational training.

The Craft Instructor Training Scheme was established with the objective of enhancing the quality of instruction in industrial training institutes and other vocational training institutions. By equipping instructors with advanced skills and knowledge, the scheme ensures that they are well-prepared to impart high-quality training to their students. This, in turn, contributes to the creation of a highly skilled workforce capable of meeting the demands of modern industry.

The initial chapters provide the importance of specialized instructor training. Following this, detailed chapters delve into the curriculum covering advanced techniques, safety protocols, and instructional strategies. Each section is designed to offer both theoretical insights and practical applications, ensuring a well-rounded understanding of the subject.

The book offers recommendations for overcoming obstacles and enhancing the effectiveness of the program, with the ultimate goal of producing highly skilled instructors capable of shaping the future workforce.

This book is intended for a diverse audience, including current and aspiring instructors, vocational training administrators, policymakers, and industry stakeholders. It serves as a valuable resource for understanding the intricacies of the subject and its pivotal role in vocational education.

I extend my heartfelt gratitude to all contributors who have shared their experiences and expertise, enriching this book with their valuable insights. Special thanks to the contribution of the development team, reviewers and NIMI that have supported this endeavor, providing essential data and resources.

It is my sincere hope that this book will inspire and guide readers in their efforts to enhance vocational training, ultimately contributing to the development of a skilled and competent workforce.

ATUL KUMAR TIWARI, I.A.S.
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त्रिशलजीत सेठी
महानिदेशक

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Director General



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

FOREWORD

The Craftsmen Training Scheme (CTS) implemented by the Directorate General of Training (DGT) provides skill training to the youth and ensures a steady flow of skilled manpower for the industry. It aims to raise quantitatively and qualitatively the industrial production by systematic training, and to reduce unemployment among the youth by providing them with employable skills.

The Craft Instructor Training Scheme (CITS) is an indispensable part of the Craftsmen Training Scheme (CTS). It offers comprehensive training both in 'skills' and in 'training methodology' to the instructor trainees to make them conversant with techniques of transferring hands-on skills.

I congratulate NIMI for taking the initiative of preparation of the course content for CITS. This will help institutionalize the mechanism for imparting training to the trainers all across the ecosystem. I also extend my gratitude to the Instructors and Officials of National Skill Training Institutes (NSTIs) and the DGT for their invaluable contribution in preparation of the CITS course content.

As we navigate the complexities of a rapidly changing world and the technological disruptions, the significance of CTS and CITS has increased manifold. It not only empowers individuals with practical skills but also lays the foundation for a prosperous future. I am confident that this book will serve as a guiding light to all instructor trainees for skill development and nation-building.


(Trishaljit Sethi)

PREFACE

The Craft Instructor Training Scheme is an indispensable module of the Craftsmen Training Scheme, which has been an integral part of the Indian skill development industry since its inception. This program aims to equip instructors with the necessary skills and teaching methodology to effectively transfer hands-on skills to trainees and promote a holistic learning experience. The first Craft Instructor Training Institute was established in 1948, followed by six more institutes across India in 1960. Today, these institutes, including the National Skill Training Institute (formerly Central Training Institute for Instructors), offer the CITS course, which is mandated by the Directorate General of Training (DGT).

The Craft Instructor training program is designed to develop skilled manpower for industries. The course aims to offer instructors an opportunity to improve their instructional skills, engage learners effectively, offer impactful mentoring, and make efficient use of resources, leading to a more skilled workforce in various industries. The program emphasizes collaborative and innovative approaches to teaching, resulting in high-quality course delivery. Overall, the Craft Instructor Training Scheme is a pivotal program that helps instructors grow in their careers and make a significant contribution to society. This program is essential for developing skilled manpower and promoting a robust learning environment that benefits both trainees and instructors alike.

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following experts to bring out this Instructional material **(Trade Practical)** for **CITS Workshop Calculation & Science - Mechanical (NSQF Level - 5)** for **Instructors**.

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

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

NIMI is grateful to all others who have directly or indirectly helped in developing this IMP.

ABOUT THE TEXT BOOK

The Vocational Instructor Training Program is a comprehensive initiative designed to equip aspiring students with the necessary skills and knowledge to effectively teach in vocational education settings. This program encompasses a range of pedagogical strategies, instructional techniques, and subject-specific content tailored to the diverse vocational fields. Participants engage in coursework that covers curriculum development, assessment methods, classroom management, and the integration of industry-relevant technologies. Practical experience and hands-on training are emphasized, allowing participants to apply theoretical concepts in real-world teaching environments. Through collaborative learning experiences and mentorship opportunities, aspiring vocational instructors develop the confidence and competence to facilitate engaging and impactful learning experiences for their students. This training program aims to cultivate a new generation of educators who are not only proficient in their respective vocational fields but also adept at fostering the success and employability of their students in today's competitive workforce.

This text book covers communication, self-management, information and communication technology, entrepreneurial and green skills. It has been developed as per the learning outcome-based curriculum.

G C Rama Murthy,
Joint Director,
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EXERCISE 1 : FRACTION

Concept, Fraction, Number, Variable Content

A fraction is a number, that's represents a part of a whole. Generally, the fraction can be a portion of any quantity out of the whole thing and the whole can be any specific things or value. A complex fraction has a fraction in the numerator or denominator. In a proper fraction, the numerator is less than the denominator.

The fractions include two parts, numerator and denominator.

- **Numerator:** It is the upper part of the fraction which is represents the sections of the fraction.
- **Denominator:** It is the lower or bottom part, which represents the total parts in which the fraction is divided.

While performing our daily activities, we use fractions unknowingly in many ways. You might say things like "We're having dinner at a quarter past seven", or "we need 2 thirds of a cup of sugar for the cake". $\frac{7}{8}$ is the largest fraction. The fraction symbol (/) appears as a line or slash dividing two numbers, one below the other. It can appear in a few different ways. For example, $\frac{3}{5}$ means three-fifths equal to 6.

Number: This is the study of the set of positive whole numbers which are usually called the set of natural numbers. A branch of pure mathematics devoted to the study of the natural numbers and the integers. The most commonly referenced are the following nine types: 1-Whole, 2-Natural, 3-Rational, 4-Irrational, 5-Even, 6-Odd, 7-Prime, 8-Composite, and 9-Integers. The symbol for numbers is (#).

Variable

A variable is a symbol, which represents one or more numbers. Each number or variable by itself, or product of numbers and variables in an algebraic expression, is called a term. The coefficient is a number which is written along with a variable or it is multiplied by the variable.

In Mathematics, a variable is an alphabet or term that's represents an unknown number or unknown value or unknown quantity. Variables are particularly used in the case of algebraic expression or algebra. For example, $x+7=3$ is a linear equation where x is a variable, where 7 and 3 are constants.

A letter or symbol that performs one specific number, known or unknown is called a constant. A letter or symbol which is represents any member of a collection of two or more numbers is called a variable.

In $3x=9$, x is the variable and 9 is the constant. Then x is the variable and 3 is the constant. Here, x and y are the variables and -10 is the constant value.

A constant has a known value. A "constant" simply means a fixed value or a value that does not change. Example of constant are 2, 5, 0, -3, -7, $\frac{2}{7}$, $\frac{7}{9}$ etc.

The diagram shows the equation $2X + 7 = 12$. Arrows point from labels to the corresponding parts of the equation: 'COEFFICIENT' points to the number 2, 'VARIABLE' points to the letter X, and 'CONSTANTS' points to both the number 7 and the number 12.

These usual symbols and their values which called mathematical constants. Examples include: 0(zero), 1(one) the natural number after zero.

EXERCISE 2 : Ratio & Proportion

A ratio is an ordered set of two numbers a & b , written a/b where b does not equal 0. A proportion is an equation in which two ratios are set equal to each other. For example, if there is 1 girl and 3 boys you could write the ratio as: 1 : 3 (for every one girl there are 3 boys) $1/4$ are girls and $3/4$ are boys

A proportion is a type of ratio that connects with a part to a whole. For example, in the class with 20 women & 80 men, the total class size is 100, and the proportion of women is $20/100$ or 20%. The proportion of men is $80/100$ or 80%.

Trade related problems

Q 1. If $a : b = 3 : 7$ and $b : c = 8 : 5$, then find $a : b : c$.

Solution

Here, we make the common term 'b' equal in both ratios.

Therefore, we multiply the first ratio by 8 and the second ratio by 7.

So, we have $a : b = 24 : 56$ and $b : c = 56 : 35$

Thus, $a : b : c = 24 : 56 : 35$

Q 2. Find the mean proportional between 0.23 and 0.24.

Solution

We know that the mean proportional between 'a' and 'b' is the square root of $(a \times b)$.

$\Rightarrow$ Required mean proportional = $\sqrt{0.23 \times 0.24} = 0.234946802$

Q 3. Divide Rs. 672 in the ratio 5 : 3

Solution

The given ratio is 5 : 3

Sum of numbers in the ratio = $5 + 3 = 8$

We divide Rs. 672 into 8 parts.

$672 / 8 = 84$

Therefore, Rs. 672 in the ratio 5 : 3 = Rs. 672 in the ratio $(5/8) : (3/8)$

$\Rightarrow$ Rs. 672 in the ratio 5 : 3 = $(5 \times 84) : (3 \times 84) = 420 : 252$

Q 4. A bag contains 50 p, 25 p, and 10 p coins in the ratio 2 : 5 : 3, amounting to Rs. 510. Find the number of coins of each type.

Solution

Let the common ratio be 100k.

Number of 50 p coins = 200 k

Number of 25 p coins = 500 k

Number of 10 p coins = 300 k

Value of 50 p coins = $0.5 \times 200 k = 100 k$

Value of 25 p coins = $0.25 \times 500 k = 125 k$

Value of 10 p coins = $0.1 \times 300 k = 30 k$

$\Rightarrow$ Total value of all coins = $100 k + 125 k + 30 k = 255 k = 510$ (given)

$\Rightarrow k = 2$

Therefore, Number of 50 p coins = $200 k = 400$

Number of 25 p coins = $500 k = 1000$

Number of 10 p coins = $300 k = 600$

Q 5. A mixture contains sugar solution and colored water in the ratio of 4 : 3. If 5 liters of colored water is added to the mixture, the ratio becomes 6 : 7. Find the initial quantity of sugar solution in the given mixture.

Solution

The initial ratio is 4 : 3.

Let 'k' be the common ratio.

=> Initial quantity of colored water = 3 k

=> Final quantity of sugar solution = 4 k

=> Final quantity of colored water = 3 k + 5

Final ratio =

$$\Rightarrow k = 3 \quad \frac{4K^2 + 15}{3} = \frac{6}{7}$$

Therefore, the initial quantity of sugar solution in the given mixture = 4 k = 12 liters

Q 6. Two friends Hari and Ram started a business with an initial capital contribution of Rs. 2 lac and Rs. 3 lacs. At the end of the year, the business made a profit of Rs. 40,000. Find the share of each in the profit.

Solution:

We know that if the time period of investment is the same, profit/loss is divided by the ratio of the value of the investment.

=> Ratio of value of investment of Hari and Ram = 2,00,000 : 3,00,000 = 2 : 3

=> Ratio of share in profit = 2 : 3

=> Share of Hari in profit = (2/5) x 40,000 = Rs. 16,000

=> Share of Ram in profit = (3/5) x 40,000 = Rs. 24,000

Q 7. There are three friends A, B, and C started a business, each investing Rs. 20,000. After 5 months A withdrew Rs. 5000, B withdrew Rs. 4000 and C invested Rs. 6000 more. At the end of the year, a total profit of Rs. 69,900 was recorded. Find the share of each.

Solution

We know that if the period of investment is not constant, the gains/losses from the business are divided in the ratio of their inputs, where input is calculated as the product of an amount of investment and the time period of investment.

So, input = value of investment x period of investment, and here, the period of investment would be broken into parts as the investment is not constant throughout the time period.

A's input = (20,000 x 5) + (15,000 x 7) = 20,5000

B's input = (20,000 x 5) + (16,000 x 7) = 2,12,000

C's input = (20,000 x 5) + (26,000 x 7) = 2,82,000

=> A : B : C = 20,500 : 2,12,000 : 2,82,000

=> A : B : C = 205 : 212 : 282

=> A : B : C = (205/ 699) : (212 / 699) : (282/ 699)

Thus, A's share = (205/ 699) x 69900 = Rs. 20,5000

B's share = (212 / 699) x 69900 = Rs. 21200

C's share = (282/ 699) x 69900 = Rs. 28200

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

Fig 1

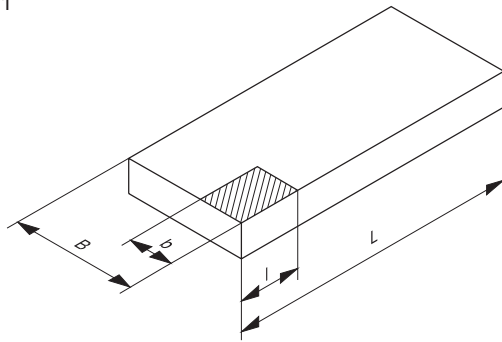
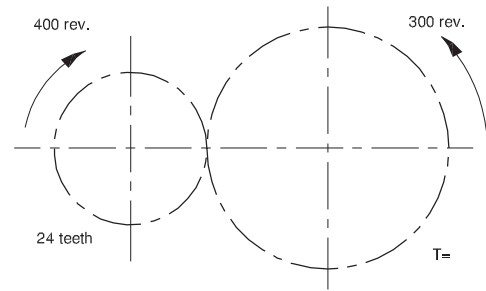


Fig 2



WSC22M0002

Find the ratio of A:B:C

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

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

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

$$A:B = 2:3$$

$$B:C = 4:5$$

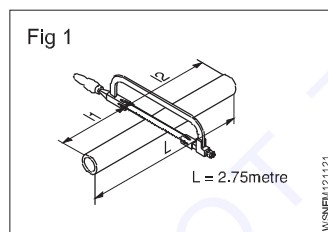
$$A:B = 8:12 \text{ (Ratio 2:3 multiply by 4)}$$

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

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

Assignment

1



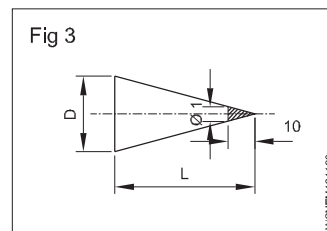
$$l1 : l2 = 2:3$$

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

$$l1 = \text{_____ metres}$$

$$l2 = \text{_____ metres}$$

3

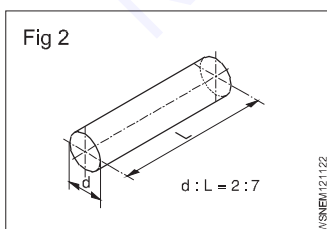


$$D : L = 1:10$$

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

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

2

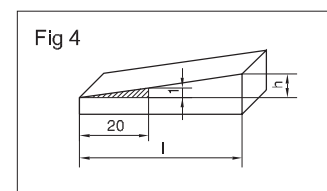


$$d : L \text{ of shaft} = 2:7$$

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

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

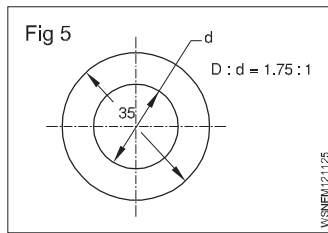
4



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

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

5



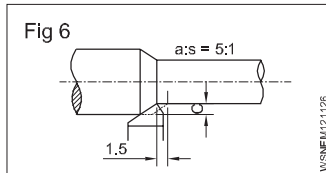
$$\Delta h = \text{_____ mm}$$

$$D : d = 1.75 : 1$$

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

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

6



$$a : s = 5 : 1$$

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

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

7 $A:B=9:12$

$B:C=8:10$

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

8 $A:B=5:6$

$B:C=3:4$

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

9 $A:55=9:11$

$A = \text{_____}$

10 $15:9.3=40:x$

$x = \text{_____}$

EXERCISE 3 : Percentage

Definition, changing percentage to decimal and fraction and vice versa. Applied problems related to trade. Estimation and cost of product.

In mathematics, a percentage is a number or ratio that's represent a fraction of 100. This is one of the ways to indicate a dimensionless relationship between two numbers; other methods include ratios, fractions, and decimals. Percentages are often denoted by the symbol "%" written after the number.

Examples of percentages are

- 10% is equal to $\frac{1}{10}$ fraction
- 20% is equivalent to $\frac{1}{5}$ fraction
- 25% is equivalent to $\frac{1}{4}$ fraction
- 50% is equivalent to $\frac{1}{2}$ fraction
- 60% is equivalent to $\frac{3}{5}$ fraction
- 75% is equivalent to $\frac{3}{4}$ fraction
- 90% is equivalent to $\frac{9}{10}$ fraction

Percentages don't have dimension. Hence it is called a dimensionless number. If we say, 30% of a number, then it means 30 percent of its whole.

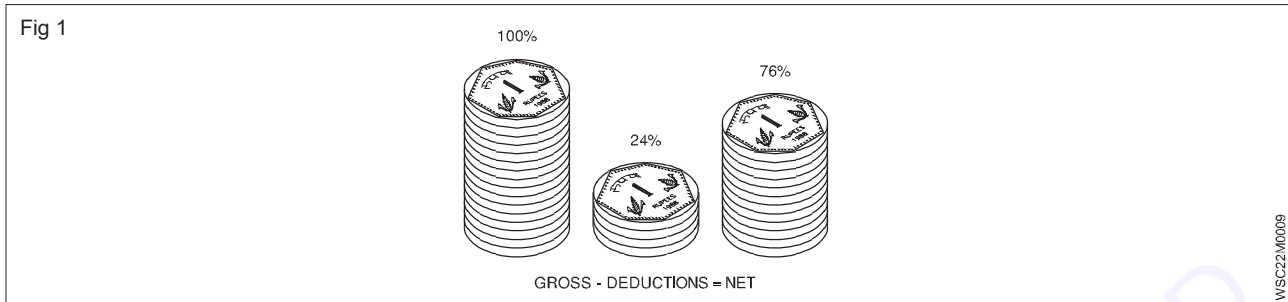
Percentages can also be performed decimal or fraction form, such as 0.6%, 0.25%, etc.

- 1 A batsman scored 110 runs which included 3 boundaries and 8 sixes. What percent of his total score did he make by running between the wickets?
 - a 45%
 - b $45\frac{5}{11}\%$ = Ans
 - c $54\frac{6}{11}\%$
 - d 55%
- 2 Two students appeared at an examination. One of them secured 9 marks more than the other and his marks was 56% of the sum of their marks. The marks obtained by them are:
 - a 39, 30
 - b 41, 32
 - c 42, 33 = Ans
 - d 3, 34
- 3 The population of a town increased from 1,75,000 in a decade. The average percent increase of population per year is:
 - a 4.37%
 - b 5% = Ans
 - c 6%
 - d 8.75%

Example

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

If the deduction amounts to 24%, what is his total salary? (Fig 1)



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, its is $\frac{1}{76} \times 984.50$

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

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

Example 1

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

Solution

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

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

Example 2

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

Solution: CP = x ,

CP = cost price

SP = sale price

SP=CP+15%of CP

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

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

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

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

Example 3

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

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

Example 4

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

Solution

Present price of Motor cycle Rs.18000

This is the value of 92% of original price

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

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

Example 5

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

Solution

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

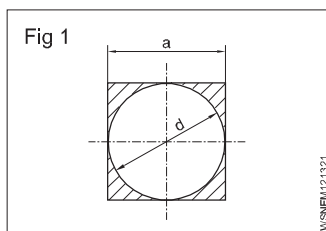
$$= (100 - 90) \frac{\text{litres}}{100} \times 100$$

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

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

Assignment

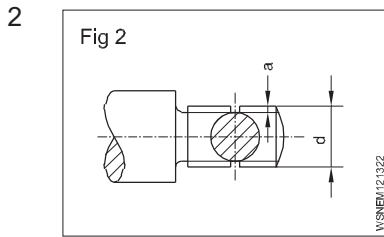
1



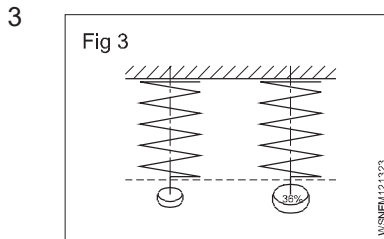
$a = 400\text{mm}$ (side of square)

$d = 400 \text{ mm}$

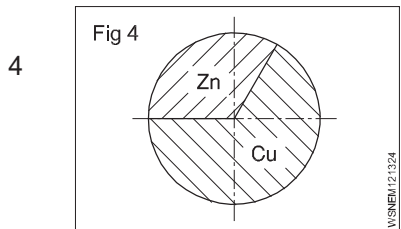
Wastage = _____ %.



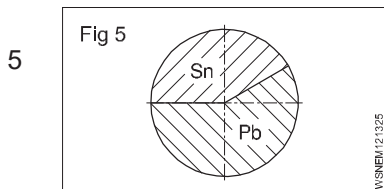
$d = 26\text{mm}$
 'a' depth of u/cut =
 2.4mm
 reduction of area at
 cross-section
 = _____ %



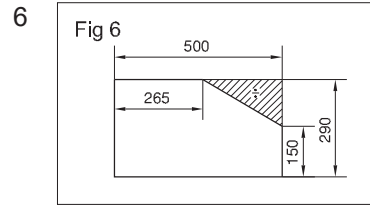
Percentage of
 increase
 = 36%
 Value of increase
 = 611.2 N/mm^2
 Original tensile
 strength



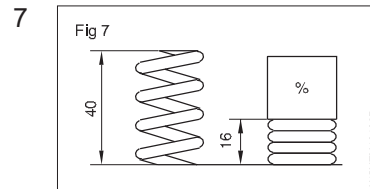
= _____ N/mm^2 .
 Copper in alloy = 27 kg
 Zinc in alloy = 18 kg
 % of Copper
 = _____ %



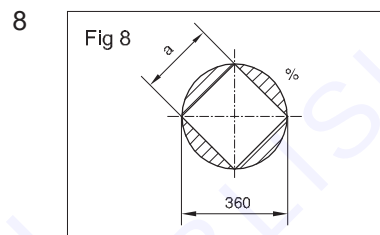
% of Zinc = _____ %.
 Weight of alloy = 140 Kgf
 Weight of Sn 40%
 Pb = _____ Kgf
 Sn = _____ Kgf.



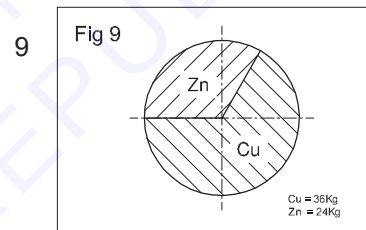
Shaded
 portion
 = _____ %.



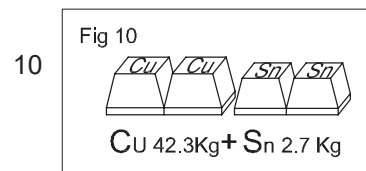
Compression
 length
 = _____ %.



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



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



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

EXERCISE 4 : Algebra

Fundamental Algebraic formulae for multiplication and factorization

Algebra is a branch of mathematics which substitutes letters for numbers. An algebraic equation depicts a scale, what is done on one side of the scale with a number is also done to either side of the scale. Algebra also includes real numbers, complex numbers, matrices, vectors and much more. The numbers are constants. X, Y, A, B are the most frequently used letters that specify algebraic problems and equations.

Algebraic equations, simple & simultaneous equations

Here is a list of Algebraic formulas –

- $a^2 - b^2 = (a - b)(a + b)$
- $(a + b)^2 = a^2 + 2ab + b^2$
- $a^2 + b^2 = (a + b)^2 - 2ab$
- $(a - b)^2 = a^2 - 2ab + b^2$
- $(a + b + c)^2 = a^2 + b^2 + c^2 + 2ab + 2bc + 2ca$
- $(a - b - c)^2 = a^2 + b^2 + c^2 - 2ab + 2bc - 2ca$
- $(a + b)^2 = a^2 + 3a^2b + 3ab^2 + b^3$; $(a + b)^3 = a^3 + b^3 + 3ab(a + b)$
- $(a - b)^3 = a^3 - 3a^2b + 3ab^2 - b^3 = a^3 - b^3 - 3ab(a - b)$
- If n is a natural number $a^n - b^n = (a - b)(a^{n-1} + a^{n-2}b + \dots + b^{n-2}a + b^{n-1})$
- If n is even ($n = 2k$), $a^n + b^n = (a + b)(a^{n-1} - a^{n-2}b + \dots + b^{n-2}a - b^{n-1})$
- If n is odd ($n = 2k + 1$), $a^n + b^n = (a + b)(a^{n-1} - a^{n-2}b + a^{n-3}b^2 - \dots - b^{n-2}a + b^{n-1})$
- $(a + b + c + \dots)^2 = a^2 + b^2 + c^2 + \dots + 2(ab + ac + bc + \dots)$
- **Laws of Exponents** $(a^m)(a^n) = a^{m+n}$; $(ab)^m = a^m b^m$; $(a^m)^n = a^{mn}$
- **Fractional Exponents** $a^0 = 1$;

Example 1: Find out the value of $5^2 - 3^2$

Solution

Using the formula $a^2 - b^2 = (a - b)(a + b)$

where $a = 5$ and $b = 3$

$$(a - b)(a + b)$$

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

$$= 2 \times 8 = 16$$

Example 2:

$$4^3 \times 4^2 = ?$$

Solution

Using the exponential formula $(a^m)(a^n) = a^{m+n}$

where $a = 4$

$$4^3 \times 4^2 = 4^{3+2} = 4^5 = 1024$$

Quadratic equations and their applications:

The Quadratic equations are the polynomial equations of degree 2 in one variable of type $f(x) = ax^2 + bx + c = 0$ where $a, b, c \in \mathbb{R}$ and $a \neq 0$. This is the general form of a quadratic equation where 'a' is called the leading coefficient and 'c' is called the absolute term of $f(x)$.

EXERCISE 5 : Mensuration 2D & 3D

Mensuration 2D: Concept on Basic Geometrical Definitions: The different types of shapes in geometry help us to understand the shapes day to day life. With the help of geometric concepts, we can calculate the area, perimeter and volume of shapes. The basic geometry is based on points, lines and planes explained in coordinate geometry.

Two Dimensional Shapes

Ex) $(x-2)^2 = 4$
 $x^2 - 4x + 4 = 4$
 $x^2 - 4x = 0$ $\longrightarrow$ Equation is now in standard form
 $x(x-4) = 0$
 $x=0$ $x=4$
 Answer: $x=0$, $x=4$

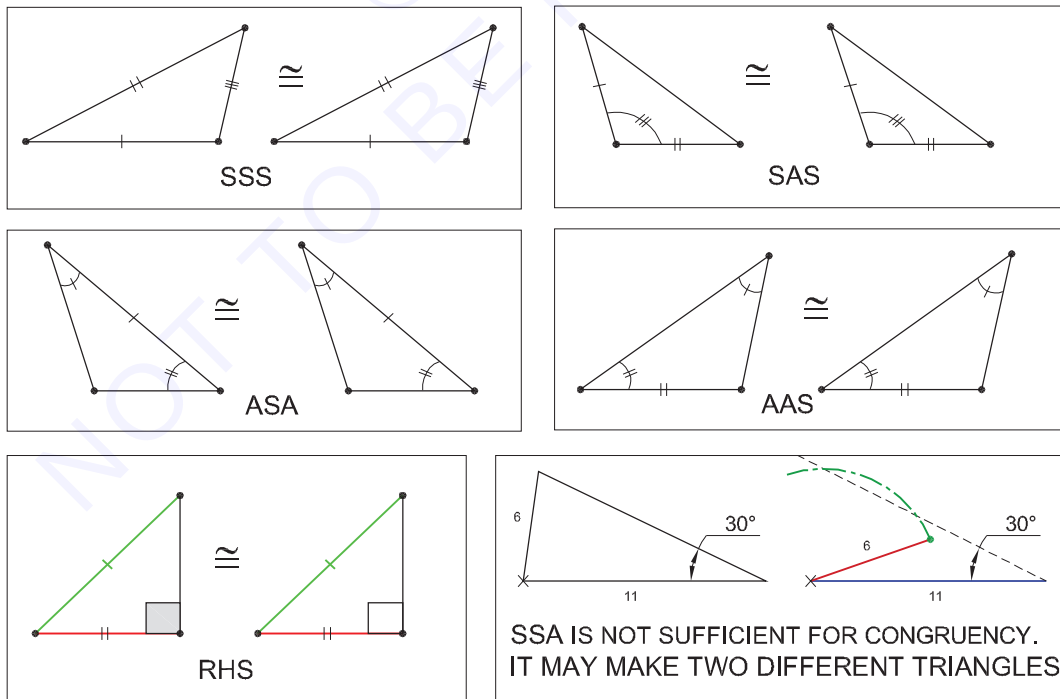
Ex) $(x^2 + 3x - 4 = 0$
 $(x - 4)(x - 1) = 0$
 $x - 4 = 0$ or $x - 1 = 0$
 $x = -4$ or $x = 1$
 Answer: $x = -4$, $x = 1$

Three Dimensional Shapes (Sphere Cube Cuboids Cone Cylinder)

Triangle Circle Semi-Circle Square Rectangle Parallelogram Rhombus Trapezium Kite Polygons (Pentagon, Hexagon, Octagon, Nonagon, Decagon, etc.)

Basic geometrical theorems

The geometry theorems are: Isosceles Triangle Theorem, Equilateral Triangle Theorem, Angle Sum Triangle Theorem, Supplementary Angle Theorem, Opposite Angle Theorem, 3 Parallel Line Theorems, Complementary Angle Theorem, Exterior Angle Theorem, Exterior Angles of a Polygon and Interior Angles of a Polygon.



RULES FOR TRIANGLES CONGRUENCY

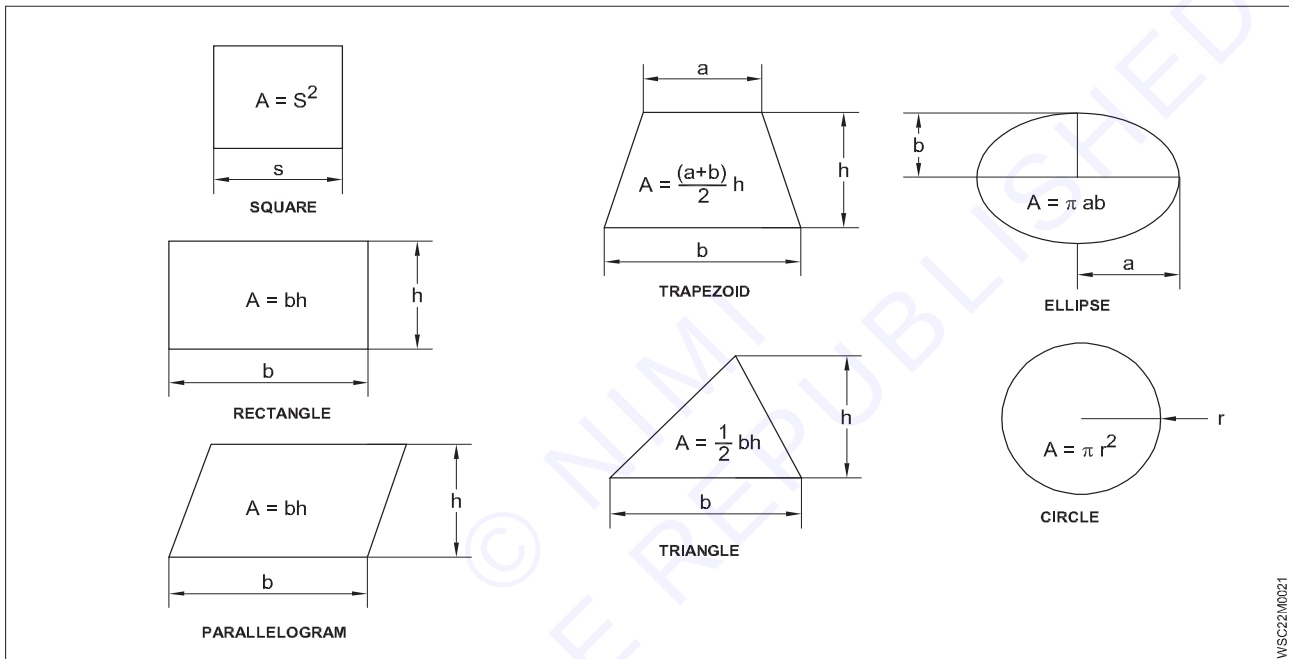
WSC221M020

The Determination of areas, perimeters of triangles, quadrilaterals, polygons, circle, sector etc.

Basic Geometry Formulas

- Perimeter of a Square = $4(\text{Side})$
- Perimeter of a Rectangle = $2(\text{Length} + \text{Breadth})$
- Area of a Square = Side^2
- Area of a Rectangle = $\text{Length} \times \text{Breadth}$.
- Area of a Triangle = $\frac{1}{2} \times \text{base} \times \text{height}$.
- Area of a Trapezoid = $\frac{1}{2} \times (\text{base1} + \text{base2}) \times \text{height}$.
- Area of a Circle = $A = \pi r^2$
- Circumference of a Circle = $2\pi r$.

Mensuration 3D: Determination of volumes, surface areas of cube, cuboids cylinders, hollow cylinder, sphere prisms, pyramids cone spheres, frustums etc.



GEOMETRIC FORMULAS	
	AREA = lw PERIMETER = $2l + 2w$
	AREA = $\frac{1}{2} bh$
	AREA = πr^2 CIRCUMFERENCE = $2\pi r$
	VOLUME = lwh
	VOLUME = $\pi r^2 h$
	$c^2 = a^2 + b^2$

Mass, Weight, Volume, Density, Viscosity, Specific gravity and related problems

Density is explained as the mass of an object per unit volume, whereas relative density, also known as specific gravity, which is defined as the ratio of a substance's weight to the weight of the same volume of water. Density & specific gravity are two different concepts. SI Unit is kg/m^3

$$W = mg$$

To calculate the weight, use the following general formula: $W=mg$. Here, "W" is the weight of the object, "m" is the mass of the object, and "g" is the acceleration due to gravity. On Earth, the value of g is 9.8 m/s^2 .

Viscosity: Viscosity is a measure of a fluid's resistance to flow. The SI unit of viscosity is Poiseuille (PI). Its other units are newton-second per square metre (N s m^{-2}) or Pascal-second (Pa s .) The dimensional formula of viscosity is $[\text{ML}^{-1}\text{T}^{-1}]$. A fluid with large viscosity resists motion due to its molecular makeup gives it a lot of internal friction. A fluid with low viscosity flows easily for the reason that, its molecular makeup results in very little friction when it is in motion.

Examples

Q. If the area of a triangle with base 'x' is equal to the area of a square with side x. then the altitude of the triangle is:

- a) $x/2$ b) x c) $2x$ d) $3x$ e) None of these

Let, altitude of the triangle is – half base 'x', then the area of the triangle is – $\frac{1}{2}(x \times h)$ square units, if side 'x', then the area of the square is – square units

Now, as per the given condition, $\frac{1}{2}(x \times h) = x^2$ or, $h = 2x$ (Answer)

So, option (c) is correct.

Q. Find the area of a triangle whose sides are 5, 5 & 6 cm

- a) 12 cm^2 b) 14 cm^2 c) 16 cm^2 d) 10 cm^2 e) None of these

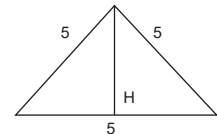
So, area of the triangle = $\frac{1}{2}(6 \times 4)$

= 12 cm^2 (Answer)

So, option (a) is correct.

$$A = \frac{1}{2} 6 \times 4$$

$$H = \sqrt{5^2 - 3^2} \\ = 4$$



Q. A cone and a hemisphere have equal bases and equal heights. Find out the ratio of their curved surface area.

- a) $1 : \sqrt{2}$ b) $\sqrt{2} : 1$ c) $2 : 1$ d) $1 : 2$ e) None of these

→ Let the base radius of hemisphere = r unit.

Base radius of cone = r unit.

Height of cone = base radius of hemisphere = r unit

So, Slant height of cone (l) = $\sqrt{(h^2 + r^2)} = \sqrt{(r^2 + r^2)} = \sqrt{2}r$ unit

The ratio between the curved surface area of hemisphere and cone is –

$$= 2\pi r^2 : \pi r l = 2\pi r^2 : \pi r (\sqrt{2}r) = 2 : \sqrt{2} = \sqrt{2} : 1 \text{ (Answer)}$$

So, option (b) is correct.

Q. A rectangular piece of paper $11 \text{ cm} \times 4 \text{ cm}$ is folded without overlapping to make a cylinder of height 4 cm. Find the volume of the cylinder.

Solution: Length of the paper will be the perimeter of the base of the cylinder and width will be its height.

Circumference of base of cylinder = $2\pi r = 11 \text{ cm}$

$$2 \times \frac{22}{7} \times r = 11 \text{ cm}$$

$$r = \frac{7}{4} \text{ cm}$$

$$\text{Volume of cylinder} = \pi r^2 h = \left(\frac{22}{7}\right) \times \left(\frac{7}{4}\right)^2 \times 4$$

$$= 38.5 \text{ cm}^3$$

Q. Find the height of a cylinder whose radius is 7 cm and the total surface area is 968 cm².

Solution: Let height of the cylinder = h, radius = r = 7cm

Total surface area = $2\pi r (h + r)$

TSA = $2 \times (22/7) \times 7 \times (7+h) = 968$

h = 15 cm.

Q. If one side of a square is 4 cm, then what will be its area and perimeter?

Solution: Given,

Length of side of square = 4 cm

Area = side² = $4^2 = 4 \times 4 = 16 \text{ cm}^2$

Perimeter of square = sum of all its sides

Since, all the sides of the square are equal, therefore;

Perimeter = $4+4+4+4 = 16 \text{ cm}$.

Q. A rectangular piece of dimension 22 cm x 7 cm is used to make a circle of the largest possible radius. Find the area of the circle formed.

Solution

In questions like this, the diameter of the circle is lesser in length and breadth.

Here, the breadth Diameter of the circle = 7 cm

=> Radius of the circle = 3.5 cm

Therefore, area of the circle = $\pi (\text{Radius})^2 = \pi (3.5)^2 = 38.50 \text{ cm}^2$.

Q. A pizza is to be divided into 8 identical pieces. What would be the angle subtended by each piece at the center of the circle?

Solution:

By identical pieces, we mean that area of each piece is the same.

=> Area of each piece = $(\pi \times \text{Radius}^2 \times \theta) / 360^\circ = (1/8) \times \text{Area of circular pizza}$

=> $(\pi \times \text{Radius}^2 \times \theta) / 360^\circ = (1/8) \times (\pi \times \text{Radius}^2)$

=> $\theta / 360^\circ = 1 / 8$

=> $\theta = 360^\circ / 8 = 45^\circ$

Therefore, the angle subtended by each piece at the center of the circle = 45 degree.

1 Find the area of the sector whose angle is 105°, and the perimeter of sector of circle is 18.6 cm.

Given:

Perimeter of a sector of a circle = 18.6 cm

Angle of sector of circle = 105°

To find:

Area = ?

Solution:

$$\begin{aligned} \text{Length of Arc } (\ell) &= \frac{\theta}{360^\circ} \times 2\pi r \text{ unit} \\ \ell &= \frac{105^\circ}{360^\circ} \times 2 \times \frac{22}{7} \times r \\ &= 1.83r \end{aligned}$$

$$\begin{aligned}
 \text{Perimeter (P)} &= \ell + 2r \text{ unit} \\
 18.6 &= 1.83r + 2r \\
 3.83r &= 18.6 \text{ cm} \\
 r &= \frac{18.6}{3.83} = 4.86 \text{ cm} \\
 \text{Area A} &= \frac{\theta}{360^\circ} \times \pi r^2 \text{ unit}^2 \\
 &= \frac{105^\circ}{360^\circ} \times \frac{22}{7} \times (4.86)^2 \text{ cm}^2 \\
 &= 21.65 \text{ cm}^2
 \end{aligned}$$

2 Find the area, if the radius is 12.4 cm and the perimeter of a sector of a circle is 64.8 cm.

Given:

Perimeter P = 64.8 cm

Radius r = 12.4 cm

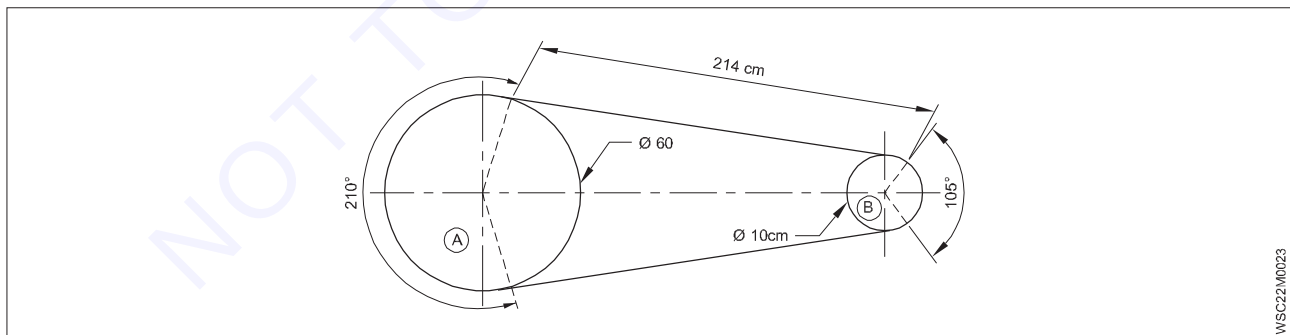
To find:

Area A = ?

Solution:

$$\begin{aligned}
 \text{Perimeter P} &= \ell + 2r \text{ unit} \\
 \ell &= P - 2r \text{ unit} \\
 &= 64.8 - 2(12.4) \text{ cm} \\
 &= 64.8 - 24.8 = 40 \text{ cm} \\
 \text{Area A} &= \frac{\ell r}{2} \text{ unit}^2 = \frac{40 \times 12.4}{2} \\
 &= 248 \text{ cm}^2
 \end{aligned}$$

3 Find out the length of the belt, if the arrangement of a belt is shown in the figure below. Solution:



$$\begin{aligned}
 \text{Length } \ell_A &= \frac{\theta}{360^\circ} \times 2\pi r \text{ unit} \\
 &= \frac{210^\circ}{360^\circ} \times 2 \times \frac{22}{7} \times 30 = 110 \text{ cm} \\
 \text{Length } \ell_B &= \frac{\theta}{360^\circ} \times 2\pi r \text{ unit}
 \end{aligned}$$

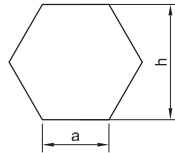
$$= \frac{105^\circ}{360^\circ} \times 2 \times \frac{22}{7} \times 5 = 91.7 \text{ cm}$$

$$= \ell_A + \ell_B + 2 \times 214 \text{ cm}$$

$$= 110 + 9.17 + 428 \text{ cm}$$

$$= 547.17 \text{ cm}$$

Hexagon



WISC22MD024

Side = a unit

Perimeter P = 6a unit

Area A = $6 \times \frac{\sqrt{3}}{4} \times a^2$ units² (Area of 6 equilateral triangle)

DAF (Distance Across Flats) = $\sqrt{3} \times a$ unit

DAC (Distance Across Corners) = 2 x a unit

1 Find out the perimeter, area, DAF and DAC of a regular hexagon whose side is 2cm

(DAF - Distance Across Flats)

(DAC - Distance Across Corners)

Given: Side of hexagon (a) = 2cm

To Find: P = ?, A = ?, DAF = ?, DAC = ?

Solution:

$$\begin{aligned} \text{Perimeter of hexagon (P)} &= 6a \text{ unit} \\ &= 6a \text{ unit} = 6 \times 2 \text{ cm} = 12 \text{ cm} \end{aligned}$$

$$\text{Area of hexagon A} = 6 \times \frac{\sqrt{3}}{4} \times a^2 \text{ unit}^2$$

$$= 6 \times \frac{1.732}{4} \times 2^2$$

$$= 10.392 \text{ cm}^2$$

DAF (Distance Across

$$\text{Flats)} = \sqrt{3} \times a \text{ unit}$$

$$= \sqrt{3} \times 2 = 1.732 \times 2$$

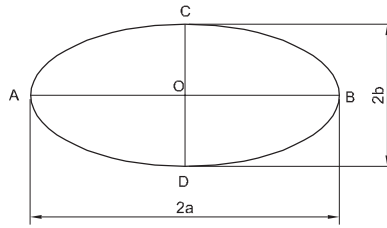
$$= 3.464 \text{ cm}$$

DAC (Distance Across

$$\text{Corners)} = 2 \times a \text{ unit}$$

$$= 2 \times 2 = 4 \text{ cm}$$

Ellipse



WSC22M0025

Major axis $AB = 2a$

Half of Major axis $OB = a$,

Minor axis $CD = 2b$

Half of Minor axis $OC = b$

Area of ellipse $A = \pi \times a \times b \text{ unit}^2$

Perimeter of ellipse $P = 2\pi \sqrt{\frac{(a^2 + b^2)}{2}} \text{ unit}$

1 Find its area and perimeter, if the major and minor axis of an ellipse are 12 cm and 8 cm respectively

Solution:

Major axis $2a = 12 \text{ cm}$

$a = \frac{12}{2} = 6 \text{ cm}$

Minor axis $2b = 8 \text{ cm}$

$b = \frac{8}{2} = 4 \text{ cm}$

Area $A = \pi \times a \times b \text{ unit}^2$

$$= \frac{22}{7} \times 6 \times 4 \text{ cm}^2$$

$$= 75.43 \text{ cm}^2$$

Perimeter (P) $= 2\pi \sqrt{\frac{(a^2 + b^2)}{2}} \text{ unit}$

$$= 2 \times \frac{22}{7} \sqrt{\frac{(6^2 + 4^2)}{2}} \text{ unit}$$

$$= 2 \times \frac{22}{7} \sqrt{\frac{(36 + 16)}{2}} \text{ unit}$$

$$= 2 \times \frac{22}{7} \times \sqrt{26}$$

$$= 2 \times \frac{22}{7} \times 5.1 = 32.06 \text{ cm}$$

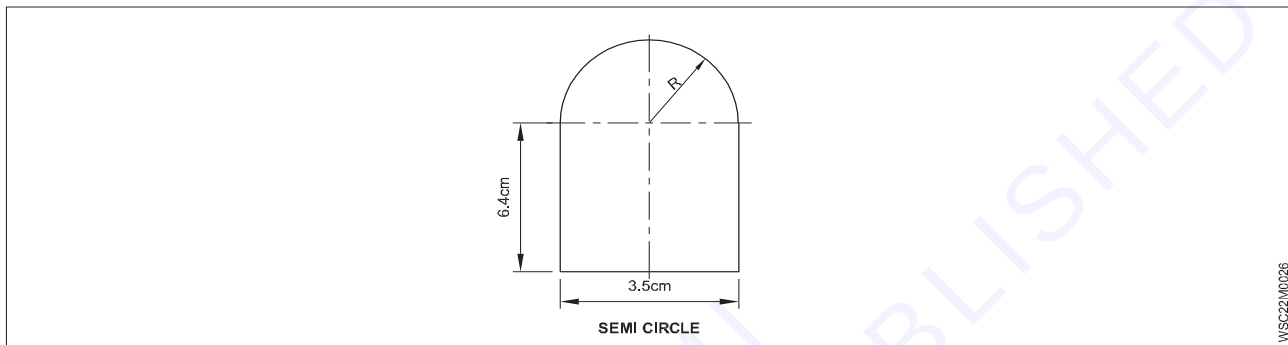
Assignment

Circle

- 1 Find the circumference and area of a circle whose radius is 10.00 metre.
- 2 Find its diameter if the area of a circle is 330 cm^2 .
- 3 Find its area if the circumference of a circle is 50 cm.
- 4 Find out the area and circumference of a circle of diameter is 50 cm.
- 5 Find its area if the circumference of a circle is 44 cm.

Semi circle

- 1 Calculate the circumference and area of semi circle whose radius is 14 cm.
- 2 Find area of the given figure.



Circular ring

- 1 Find out area of a ring washer, whose inner radius and outer radius are 13 cm and 15 cm respectively.
- 2 Find the area of a ring portion of a washer whose outer dis is 30 m and inner dis is 20 m. Also calculate the difference between the circumference of circles.

Sector of circle

- 1 Find the perimeter and area of a sector of a circle of radius 5cm and its angle is 96° .
- 2 Find the radius of the circle if the angle is 90° and the area of sector of a circle is 196 cm^2 .

Hexagon

- 1 Find out the Area, perimeter, DAF, and DAC of hexagon of side 4cm.
- 2 Find the area of cross section of a regular hexagon rod whose side is 7.5 cm.

Ellipse

- 1 Find the area of the biggest ellipse that can be inscribed in a rectangle of length 18 cm and breadth 12 cm. Also calculate its perimeter.
- 2 How much fencing will be required to enclose an elliptical plot of ground the axes of the ellipse being 200 and 170 meter respectively

Cube

- 1 Find the diagonal, lateral surface area,, total surface area and volume of a cube of side 4.5 cm.

$$\begin{aligned}
 \text{side } a &= 4.5 \text{ cm} \\
 \text{diagonal } d &= \sqrt{3} \text{ a unit} \\
 &= 1.732 \times 4.5 \\
 &= 7.794 \text{ cm} \\
 \text{L.S.A} &= 4a^2 \text{ unit}^2 \\
 &= 4 \times 4.5 \times 4.5 \\
 &= 81 \text{ cm}^2
 \end{aligned}$$

$$\begin{aligned}\text{T.S.A} &= 6a^2 \text{ unit} \\ &= 6 \times 4.5 \times 4.5 \\ &= 121.5 \text{ cm}^2 \\ V &= a^3 \text{ unit}^3 \\ &= 4.5 \times 4.5 \times 4.5 \\ &= \mathbf{91.125 \text{ cc.}}\end{aligned}$$

- 1 Find the volume and surface area of a sphere of 3 cm radius.

$$\begin{aligned}V &= \frac{4}{3} \pi r^3 \text{ unit}^3 \\ &= \frac{4 \times 22 \times 3 \times 3 \times 3}{3 \times 7} \\ &= 113.1 \text{ cm}^3 \\ \text{Total Surface Area} &= 4\pi r^2 \text{ unit}^2 \\ &= 4 \times \frac{22}{7} \times 3 \times 3 \\ &= \mathbf{113.1 \text{ cm}^2}\end{aligned}$$

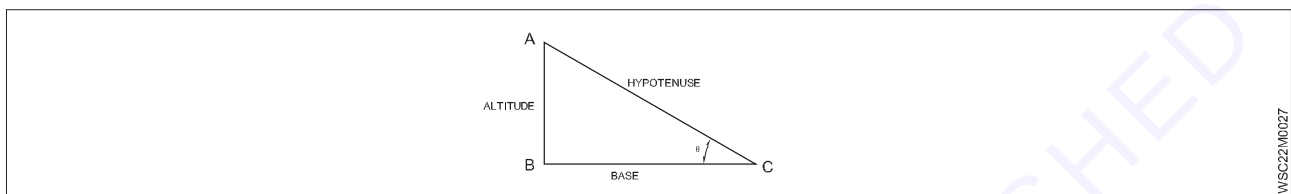
- 2 Find the diameter of sphere having volume of 15625 cc.

$$\begin{aligned}\frac{4}{3} \pi r^3 &= \text{Volume} \\ \frac{4}{3} \times \frac{22}{7} \times r^3 &= 15625 \\ r^3 &= \frac{15625 \times 3 \times 7}{4 \times 22} \\ &= \frac{328125}{88} \\ &= 3728.69 \\ r &= \sqrt[3]{3728.69} \\ &= 15.51 \text{ cm} \\ \text{diameter} &= 2 \times \text{radius} \\ &= 2 \times 15.51 \\ &= \mathbf{31.02 \text{ cm}}\end{aligned}$$

EXERCISE 6 : Trigonometry

Concept of angles, grades and radians and their conversions, measurement of angles in degrees. Trigonometrically ratios and their relations. Review of ratios of some standard angles (0, 30, 45, 60, 90 degrees), Height & Distances, Simple problems.

Trigonometry is a most significant topic of math's that will help us to understand the relationships between the angles and sides of triangles and Trigonometry formulas give us the facility to solve complex problems involving angles, distances, and other geometric conception. This article on Trigonometry Formulas includes a trigonometry table with function values and all trigonometry formulas which is very useful in board exams.



WSC22MD027

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° = 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 .

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

$$\text{Circumference} = \pi \times \text{dia}$$

$$= 2\pi r \text{ (where } r \text{ is radius of the circle)}$$

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

Examples

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

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

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

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

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

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

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

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

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

$$= \left(23 + \frac{25}{60} + \frac{32}{3600} \right) \text{ degrees}$$

$$= \frac{82800 + 1500 + 32}{3600}$$

$$= \frac{84332}{3600}$$

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

$$\text{Therefore } 23.4255 \text{ degrees}$$

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 Radians

9 2.625 Radians

10 $3/5$ Radians

Simplify:

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

Simplify:

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

Simplify:

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

Simplify:

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

$$\cot \theta + \tan (180^\circ + \theta) + \tan (90^\circ + \theta) + \tan (360^\circ - \theta)$$

$$\cot \theta + \tan \theta - \cot \theta - \tan \theta = 0$$

EXAMPLE

From the tables obtain the cosine of $45^\circ-20'$.

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

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

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

SINE TABLE

$$1 \quad \sin 25^\circ = 0.4226$$

$$2 \quad \sin 17^\circ 5'$$

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

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

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

$$3 \quad \sin 17^\circ 45' 13''$$

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

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

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

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

$$13'' = \frac{0.0003}{60} \times 13$$

$$= \frac{0.0039}{60}$$

$$= \frac{0.00039}{60}$$

$$= \frac{0.00039}{60}$$

$$= 0.000065$$

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

$$13' = 0.000065$$

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

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.

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

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.

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

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

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

Setting angle

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

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

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

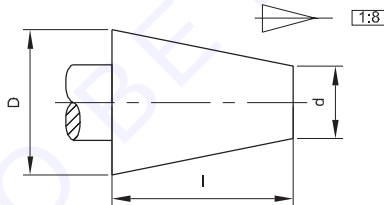
$$= \frac{\text{difference in diameter}}{2 \times \text{taper length}}$$

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



W5C221M0028

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.

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

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

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

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

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

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

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:

$$1 \cos \theta = 0.5150$$

$$\theta = 59^\circ$$

$$2 \cos \theta = 0.0192$$

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

$$3 \cos \theta = 0.9682$$

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

$$(-) 4 = 5'$$

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

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

$$4 \cos \theta = 0.8476$$

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

$$(-) 0.0003 = 2'$$

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

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

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

$$0.0001 = \frac{60}{0.0002} \times 0.0001$$

$$= \frac{60}{2} \times 1$$

$$= 30''$$

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

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

$$0.8476 = \cos 32^\circ 2' 30''$$

tan Table

$$\begin{aligned} 1 \quad \tan 35^\circ 37' \\ \tan 35^\circ 36' &= 0.7159 \\ 1' &= 0.0004 \end{aligned}$$

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

$$\begin{aligned} 2 \quad \tan 50^\circ 5' \\ \tan 50^\circ 0' &= 1.1918 \\ 5' &= 0.0036 \end{aligned}$$

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

Find the corresponding angles when tan values are given

$$\begin{aligned} 1 \quad \tan \theta &= 0.3972 \\ 0.3959 &= \tan 21^\circ 36' \\ 0.0013 &= 4' \end{aligned}$$

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

$$\begin{aligned} 2 \quad \tan \theta &= 1.0065 \\ 1.0035 &= \tan 45^\circ 6' \\ 0.0030 &= 5' \end{aligned}$$

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

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.

$$\begin{aligned} \sin \theta &= \frac{\text{Opp.side}}{\text{Hyp}} = \frac{h}{l} \\ &= \frac{5 \text{ cm}}{250 \text{ mm}} \\ &= \frac{50 \text{ cm}}{250 \text{ mm}} \\ &= 0.2000 \end{aligned}$$

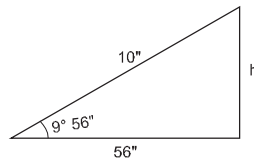
$$\theta = 11^\circ 32'$$

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".

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

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

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



W5C221M029

$$\begin{aligned}\sin 9^{\circ} 0'' &= 0.1564 \\ \sin 9^{\circ} 1'' &= 0.1567 \\ 1' \text{ (or) } 60'' &= 0.0003 \\ 56'' &= \frac{0.0003}{60} \times 56\end{aligned}$$

$$\begin{aligned}&= \frac{0.0163}{60} \\ &= \frac{0.00163}{6}\end{aligned}$$

$$\begin{aligned}&= 0.00028 \\ \sin 9^{\circ} 0' 00'' &= 0.1564 \\ 56'' &= 0.00028\end{aligned}$$

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

$$\begin{aligned}h &= 10 \times \sin 9^{\circ} 56'' \\ &= 10 \times 0.15668 \\ &= 1.5668 \text{ cm}\end{aligned}$$

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

$$\begin{aligned}\cos C &= \frac{BC}{AC} \\ \cos \theta &= \frac{1 \text{ m}}{4.5 \text{ m}} = 0.2222\end{aligned}$$

$$\begin{aligned}\cos &= 0.2222 \\ 0.2233 &= \cos 77^{\circ} 6' \\ (-) 0.0011 &= 4' (+)\end{aligned}$$

$$0.2222 = \cos 77^{\circ} 10'$$

$$\theta = 77^{\circ} 10'$$

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 $\cos 47^\circ 39'$
- 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 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.

There are six trigonometric functions: Sin, Cos, Tan, Sec, Cosec, and Cot. Trigonometric ratios can be used to calculate the current lengths and angles. A list of trigonometry formulas has been developed having relation to a right-angled triangle.

Trigonometric Ratios	
$\sin \theta$	Opposite side/Hypotenuse
$\cos \theta$	Adjacent side/Hypotenuse
$\tan \theta$	Opposite side/Adjacent side
$\cot \theta$	Adjacent side/Opposite side
$\sec \theta$	Hypotenuse/Adjacent side
$\csc \theta$	Hypotenuse/Opposite side

Trigonometric Formula Ratios In Other Words

Trigonometry ratios relate angles and sides in triangles in Trigonometry. Sine (sin) is opposite/hypotenuse, cosine (cos) is adjacent/hypotenuse, and tangent (tan) is opposite/adjacent. These trigonometric ratios help us to solve triangle problems and model world phenomena in various fields, like physics, space, and engineering.

$$\sin \theta = \text{Opposite Side} / \text{Hypotenuse}$$

$$\cos \theta = \text{Adjacent Side} / \text{Hypotenuse}$$

$$\tan \theta = \text{Opposite Side} / \text{Adjacent Side}$$

$$\sec \theta = \text{Hypotenuse} / \text{Adjacent Side}$$

$$\csc \theta = \text{Hypotenuse} / \text{Opposite Side}$$

$$\cot \theta = \text{Adjacent Side} / \text{Opposite Side}.$$

Trigonometry Formulas in Degrees

Trigonometry ratios are used to create the relationship between triangle angles and side lengths. The identities and ratios serve as the foundation for all trigonometry formulas. Trigonometry formulas are displaying common trigonometric functions for angles in degrees. This is made up of trigonometric ratios such as sine, cosine, tangent, cosecant, secant, and cotangent. These ratios can be expressed as sin, cos, tan, cosec, sec, and cot in a trigonometry table. The trigonometric ratios values can be used to calculate the values of trigonometric standard angles such as 0° , 30° , 45° , 60° , and 90° .

Angles (In Degrees)	0	30	45	60	90	180	270	360
Angle(In Radians)	0	$\pi/6$	$\pi/4$	$\pi/3$	$\pi/2$	π	$3\pi/2$	2π
sin	0	1/2	$1/\sqrt{2}$	$\sqrt{3}/2$	1	0	-1	0
cos	1	$\sqrt{3}/2$	$1/\sqrt{2}$	1/2	0	-1	0	1
tan	0	$1/\sqrt{3}$	1	$\sqrt{3}$	∞	0	∞	0
cot	∞	$\sqrt{3}$	1	$1/\sqrt{3}$	0	∞	0	∞
cosec	∞	2	$\sqrt{2}$	$2/\sqrt{3}$	1	∞	-1	∞
sec	1	$2/\sqrt{3}$	$\sqrt{2}$	2	∞	-1	∞	1

Sum and Difference Formulas for Cosines, Sin and Tangent

$$\cos(\alpha + \beta) = \cos \alpha \cos \beta - \sin \alpha \sin \beta$$

$$\cos(\alpha - \beta) = \cos \alpha \cos \beta + \sin \alpha \sin \beta$$

$$\sin(\alpha + \beta) = \sin \alpha \cos \beta + \cos \alpha \sin \beta$$

$$\sin(\alpha - \beta) = \sin \alpha \cos \beta - \cos \alpha \sin \beta$$

$$\tan(\alpha + \beta) = \frac{\tan \alpha + \tan \beta}{1 - \tan \alpha \tan \beta}$$

$$\tan(\alpha - \beta) = \frac{\tan \alpha - \tan \beta}{1 + \tan \alpha \tan \beta}$$

$$\sin(90^\circ - \theta) = \cos \theta$$

$$\cos(90^\circ - \theta) = \sin \theta$$

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

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

$$\sec(90^\circ - \theta) = \csc \theta$$

$$\csc(90^\circ - \theta) = \sec \theta$$

Three Pythagorean Trigonometry Identities	Some Equivalent Forms
$\sin^2 \theta + \cos^2 \theta = 1$	$\sin^2 \theta = 1 - \cos^2 \theta$ or $\cos^2 \theta = 1 - \sin^2 \theta$
$\tan^2 \theta + 1 = \sec^2 \theta$	$\tan^2 \theta = \sec^2 \theta - 1$ or $\sec^2 \theta = 1 + \tan^2 \theta$
$\cot^2 \theta + 1 = \csc^2 \theta$	$\cot^2 \theta = \csc^2 \theta - 1$ or $\csc^2 \theta = 1 + \cot^2 \theta$

Trigonometry Formulas Solved Problem Q.1:

What is the value of $(\sin 30^\circ + \cos 30^\circ) - (\sin 60^\circ + \cos 60^\circ)$?

Solution:

Given,

$$(\sin 30^\circ + \cos 30^\circ) - (\sin 60^\circ + \cos 60^\circ)$$

$$= \left(\frac{1}{2}\right) + \left(\frac{\sqrt{3}}{2}\right) - \left(\frac{\sqrt{3}}{2}\right) - \left(\frac{1}{2}\right)$$

$$= 0$$

Trigonometry Formulas Problem Q.2:

If $\cos A = 4/5$, then find the value of $\tan A$.

Solution:

Given,

$$\cos A = \frac{4}{5}$$

As we know, from trigonometry identities,

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

$$\sec^2 A - 1 = \tan^2 A$$

$$(1/\cos^2 A) - 1 = \tan^2 A$$

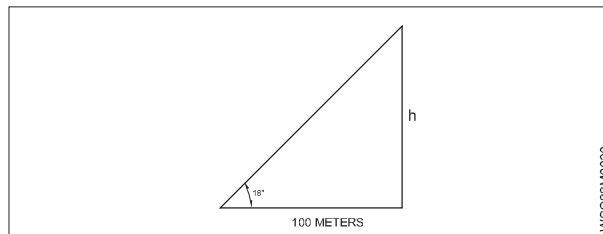
Putting the value of $\cos A = \frac{4}{5}$.

$$(5/4)^2 - 1 = \tan^2 A$$

$$(25 - 16)/16 = \tan^2 A$$

$$\tan^2 A = \sqrt{9/16}$$

$$\tan A = 3/4.$$



2. If $x \sin^3 \theta + y \cos^3 \theta = \sin \theta \cos \theta$ and $x \sin \theta = y \cos \theta$, then prove that $x^2 + y^2 = 1$.

Solution:

$$\Rightarrow x \sin^3 \theta + y \cos^3 \theta = \sin \theta \cos \theta$$

$$\Rightarrow x \sin^3 \theta + y \cos^3 \theta = \sin \theta \cos \theta$$

$$\Rightarrow y \cos \theta (1 - \cos^2 \theta) + y \cos^3 \theta = \sin \theta \cos \theta$$

$$\Rightarrow y \cos \theta - y \cos^3 \theta + y \cos^3 \theta = \sin \theta \cos \theta$$

$$y = \sin \theta$$

$$x = \cos \theta$$

$$\text{LHS} = x^2 + y^2 = \cos^2 \theta + \sin^2 \theta = 1 = \text{RHS}$$

3. An aeroplane is flying parallel to the Earth's surface at a speed of 175 m/sec and at a height of 600 m. The angle of elevation of the aeroplane from a point on the Earth's surface is 37° at a given point. After what period of time does the angle of elevation increase to 53° ? ($\tan 53^\circ = 1.3270$, $\tan 37^\circ = 0.7536$).

Solution:

$$\tan \theta = \frac{\text{opp}}{\text{adj}}$$

$$\tan 37^\circ = \frac{600}{x + y}$$

$$0.7536 = \frac{600}{x + y}$$

$$(0.7536)(x + y) = 600$$

$$\tan 53^\circ = \frac{600}{x}$$

$$x = \frac{600}{1.3270}$$

$$x = 452.15$$

$$0.7536x + 7536y = 600$$

$$0.7536 \times 452.15 + 0.7536y = 600$$

$$0.7536y = 600 - 340.74$$

$$0.7536y = 259.26$$

$$y = \frac{259.26}{0.7536}$$

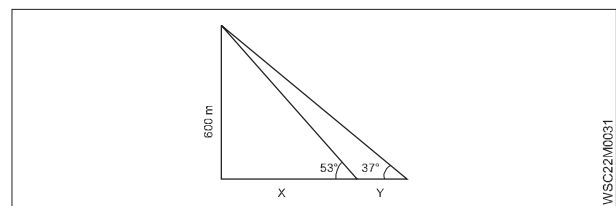
$$y = 344.03$$

$$\text{Distance} = 344.03$$

$$\text{Time} \times \text{speed} = 344.03$$

$$\text{Time} = \frac{344.03}{\text{speed}} = \frac{344.03}{175} = 1.97 \text{ sec}$$

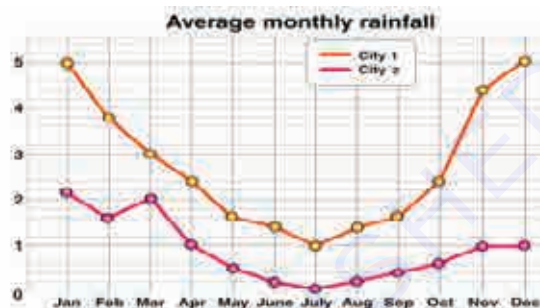
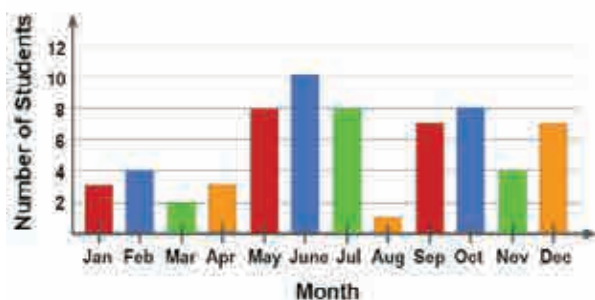
$$\text{Time} = 1.97 \text{ sec}$$



EXERCISE 7 : Graphs

Basic Concept:

A basic two-dimensional graph contains of a vertical and a horizontal line which intersects at a point called origin. The horizontal line is the x axis, the vertical line is the y axis. In simple line graphs, the x and y axes are each divided into similarly spaced subdivisions that are assigned to numerical values. A graph is determined as a structure of mathematical which represents a particular function by connecting a set of points. It is used to generate a pair wise relationship between objects. Graph is mathematic representation of a network and it describes the relationship between lines and points.



Importance

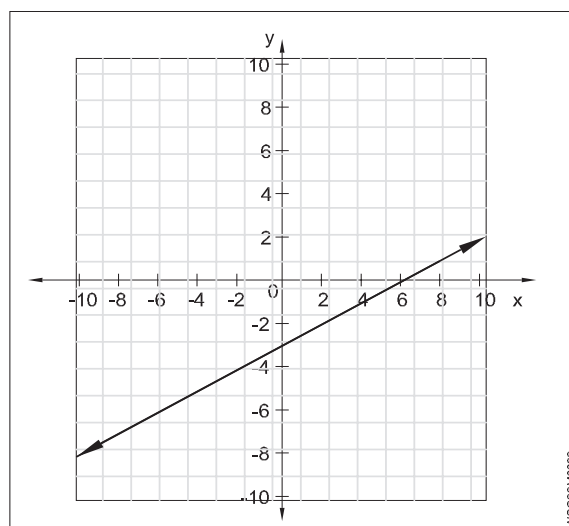
Graphs play an essential role in our everyday lives, often going unnoticed as powerful tools that bring information in a visual and accessible manner. Whether in education, business, or personal decision-making, graphs help us make sense of complex data and also tell compelling stories. The three superiorities of graphs are as follows: it makes data presentable and easy to understand. It helps in summarizing the data in a crisp manner. It helps in the comparison of data in a stronger way. Modern Applications of Graph Theory discusses many cutting-edge applications of graph theory, such as traffic networks, navigable networks and optimal routing for emergency response, and graph-theoretic approaches to molecular epidemiology.

Plotting Graphs of Simple Linear Equation

In graphs there are three basic procedure of graphing linear functions. The first is by plotting points and then drawing a line through the points. The second is by using the y-intercept and slope. And the third is by using transformations of the identity function $f(x)=x$.

Graph Linear Equations in Two Variables

- Plot points in a rectangular coordinate system.
- Graph a linear equation by plotting points.
- Graph vertical and horizontal lines.
- Find the x- and y-intercepts.
- Graph a line using the intercepts.



Example: Draw a graph of the linear equation $x+2y=7$.

Solution: We will follow the following steps:

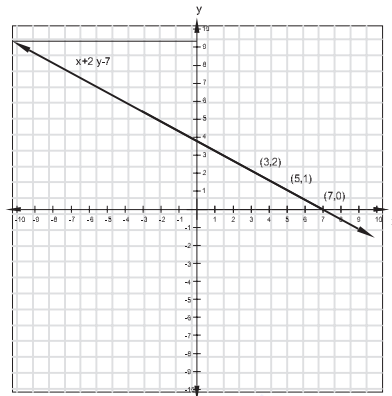
- **Step 1:** Check if the given linear equation $x+2y=7$ is of the form of $y = mx + b$. [On converting, we get: $y = - (1/2)x + 7/2$]
- **Step 2:** Find the x and y-intercept respectively. For that, put $y = 0$ in the equation: $x = 7-2(0)$, $x=7$. Now, put $x=0$ in the equation. $2y=7-(0)$, $y=7/2 = 3.5$
- **Step 3:** Apply the trial and error method and find 3 pairs of values of (x, y) that satisfy the given linear equation $x=7-2y$. (See table below)

- **Step 4:** Plot the points (7,0), (5,1), and (3,2) on the graph.
- **Step 5:** Join all the points which are marked on the graph paper and get a straight line that represents the given linear equation graphically.

See the values of x and y in the following table:

SEE THE VALUES OF X AND Y IN THE FOLLOWING TABLE

X	7	5	3
Y	0	1	2



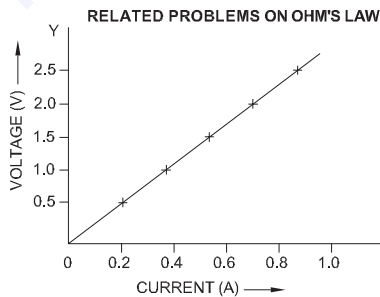
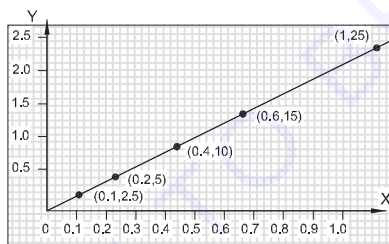
WSC22M0032

Example 2: Vikram wants to plot the graph of $-1/2x + 1/3y = 1$. Help him to plot the graph for linear equations.

Solution

The given linear equation is $-1/2x + 1/3y = 1$. Convert the equation in the form of $y = mx + b \Rightarrow 6 + 6x/2$. We need to find the x and y-intercept respectively. For that, we can apply the hit and trial method, put $y=6$ in the equation $\Rightarrow x=3$. Now, put $x=2$ in the equation. $y=3$. See the values of x and y in the following table.

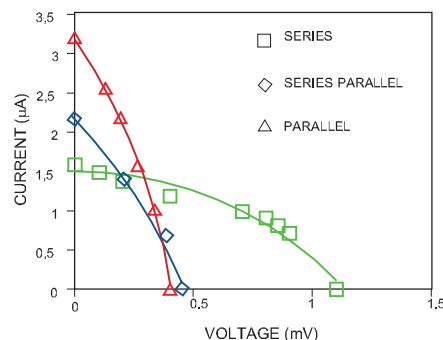
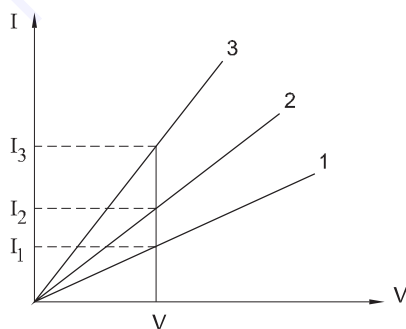
I (AMPERES)	0.1	0.2	0.4	0.6	1
V (VOLTS)	2.5	5	10	15	25



WSC22M0034

Series-Parallel Combination

In the graph theory, series-parallel graphs are graphs with two distinguished vertices called terminals, formed recursively by two simple composition operations. They can be used to model series and parallel electric circuits.



WSC22M0035

EXERCISE 8 : Statistics

Frequency tables

A frequency table consists of the lists of items in a given data set and the number of times each item occurs in the data set. It is calculated by dividing the number of times a particular value for a variable has been observed, by the total number of values in the population. For example, in a total of 20 coins tosses where are 14 heads and 6 tails, the proportion of heads is 0.7 (14 divided by 20).

The different types of frequency distributions are grouped frequency distributions, ungrouped frequency distributions, relative frequency distributions and cumulative frequency distributions.

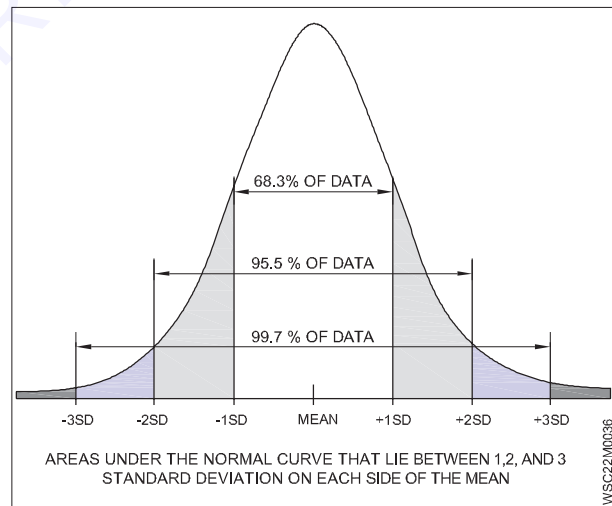
To make such a frequency distribution table, you should first, write the class intervals in one column. Next, tally the numbers in each category based on the number of times it appears. Finally, write the frequency in the final column. A frequency distribution table drawn above is called a grouped frequency distribution table.

Class interval	Tally marks	Frequency	Cumulative frequency
60-75	II	2	2
75-90	IIII	4	6
90-105	IIII	6	12
105-120	II	2	14
120-135	IIII	6	20
135-150	IIII	4	24

Weights (in kg)	Frequency	Relative Frequency
50	10	$\frac{10}{50} = 0.2$
60	12	$\frac{12}{50} = 0.24$
70	5	$\frac{5}{50} = 0.1$
55	13	$\frac{13}{50} = 0.26$
40	10	$\frac{10}{50} = 0.2$
Total	50	

Normal Distribution: Normal distribution tables are used in securities trading to help identify uptrends or downtrends, resistance levels or support and other technical indications.

$z = (X - \mu) / \sigma$ where X is a normal random variable, μ which mean of X , and σ is the standard deviation of X . You can also find the normal distribution formula here. In probability theory, the normal or Gaussian distribution is a very general continuous probability distribution.



Measure of Central Tendency – Mean, Median & Mode:

As we know, mean is the average of a given data set, median is the middlemost data value and the mode represents the most frequently take place data value in the set. The central tendency can be found using the formulas of mean, median or mode in most of the cases.

Measures of central tendency, helps you to find the middle, or the average, of a data set. The 3 most common measures of central tendency are the mean, median and mode.

The Mean: The Mean (average) of a data which set is found by adding all numbers in the data set and then dividing by the number of values in the set.

To calculate the mean, you should first add all the numbers together ($4 + 12 + 5 + 7 + 10 + 9 + 8 + 3 = 58$). Then you divide the total sum by the number of scores used ($58/8=7.2$). In this example, the mean or average of the number set is 7.2.

The Median: The median is the middle value when a data set is ordered from least to greatest.

The median is the number in the middle {2, 3, 11, 16, 26, 34, 47}, which in this instance is 16 since there are three numbers on either side. To find the median value in a list with an even amount of numbers, one must determine the middle pair, add them, and divide by two.

The Mode: The mode is the number which is occurs most often in a data set. The mode in statistics refers to a number in a set of number that appears the most often. For example, if a set of numbers contained the following digits, 1, 1, 3, 5, 6, 6, 7, 7, 7, 8, the mode would be 7, as it appears the most out of all the numbers in the set.

Concept of probability:

Probability is a number between 0 and 1 which describes the chance that stated event will happen. An event is a specified set of outcomes of a random variable. Mutually exclusive events can occur only one at a time. Exhaustive events cover or carry all possible outcomes. The definition of this term is to check the extent to any event is likely to happen. For example, when we flip a coin in the air, what is the possibility of getting a head? The answer to this question is based on the number of possible outcomes. There are three basic rules correlated with probability: the addition, multiplication, and complement rules. The addition rule is used to calculate the probability of event A or event B happening; we express it as: $P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)$.

Four main types of probability exist: axiomatic, classical, empirical and subjective.

Charts like pie chart, bar chart, line diagram, histogram and frequency polygon:

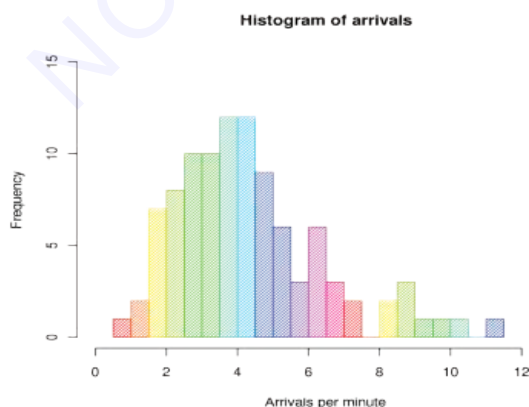
A pie chart is a type of graph representing data in a circular form, with each slice of the circle representing a fraction or proportionate part of the whole. A bar graph that shows data in intervals is called a histogram. A line graph which is a whole unbroken line is called a linear graph. A line graph is used to display data that changes continuously over periods of time.

Based on the structure of the bars and the number of parameters, the bar graph is classified into the following six types:

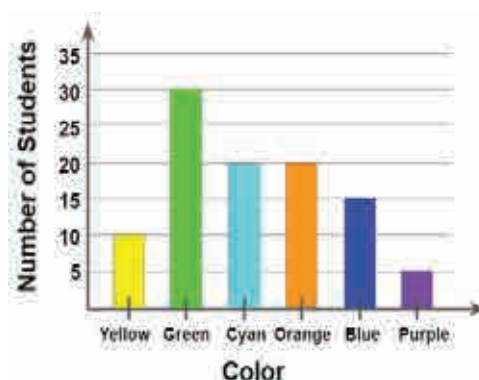
- Horizontal bar graph.
- Vertical bar graph.
- Double bar graph (Grouped bar graph)
- Multiple bar graph (Grouped bar graph)
- Stacked bar graph.
- Bar line graph.

Histograms are used to examine continuous data distributions, bar charts are used to compare categorical data in the middle of groups or categories, and pie charts are used to show the proportion of categories as part of a whole.

- 1. Histogram:** A histogram can only be used for quantitative data, there should not be gaps between bins, unless a bin has no data in it. Often confused with bar graphs.

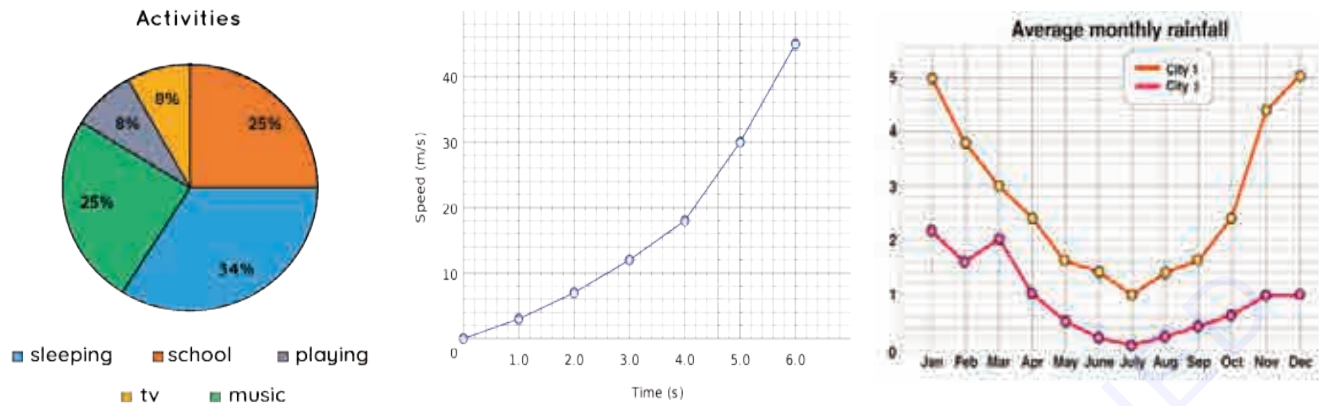


- 2. Bar graph:** A bar graph can be used for either quantitative or categorical data. There should be small gaps between the bars.

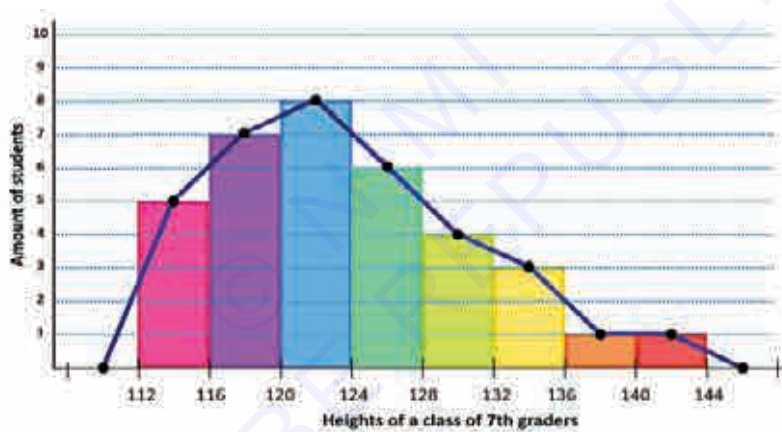


3. Pie Graphs: A Pie Graph can be either categorical or quantitative, but it is expressed as percent of the whole.

A line graph associate individual data points that, typically, display quantitative values over a specified time interval. Line graphs consist of two axes: x-axis (horizontal) and y-axis (vertical), graphically denoted as (x,y).



A frequency polygon is a line graph of class frequency which plotted against class midpoint. This can be obtained by joining the midpoints of the tops of the rectangles in the histogram.



EXERCISE 1 : Unit and Dimensions

Dimensions are physical quantities which can be measured, whereas units are arbitrary names that's correlate to particular dimensions to make it relative (e.g., a dimension is height, whereas a meter is a relative unit that relate to height). Seven base dimensions that can be combined to describe all of the other dimensions of interest in engineering and physics, among other disciplines.

Conversions between British & metric system of Units

The imperial system is based on the convention of measuring based on the human form, whereas the metric system is based on the definition of metre. The metric & imperial systems are different based on their origin, units of measurement, and countries of use.

Conversion between Metric System and English System Units

1 inch = 2.54 cm. 1 ft = 30.48 cm. 1 mile = 1.609 km. 1 pound = 0.454 kg.

Also length: Kilometer to mile by multiplying by 5/8, e.g. 40km = 25 miles. Centimetre to inch by dividing by 2.5, e.g. 5 cm = 2 inches, 30 cm = 12 inches = 1 ft.

Fundamental and derived units in SI System

The SI system's basic units are the units of fundamental physical quantities which are not produced from other SI units. It is called a derived unit when derived quantities are expressed in the same unit. The meter, kilogram, ampere and second are the 7 fundamental and derived units in physics.

Derived SI Units

- Length - meter (m)
- Time - second (s)
- Amount of substance - mole (mole)
- Electric current - ampere (A)
- Temperature - kelvin (K)
- Luminous intensity - candela (cd)
- Mass - kilogram (kg)

The other derived Quantities

- Area (A): Square Meter (m^2)
- Volume (V): Cubic Meter (m^3)
- Speed (v): Meter per Second (m/s)
- Acceleration (a): Meter per Second Squared (m/s^2)
- Force (F): Newton (N) [$kg \cdot m/s^2$]
- Energy (E): Joule (J) [$kg \cdot m^2/s^2$]
- Power (P): Watt (W) [$kg \cdot m^2/s^3$]
- Pressure (P): Pascal (Pa) [N/m^2]

Dimensions of Physical Quantities (MLT)-Fundamental & Derived

The dimensions of any physical quantity determine its nature. We have seven primary dimensions. Primary (sometimes it's called basic) dimensions are defined as independent or fundamental dimensions, from which other dimensions can be obtained. The primary dimensions are: mass, length, time, temperature, electric current, amount of light, and amount of matter.

The equations defined how force depends on mass, length and time. We use the symbols MLT (not in italics) to indicate the fundamental dimensions of mass, length and time.

The dimensional formula of a derived quantity is an equation that shows the powers to which the fundamental units must be raised to acquire one unit of that physical quantity. If Q is the unit of a derived quantity, $Ma^bL^cT^d$ is the dimensional formula, and the exponents a , b , and c are the dimensions.

Some examples are Force, Velocity, Density, Heat, Power, Energy, Momentum, and Acceleration. The units used to measure these derived quantities are referred to as derived units.

List of physical quantities

Derived quantity	Symbol	Description
Angular velocity connecting	ω	The angle incremented in a plane by a segment an object and a reference point per unit time
Area	A	Extent of a surface
Area density	ρA	Mass per unit area
Capacitance	C	Stored charge per unit electric potential

EXERCISE 2 : Engineering Materials

Classification properties and uses of ferrous metals, non-ferrous metals, alloys etc. Properties and uses of non-metals such as wood, plastic, rubber, ceramics industrial adhesives.

The Engineering materials are used to bring the mechanical strength and stiffness. There are different classes of engineering materials that includes composites, ceramics, polymers, and metals. These materials have an intrinsic property to oppose the damage due to the presence of the microstructures inside the materials.

The engineering materials are mainly classified as:

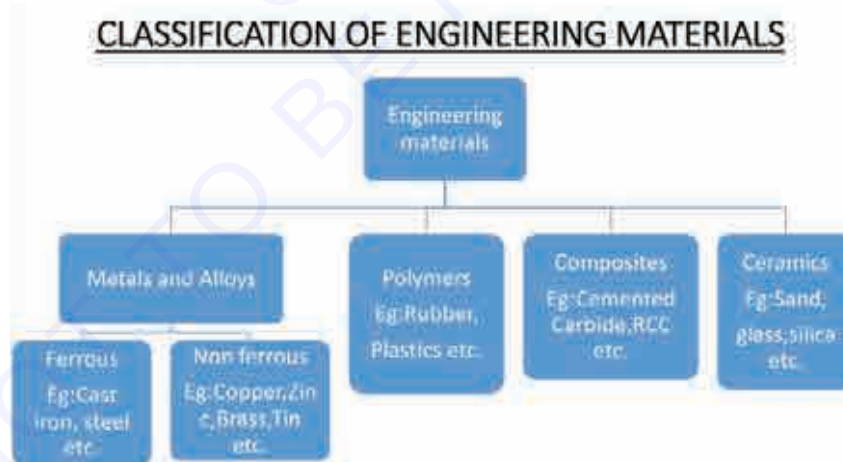
- 1 Metals and their alloys, such as Copper, Steel, Iron, Aluminum, etc.
- 2 Non-metals, such as plastic, glass rubber, etc.

Metal is a solid material that conducts heat & electricity, hard, shiny, fusible, ductile, and malleable. Metals are substances that have the tendency to donate electrons. Metals are electropositive in nature because all metals lose electrons from their outermost shell in order to become stable and hence become positively charged. They are electropositive in nature.

The engineering materials can mostly be classified as

- a Ferrous Metals (M.s, steel, C.I, etc)
- b Non-ferrous Metals (aluminum, copper, magnesium, nickel, titanium)
- c Plastics (thermoplastics, thermo sets)
- d Ceramics and Diamond e) Composite Materials
- f Nano-materials.

The engineering materials are often primarily selected based on their mechanical, physical, chemical and manufacturing properties.



Metals & Alloys

- Metals: Elements which give up electrons to form metallic bonds.
- Strength, lustrous, opaque to light, ductile, dimensional stability, malleable, good electrical and thermal conductivity.
- Crystalline in nature (Ordered arrangement of atoms).
- Castability, forgeability, machinability, weldability
- **Metals are classified into two.**
- Ferrous metal: Principal constituent iron. Ex: Cast iron, Wrought iron, Steel.

- Non ferrous metal: Do not possess iron as main Constituent. Ex: Copper, Tin, Zinc.
- Alloy is a mixture of two or more elements, with one being a metal. Ex. Bronze, Brass.

Polymers

- Organic compounds consist of carbon + one or more other element such as oxygen, hydrogen, nitrogen and chlorine.
- Long chain molecules formed by polymerization
- Basic building unit monomer
- Light in weight, soft, poor conductors of heat and electricity, corrosion resistance, formability
- Ex: Plastics, Leather, Cotton, Rubber, etc.

Composites

- Consists of two or more phases whose combination produces properties that are superior to its constituents.
- Matrix + Reinforcement = composite

Ex: Cemented carbide, Reinforced cement concrete, Fiber glass reinforced plastic etc.

Factors in selection of Materials for

Engineering Application

- Availability of the material
- Ease of handling
- Cost of the material
- Cost of processing
- Aesthetic
- Recycling
- Easiness in fabrication such as machinability, weldability, castability, forgeability etc.
- Capacity to meet service demand Ex: proper strength, wear resistance, corrosion resistance etc.
- **Hardness:** Resistance to indentation (penetration), abrasion or scratching
- Desirable property for dies, punches, cutting tool
- **Toughness:** Ability of material to absorb energy during plastic deformation up to fracture (During impact or shock load)

Mechanical Properties

- **strength:** Ability of material to withstand external load or force without failure
- **Tensile strength:** Ability of material to withstand tensile load (axial pull) without failure
- **Tensile strength = $\frac{\text{Max.tensile load}}{\text{original cr.sectional area}}$**
- **Compressive strength :** Ability of material to withstand compressive load (axial push) without failure
- **Compressive strength = $\frac{\text{Max.compressive load}}{\text{original cr.sectional area}}$**
- **shear strength:** Ability of material to withstand tangential load without failure across resisting section
- **shear strength = $\frac{\text{Max.tangential load}}{\text{original cr.sectional area}}$**
- **Torsional strength:** Ability of material to withstand twisting load without failure across resisting section
- **Torsional strength = $\frac{\text{Max.twisting load}}{\text{original cr.sectional area}}$**
- **Bending strength:** Ability of material to withstand breaking load by bending across resisting section
- **Bending strength = $\frac{\text{Max.bending load}}{\text{original cr.sectional area}}$**

- **Resilience:** Ability of material to absorb energy up to elastic limit
- Desirable property for spring materials
- Indicated by area under stress strain curve up to elastic limit
- **Brittleness:** Fracture without much deformation
- Opposite to ductility
- Ex for brittle material: Glass, Cast iron
- **Ductility:** Undergo deformation under tensile load without rupture.
- This property enables wire drawing.

Malleability: Undergo deformation under compressive load without rupture

- This property is useful in rolling of thin sheets
- Elasticity: Ability of a material to regain its original shape and size after removal of load

Ex: Steel, rubber

- **Plasticity:** Ability of material to be permanently deformed (without fracture) even after the load is removed.
- This property finds its use in forming, shaping and extruding operations of metals.

Creep: Slow and continuous deformation of material with time under constant load

- Metals shows creep at high temperature where as plastic creep at low temperature
- Ex: Beams in the roof of building shows creep with time.
- This property is considered in designing of boilers, IC engines, steam turbines etc.
- **Fatigue:** Failure of material caused due to cyclic or fluctuating loads.
- Occurs abruptly without showing any sign of failure
- This property is considered in designing of motor shafts, wire ropes, springs etc. subjected to cyclic loading.

Stiffness: Resistance of material to elastic deformation

- Modulus of rigidity is the measure of stiffness
- Materials which suffer less deformation under load have high degree of stiffness.
- This property is made used in spring balance and spring controlled measuring instruments.

Chemical Properties

- **Corrosion resistance:** Resistance to deterioration or decaying of metal by chemical or electrochemical reaction with its environment.
- Corrosion degrade material properties and reduce economic value.
- **Acidity:** Substance that gives hydrogen (H⁺) ions or hydronium ions (H₃O⁺) in aqueous solution.
 $\text{HCl} + \text{H}_2\text{O} = \text{H}_3\text{O}^+ + \text{Cl}^-$
- **Alkalinity:** Substance that gives hydroxyl ions (OH⁻) ions in aqueous solution
 $\text{Na}(\text{OH}) + \text{H}_2\text{O} = \text{Na}^+ + \text{OH}^-$

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Physical properties

- Density:
- Amount of mass contained in unit volume of material
- Higher the density the heavier is the substance
- For water 1000 Kg/m³
- $\rho = \frac{\text{Mass}}{\text{volume}}$
- **Unit:**
Kg/m³
- Viscosity(dynamic viscosity): Property of fluid which offers resistance to the flow of one layer of fluid over another adjacent layer of fluid
- Unit of viscosity : Ns/m²
- Kinematic viscosity, $\mu = \frac{\text{Dynamic viscosity}}{\rho}$
- Unit:m²/s
- **Specific gravity**
- Ratio of density of a substance to the density of fresh water at 4°C
- **S = Density of substance**
Density of water
- No unit. For mercury 13.6
- **Colour:**
- Represents reflective properties of substance
- Colour of material is that colour which is reflected.Eg: Yellow colour of gold
- **Porosity:** Presence of small holes or vacant space
- **Eg:Clay**
- **Melting point:** Temperature at which material changes its state from solid to liquid at standard atmospheric pressure

Types of Metal	Composition	Uses
Cast Iron	Has more carbon than most other types, which relatively affordable due to lack of other alloying elements outside of iron carbon.	Cookware, small components subject to wear such as, rods, gears, pins, and mining equipment.
Carbon Steel	Typically over 90% iron and the most frequently used ferrous metal.	Furniture, structure and automotive components.
Stainless Steel	100% recyclable usually a high amount of chromium which helps resist corrosion better than carbon steels.	Appliances, pharmaceutical and medical equipment, food-grade equipment, and knives.
Engineering Steel	Mostly iron, but amounts of copper, vanadium, tungsten manganese, and other elements can tailor it for toughness, ductility, tensile strength, hardness, and other properties.	Tools, dies, and machining equipment.

Alloy steel is a type of steel alloyed with several elements such as manganese, nickel, chromium, molybdenum, vanadium silicon and boron. These alloying elements are added to increase hardness, strength, wear resistance, and toughness.

Uses of Alloys in Daily Life

- Manufacturing of kitchenware.
- Manufacturing of plumbing.

- Manufacturing of hardware.
- Manufacturing of transport materials, automobile parts, etc
- Manufacturing of construction materials.
- Manufacturing of weapons.
- Manufacturing of heating appliance.
- Manufacturing of furniture.

Tools steels are distinguished by their hardness, resistance to wear, toughness, and resistance to softening at high temperatures. These properties make them suitable candidates for tool manufacturing, including reamers, drills, machine dies, and hand tools. Non-ferrous metals are used in countless manufacturing applications. You can find them in airplane fuselages as well automotive engines, fasteners, wiring kits, building roofs, pipes and more. Unlike ferrous metals, non-ferrous metals contain any meaningful amount of iron.

Types of Metals	Composition	Uses
Aluminium	Without the addition of alloying elements, it is more ductile and not quite as strong as many steels (and far lighter) but can still achieve very strengths. It forms a protective oxide layer that helps it reduce the risk of corrosion.	Marine equipment, construction material such as beams and rails, and certain types of cookware.
Copper	In an unalloyed state it is softer, more ductile, and not as strong as carbon steel. Copper can be alloyed with other elements to give it improved mechanical properties. When copper is alloyed with tin is bronze and when alloyed with significant amounts of zinc, it is brass.	Electrical components such as wires terminals, and other types of connectors, coating on some currency, pipes for plumbing, tools, and decorative work.
Nickel	Nickel is another popular non-ferrous alloy. Nickel is known for its toughness, ability to perform in high temperature and low temperature environments, and corrosion resistance. Nickel is not often used in its pure form, and like copper and aluminium, it is often alloyed with other elements to gain superior chemical and mechanical properties.	Cryogenic equipment such as tanks; hot-section aerospace equipment such as combustion chamber components; and marine equipment.
Brass	Brass is copper alloyed with a lot of zinc. Adding aluminium improves resistance to corrosion, manganese, iron, tin and aluminium its durability, and lead its machinability. Brass has high thermal and electrical conductivity.	Taps, locks, piping, letter boxes, ornaments and many electrical appliances.

Non-metallic materials are widely used across a range of industries for a wealth of applications, from composites used in aerospace to polymer pipes used to transport fluids and liquids. Rubber, vinyl and ceramic are all commonly used non-metallic materials, as well as adhesives and sealants.

Wood is a non-metallic material that sees heavy use in the construction industry. Wood still makes up furniture, home constructions, bridges, and innumerable smaller applications.

A rubber band is made up of almost all non-metal elements (mostly carbon and hydrogen) and they are very flexible.

Chair, table, bathroom items, duster, chalk, container, clothes, etc. a lot of items are made up of non-metallic materials, floor, walls, shoes, photo-frames, books, library shelves are also can be of non-metallic material.

It is categorized as non-metal because it is an allotrope of carbon that is a poor conductor of heat and electricity, non-malleable and non-ductile, non-reactive, and does not produce oxides and uses of ferrous metals, non-ferrous metals, alloys etc.

Properties use of non-metals, such as wood, plastic, rubber, ceramics industrial adhesives.

EXERCISE 3 : Heat & Temperature: Concepts

Heat & Temperature: Concepts

Differences: Temperature is a measurement of the average kinetic energy of particles in an object. Heat is a flow of energy from an object at a higher temperature to an object at a lower temperature. If you add energy as heat to a pot of water, the water's temperature starts to increase. Heat refers to the amount of energy in an object, measuring the total kinetic and potential energy contained by the molecules in that object. Temperature refers to the intensity of heat, measuring the average kinetic energy of molecules in a substance.

Effects of Heat: The important effects of heat on an object are:

Raises the temperature.

Increases volume.

Changes state.

Brings about chemical action.

Changes physical properties.

Different Units: Heat and temperature are two different but closely related concepts. Note that they have different units: temperature typically has units of degrees Celsius (°C) or Kelvin (K), and heat has units of energy, Joules

Units of Heat

Calories	1 cal	4.184J
Joules	1J	0.000239006 kcal / 0.000947817Btu
BTU	1 Btu	1055.06 J

The amount of heat gained or lost by a sample (q) can be calculated using the equation $q = mc\Delta T$, where m is the mass of the sample, c is the specific heat, and ΔT is the temperature change.

Relation of Specific Heat: Specific heat is defined by the amount of heat needed to raise the temperature of 1 gram of a substance 1 degree Celsius (°C). Water has a high specific heat, meaning it takes more energy to increase the temperature of water compared to other substances. The S.I. unit is joule per kilogram per Kelvin (Jkg-1K-1). This quantity is known as the specific heat capacity (or simply, the specific heat), which is the heat capacity per unit mass of a material. Experiments show that the transferred heat depends on three factors: (1) The change in temperature, (2) the mass of the system, and (3) the substance and phase of the substance. Specific heat capacity has two sub-classes called molar specific heat capacity at constant pressure and molar specific heat capacity at constant volume.

Thermal Capacity: Thermal capacity is defined as the quantity of heat necessary to produce a unit change of temperature in a unit mass of a material. Heat capacity is thus an inherent property of a substance. For example, water has an extremely high heat capacity of 4184 J per kilogram. This implies that 4184 J of heat energy is needed to raise the temperature of water by 1 Kelvin (or 1 Celsius). Start with the object at a known uniform temperature, add a known amount of heat energy to it, wait for its temperature to become uniform, and measure the change in its temperature.

Latent Heat

Latent heat is defined as the heat or energy that is absorbed or released during a phase change of a substance. It could either be from a gas to a liquid or liquid to a solid and vice versa. Latent heat is related to a heat property called enthalpy. The heat of freezing is the amount of thermal energy given off as liquid freezes, and the heat of vaporization is the amount of thermal energy that must be added to change a liquid to a gas. The SI unit of latent heat is J/kg. The symbol of latent heat is L.

Water Equivalent: The amount of water required to consume the same amount of heat as a substance consumes for one degree rise in the temperature is called water equivalent of a substance. It is also equivalent to the product of the mass of the substance and its specific heat. SI unit of water equivalent of calorimeter is kilogram i.e. Kg. Water equivalent is generally used in comparison of a water quantity. For example, Water equivalent of a calorimeter is nothing but amount of water which will absorb same amount of heat that the calorimeter will absorb. $\text{Water equivalent} = \text{mass} \times \text{specific heat} = m \times s \text{ calg}^{-1}\text{C}^{-1} = ms \text{ cal}^{\circ}\text{C}^{-1}$.

Mechanical Equivalent of Heat: Joule's mechanical equivalent of heat is the amount of work required to produce 1 calorie of heat. According to the first law of thermodynamics, the change in internal energy associated with a system is equal to the sum of work done by the system and heat added to the system. The potential energy of an object is due to its position and kinetic energy is due to its motion. The potential energy of an object is zero when it is in the movement and kinetic energy is zero when the object is in rest. The formula of mechanical energy is. $M.E = K.E + P.E$.

Different Temperature measuring scales and their relation

Celsius, Fahrenheit, and Kelvin are the three most popular temperature scales. Thermometers measure temperature using these three units, using predefined reference points to aid in comparison. Water has a freezing point of 0 °C and a boiling temperature of 100 °C on the Celsius scale with unit degrees Celsius.

5 different temperature scales?

- 1 Celsius scale.
- 2 Kelvin scale.
- 3 Fahrenheit scale.
- 4 Rankine scale.
- 5 Delisle scale.
- 6 Newton scale.
- 7 Réaumur scale.
- 8 Rømer scale.

Transference of heat

Heat transfer, any or all of several kinds of phenomena, considered as mechanisms, that convey energy and entropy from one location to another. The specific mechanisms are usually referred to as convection, thermal radiation, and conduction (see thermal conduction). A form of energy pass on through the conduction, convection, and radiation. Heat transfer occurs any time there is a temperature difference between two objects and occurs in the direction of decreasing temperature, meaning from a hot object to a cold object.

Conduction, Convection and Radiation

In conduction, heat transfer occurs between objects by direct contact. In convection, the heat transfer takes within the fluid. In radiation, heat transfer occurs through electromagnetic waves without involving particles. The heat transfer takes place due to the difference in temperature.

Heat can be transferred in three ways: by conduction, by convection, and by radiation.

Conduction is the transfer of energy from one molecule to another by direct contact. ...

Convection is the movement of heat by a fluid such as water or air. ...

Radiation is the transfer of heat by electromagnetic waves.

A blacksmith heating up a sword in hot coals, and the heat transferring up through the metal

Convection is the mode of heat transfer that is taking place in boiling of water, heat or light from the sun, microwaves from an oven, X rays from an X-ray tube and gamma rays radioactive elements.

Thermal Expansion

Thermal expansion is where an object expands and becomes larger due to a change in its temperature. A higher temperature means that the molecules are moving faster on average, causing them to take up more space. Consequently, objects that are heated up increase in size.

There three types of thermal expansion

Linear thermal expansion.

Areal thermal expansion.

Volume thermal expansion.

Thermal expansion defines the tendency of an object to change its dimension either in length, density, area, or volume due to heat. Gases expand much more than liquids and liquids expand much more than solids for a given rise in temperature.

Thermal expansion is used in various applications such as railroad track buckling, engine coolants, mercury in thermometers, joint expansion, etc. This article will cover the thermal expansion of solids, liquids, and gases and their applications.

$\Delta L = \alpha L \Delta T$ is the formula for linear thermal expansion, where ΔL is the change in length L , ΔT is the change in temperature, and α is the linear expansion coefficient, which varies slightly with temperature

Difference between heat and temperature

Heat	Temperature
1 It is a form of energy.	This tells the state of heat.
2 Its unit is calorie.	Its unit is degree.
3 Heat is measured by calorimeter.	Temperature is measured by thermometer.
4 By adding quantity of heat of two substances their total heat can be calculated.	By adding two temperatures we cannot find the temperature of the mixture.
5 By heating a substance the quantity of heat is though increased regardless of increase in temperature. them.	Two substances may read the same temperature they might be having different amount of heat in temperature is measured by thermometers.

Boiling point

Any substance starts turning into a gas shows the temperature at which it boils this is known as the boiling point. The boiling point of water is 100°C.

Melting point

The temperature at which any solid melts into liquid or liquid freezing to solid is called the melting point of substance. The melting point of ice is 0°C.

List of melting point and boiling point of metals and Non -metals

Metals and Non-metals	Melting point °C	Boiling point °C	Metals and Non-metals	Melting point °C	Boiling point °C
Aluminium	660.25	2519	Manganese	1246	2061
Argon	-189.19	-185.85	Mercury	-38.72	357
Arsenic	817	614	Molybdenum	2617	4639
Barium	729	1897	Nickel	1453	2913
Beryllium	1287	2469	Nitrogen	-209.86	-195.79
Bromine	-7.1	58.8	Oxygen	-226.65	-182.95
Cadmium	321.18	767	Phosphorus (white)	44.1	280
Calcium	839	1484	Plutonium	640	3228
Carbon (diamond)	3550	4827	Potassium	63.35	759
Carbon (graphite)	3675	4027	Radium	700	1737
Chlorine	-100.84	-34.04	Silicon	1410	3265
Cobalt	1495	2927	Silver	961	2162
Copper	1084.6	2562	Sodium	98	883
Gold	1064.58	2856	Sulfur	115.36	444.6
Helium	-	-268.93	Tin	232.06	2602
Hydrogen	-259.98	-252.87	Titanium	1660	3287
Iodine	113.5	184.3	Tungsten (wolfram)	3422	5555
Iridium	2443	4428	Uranium	1132	4131
Iron	1535	2861	Zinc	419.73	907
Lead	327.6	1749			
Lithium	180.7	1342			
Magnesium	650	1090			

Related Calculations

Example 1

A rod of length 5 m heated to 40°C. If the length increases to 7 m after some time.

Find the expansion coefficient. Room temperature is 30°C.

Solution

Given

Initial length $L_0 = 5$ m,

Expanded length $L = 7$ m

Change in length $\Delta L = 7 - 5 = 2$ m

Temperature difference $\Delta T = 40^\circ\text{C} - 30^\circ\text{C} = 10^\circ\text{C}$

Absolute temperature $T = 10^\circ\text{C} + 273 = 283$ K

The linear expansion formula is given by,

$$\Delta L / (L_0 \Delta T) = \alpha$$

$\therefore$ Length expansion coefficient is given by,

$$\alpha = \Delta L / (L_0 \Delta T)$$

$$= 2 / 5 \times 283$$

$$\alpha = 14 \times 10^{-4} \text{ K}^{-1}$$

Where,

A = original area,

ΔA = change in the area,

αA = area expansion coefficient,

ΔT = temperature difference,

A_0 = expanded area.

Example 1

A rod of length 5 m heated to 40°C. If the length increases to 7 m after some time. Find the expansion coefficient. Room temperature is 30°C.

Solution

Given:

Initial length $L_0 = 5$ m,

Expanded length $L = 7$ m

Change in length $\Delta L = 7 - 5 = 2$ m

Temperature difference $\Delta T = 40^\circ\text{C} - 30^\circ\text{C} = 10^\circ\text{C}$

Absolute temperature $T = 10^\circ\text{C} + 273 = 283$

Assignment

- 1 Convert 0°C into $^{\circ}\text{F}$

$$\frac{{}^{\circ}\text{F} - 32}{180} = \frac{{}^{\circ}\text{C}}{100}$$

$${}^{\circ}\text{F} - 32 = \frac{{}^{\circ}\text{C}}{100} \times 180$$

$${}^{\circ}\text{F} - 32 = \frac{0}{100} \times 180$$

$${}^{\circ}\text{F} = 0 + 32$$

$$= 32^{\circ}\text{F}$$

$$\mathbf{0^{\circ}\text{C} = 32^{\circ}\text{F}}$$

- 2 Convert -40°C into $^{\circ}\text{F}$

$$\frac{{}^{\circ}\text{F} - 32}{180} = \frac{{}^{\circ}\text{C}}{100}$$

$${}^{\circ}\text{F} - 32 = \frac{{}^{\circ}\text{C}}{100} \times 180$$

$${}^{\circ}\text{F} - 32 = \frac{-40}{100} \times 180$$

$$\text{F} - 32 = -72$$

$${}^{\circ}\text{F} = -72 + 32$$

$$= -40^{\circ}\text{F}$$

$$\mathbf{-40^{\circ}\text{C} = -40^{\circ}\text{F}}$$

- 3 Convert 37°C into K

$$\frac{{}^{\circ}\text{C}}{100} = \frac{{}^{\circ}\text{K} - 273}{100}$$

$${}^{\circ}\text{K} - 273 = \text{C}$$

$${}^{\circ}\text{K} = \text{C} + 273$$

$${}^{\circ}\text{K} = 37 + 273$$

$$= 310 \text{ K}$$

$$\mathbf{37^{\circ}\text{C} = 310\text{K}}$$

- 4 Convert 70°C into Reaumur

$$\frac{{}^{\circ}\text{C}}{100} = \frac{{}^{\circ}\text{R}}{80}$$

$${}^{\circ}\text{R} = \frac{\text{C}}{100} \times 80$$

$${}^{\circ}\text{R} = \frac{70}{100} \times 80 = 56$$

$$\mathbf{70^{\circ}\text{C} = 56^{\circ}\text{R}}$$

5 Convert -25°F into $^{\circ}\text{C}$

$$\frac{^{\circ}\text{C}}{100} = \frac{^{\circ}\text{F} - 32}{180}$$

$$\frac{^{\circ}\text{C}}{100} = \frac{-25 - 32}{180}$$

$$^{\circ}\text{C} = \frac{-57}{180} \times 100$$

$$^{\circ}\text{C} = \frac{-285}{9} = -31.66$$

$$\mathbf{-25^{\circ}\text{F} = -31.7^{\circ}\text{C}}$$

6 Convert 98.6°F into $^{\circ}\text{C}$

$$^{\circ}\text{C} = \frac{^{\circ}\text{F} - 32}{180} \times 100$$

$$^{\circ}\text{C} = \frac{98.6 - 32}{180} \times 100$$

$$= \frac{66.6}{180} \times 100$$

$$= \frac{6660}{180} = 37^{\circ}\text{C}$$

$$\mathbf{98.6^{\circ}\text{F} = 37^{\circ}\text{C}}$$

Assignment

1 $10.5^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

2 $40^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

3 $60^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

4 $80^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

5 $105^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

6 $100^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

7 $-80^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

8 $200^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

9 $605^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

10 $1250^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{F}$

11 $77^{\circ}\text{F} = \underline{\hspace{1cm}}^{\circ}\text{C}$

12 $20^{\circ}\text{F} = \underline{\hspace{1cm}}^{\circ}\text{C}$

13 $428^{\circ}\text{F} = \underline{\hspace{1cm}}^{\circ}\text{C}$

14 $-210^{\circ}\text{F} = \underline{\hspace{1cm}}^{\circ}\text{C}$

15 $88^{\circ}\text{F} = \underline{\hspace{1cm}}^{\circ}\text{C}$

16 $110^{\circ}\text{F} = \underline{\hspace{1cm}}^{\circ}\text{C}$

17 $72^{\circ}\text{F} = \underline{\hspace{1cm}}^{\circ}\text{C}$

18 $50^{\circ}\text{F} = \underline{\hspace{1cm}}^{\circ}\text{C}$

19 $900^{\circ}\text{F} = \underline{\hspace{1cm}}^{\circ}\text{C}$

20 $72^{\circ}\text{R} = \underline{\hspace{1cm}}^{\circ}\text{C}$

21 $143^{\circ}\text{C} = \underline{\hspace{1cm}}^{\circ}\text{K}$

22 $373^{\circ}\text{K} = \underline{\hspace{1cm}}^{\circ}\text{C}$

23 $746^{\circ}\text{K} = \underline{\hspace{1cm}}^{\circ}\text{F}$

24 At what temperature will the reading of a Fahrenheit thermometer be double of a centigrade one.

EXERCISE 4 : Force and Motion

Force and Motion

Newton's laws of motion

An object at rest remains at rest, and an object in motion remains in motion at constant speed in a straight line unless acted on by an unbalanced force. The acceleration of an object depends on the mass of the object and the amount of force applied. Whenever one object exerts a force on another object, the second object exerts an equal and opposite on the first.

Newton's three laws of motion help someone understand how objects behave when standing still, when moving and when forces act upon them. Sir Newton's three laws are Newton's First Law: Inertia, Newton's Second Law: Force, Newton's Third Law: Action & Reaction.

Displacement

Displacement is defined as the change in position of an object. It is a vector quantity and has a direction and magnitude. It is represented as an arrow that points from the starting position to the final position. For example- If an object moves from a position to B, then the object's position changes.

Displacement is the change in the position of an object. It is a vector quantity. The SI unit of displacement is meter (m).

Displacement can be calculated by measuring the final distance away from a point, and then subtracting the initial distance. Displacement is key when determining velocity, (which is also a vector). Velocity = displacement/time whereas speed is distance/time.

Velocity

Velocity is the prime indicator of the position as well as the rapidity of the object. It can be defined as the distance covered by an object in unit time. Velocity is defined as the rate of change of distance of a body with respect to time. Its unit in SI is m/s. The different types of velocities are uniform velocity, variable velocity, average velocity and instantaneous velocity. A body when covers an equal distance with an equal interval of time, this condition of the velocity is known as uniform velocity. Or, we can say that when the direction and magnitude of speed of a body do not change with time, then the body is said to be at uniform velocity.

Acceleration

Acceleration is the rate of change of velocity. Usually, acceleration means the speed is changing, but not always. When an object moves in a circular path at a constant speed, it is still accelerating, because the direction of its velocity is changing. the SI unit of acceleration is m/s^2 (meter per sec square). The acceleration can be positive, negative, or zero depending upon the velocity and its direction. Mainly Uniform acceleration, non-uniform acceleration, and average acceleration are the three types of accelerated motions. Acceleration (a) is the change in velocity (Δv) over the change in time (Δt), represented by the equation $a = \Delta v / \Delta t$. This allows you to measure how fast velocity changes in meters per second squared (m/s^2). Acceleration is also a vector quantity, so it includes both magnitude and direction. if you are traveling in a car which is moving at the speed of 60 kmph and after 1 min the speed of the car is 65 kmph, which means you are accelerating.

Retardation

Retardation is defined as the rate of decrease of velocity with time. Suppose if a car is slowing down, its velocity is decreasing, so its acceleration is negative. But retardation is positive. Retardation is negative of acceleration. The SI unit of Retardation (m/s^2) meter per second squared. According to the definition, Acceleration can be defined as the rate of change of the velocity of any object. Retardation is the total opposite of acceleration i.e., negative acceleration.

Rest & Motion Such As Linear, Angular

Rest: An object is said to be at rest if it does not change its position with respect to its surroundings with time.

Motion: An object is said to be in motion if its position changes with respect to its surroundings and time. A body may be at rest relative to one object and at the same time it may be in motion relative to another object. For example, a passenger sitting in a moving bus is at rest with respect to his fellow passenger but he is in motion with respect to a man standing outside the bus.

The examples of motion include: running, cycling, jumping, swimming, eating, drinking, playing, writing, typing, moving cars, throwing ball. The examples of rest include: sleeping, sitting, standing, staring, lying, a fixed clock, bottle kept on a table, a stopped car.

Linear motion is any that moves along a straight line in one direction. The direction can either be horizontal vertical or inclined direction. Example approach run. Angular motion is rotator motion it occurs when all points on a body or object move in a circular path about the same fixed central line or axis.

Examples include the rotation of a bicycle tire, a merry-go-round, a toy top, a food processor, a laboratory centrifuge, and the orbit of the Earth around the Sun an athlete running a 100-meter dash along a straight track.

Force: Force can be defined as a push or a pull that changes or tends to change the state of rest or uniform motion of an object or changes the direction or shape of an object. It causes objects to accelerate or add to their overall pressure. The two main types of forces are contact and non-contact forces.

Some examples of force are Nuclear force, gravitational force, Frictional force, magnetic force, electrostatic force, spring force and so on.

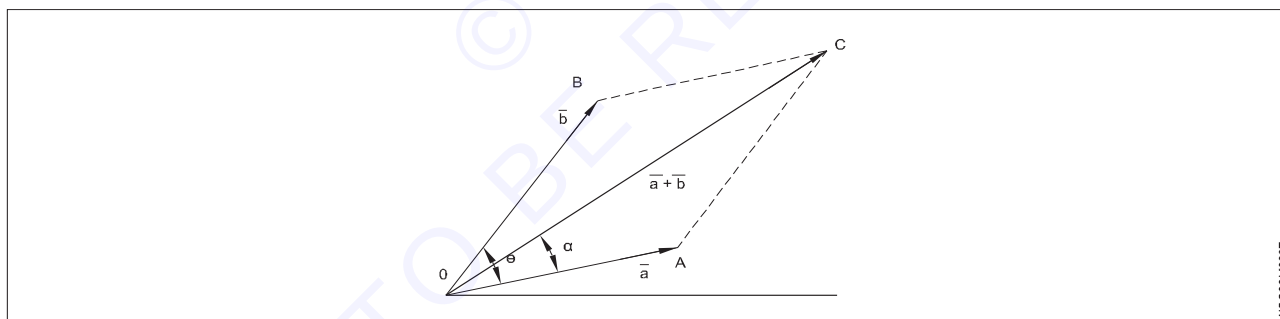
Units: Therefore, the unit of force is kg m/s², which is what we refer to as Newton or N. In the CGS system of units, the unit of mass is gram or g, and the unit of acceleration is cm/s². Therefore, the CGS unit of force is g cm/s², which is called dyne or Dyn.

One Newton is the force needed to accelerate one kilogram of mass at the rate of one metre per second squared. 1 N = 1 kgm / sq.sec.

The Newton (symbol: N) is the SI unit of force. It is named after Sir Isaac Newton. The newton because of his work on classical mechanics. A Newton is how much force is required to make a mass of one kilogram accelerate at a rate of one metre per second squared.

Different Laws for Composition and Resolution of Forces

A force is to be resolved into two components. Then: When one of the components is known, the second component can be obtained by applying the triangle rule. When the line of action of each component is known, the magnitude and the sense of the components are obtained by parallelogram law.



The process of substituting a force by its components so that the new effect on the body remains the same is known as resolution of a force. The process of finding out the resultant force of a number of given forces is called the composition/compounding of forces.

Any force can be resolved into individual component forces in the same way as individual component forces can be composed together. A force can be resolved into two component forces graphically or with the use of trigonometry.

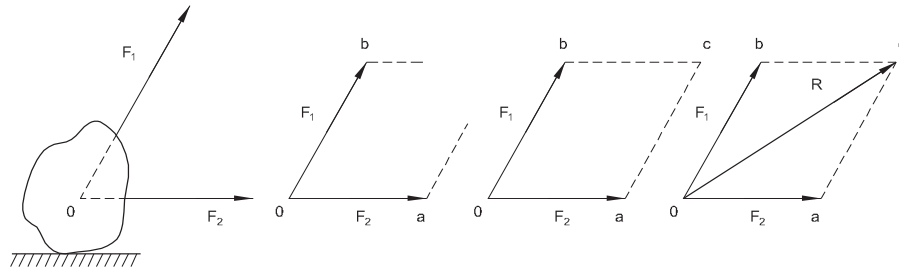
$$\text{Resultant } R = \sqrt{P^2 + Q^2 + 2PQ\cos\theta}$$

$$\alpha = \tan^{-1} \left(\frac{Q \sin\theta}{P + Q \cos\theta} \right)$$

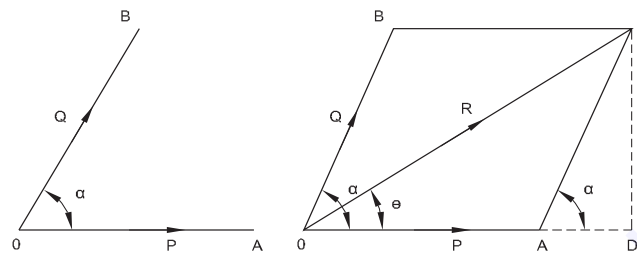
- ✓ The process of replacing a force system by its resultant is called composition.
- ✓ The Resultant of a pair of concurrent (occurring at the same time and gathering at the same point) forces can be determined by means of Parallelogram Law, which states that:

Two forces on a body can be replaced by a single force called the resultant by drawing the diagonal of the Parallelogram with sides equivalent to the two forces.

For example if F₁ and F₂ are two forces, the resultant (R) can be found by constructing the parallelogram.



"If two forces, acting at a point be represented in magnitude and direction by the two adjacent sides of a parallelogram, then their resultant is represented in magnitude and direction by the diagonal of the parallelogram passing through that point".



From C draw CD perpendicular to OA produced.

Let α = Angle between two forces P and Q = $\angle AOB$

Now $\angle DAC = \angle AOB$ (Corresponding angles) = α

In parallelogram OACB, AC is parallel and equal to OB.

• $\therefore AC = Q$

In triangle ACD,

$AD = AC \cos \alpha = Q \cos \alpha$

$CD = AC \sin \alpha = Q \sin \alpha$

In triangle OCD,

$OC^2 = OD^2 + DC^2$

But $OC = R$

$OD = OA + AD = P + Q \cos \alpha$

And

$DC = Q \sin \alpha$

$\therefore R^2 = (P + Q \cos \alpha)^2 + (Q \sin \alpha)^2$

$= P^2 + Q^2 \cos^2 \alpha + 2PQ \cos \alpha + Q^2 \sin^2 \alpha$

$= P^2 + Q^2 (\cos^2 \alpha + \sin^2 \alpha) + 2PQ \cos \alpha$

$= P^2 + Q^2 + 2PQ \cos \alpha$ ($\therefore \cos^2 \alpha + \sin^2 \alpha = 1$)

Magnitude of Resultant (R) $\therefore R = \sqrt{P^2 + Q^2 + 2PQ \cos \alpha}$

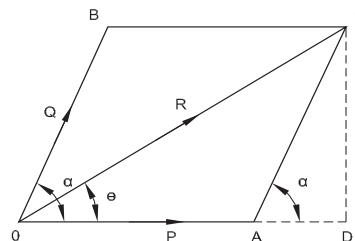
• Direction of Resultant

Let θ = Angle made by resultant with OA.

Then from triangle OCD,

$$\tan \theta = \frac{CD}{OD} = \frac{Q \sin \alpha}{P + Q \cos \alpha}$$

$$\theta = \tan^{-1} \left(\frac{Q \sin \alpha}{P + Q \cos \alpha} \right)$$



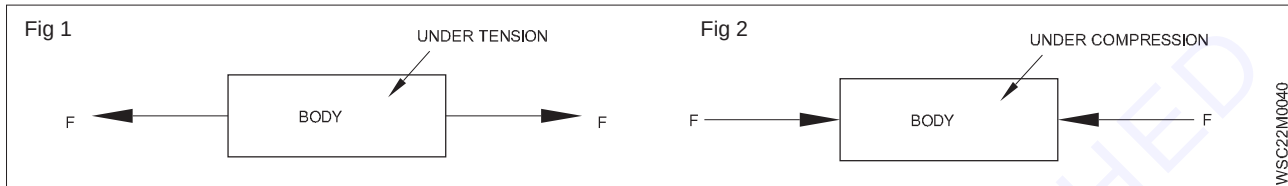
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Types of forces

- tensile force
- compressive force
- shear force.

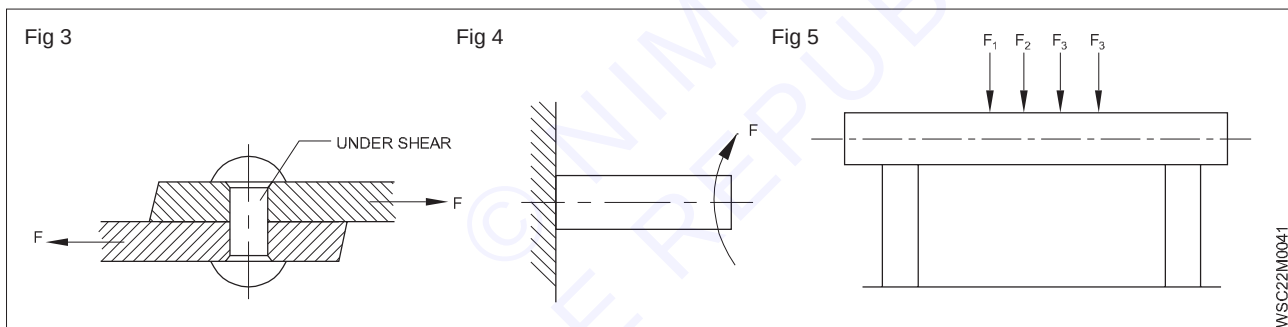
Tensile force: When two equal and opposite forces act on a body and have the same line of action, and if they tend to increase the length of the body, the applied forces are called tensile forces. (Fig 1)

Compressive force: When two equal and opposite forces act on a body having the same line of action and if they tend to compress the body and try to reduce the length of the body, the forces applied are called compressive forces. (Fig 2)



Shear force: When two equal and opposite forces having different lines of action act on a body such that one section of the body tends to slide over another section which results in a shearing action then the forces are referred to as shear forces. (Fig 3)

Direct effect of forces: Forces acting on a body can cause in the material. (Fig 4 & Fig 5)



- Tension
- Compression
- Shearing effect
- Twisting effect
- Bending effect.

Force is mainly classified as tensile force, compressive force and shear force.

Stress

The internal opposite force to the external load per unit area is known as stress. The unit of stress depends upon the force applied and area of original cross-section of material. It is represented by σ (Sigma)

$$\therefore \text{Stress} = \frac{\text{Force applied}}{\text{Area of original cross section}}$$

$$\text{Shear stress } (\tau) = \frac{F}{A} \left(\frac{\text{N}}{\text{cm}^2} \text{ or } \frac{\text{Kg}}{\text{cm}^2} \right)$$

Types of Stress

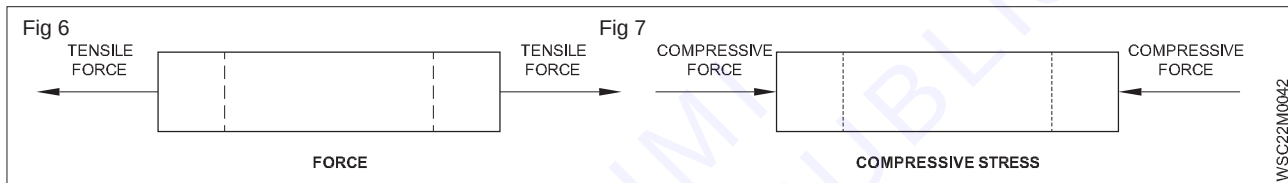
- 1 Tensile stress
- 2 Compressive stress
- 3 Shear stress
- 4 Torsional Stress

1 **Tensile stress:** When a material is subjected to two equal and opposite axial pulls, the material tends to increase in length. The resistance offered against this increase in length is called tensile stress. The corresponding strain is called tensile strain. (Fig 6)

E.g.

- 1 When brake is applied the brake rod is under tensile stress.
- 2 During tightening of bolt or nut.
- 3 Belt driving the fan.
- 4 Crane rope (When rope is pulling)

2 **Compressive stress:** When a material is subjected to two equal and opposite axial pushes, the material tends to decrease in length. The resistance offered against the decrease in length is called compressive stress. The corresponding strain is called compressive strain. (Fig 7)



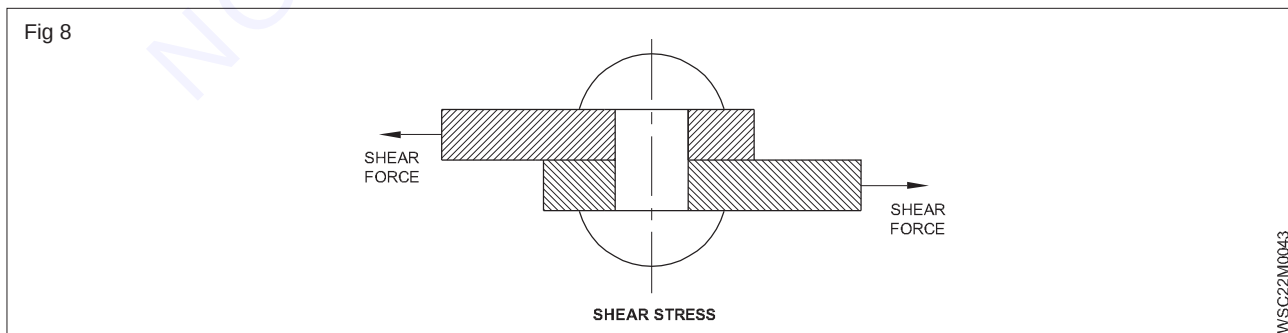
$$\text{Compressive stress} = \frac{\text{Axial push}}{\text{Area of cross section}}$$

$$\text{Compressive stress} = \frac{\text{Decrease in length}}{\text{Original length}}$$

Eg.

- 1 Compressive stress on connecting rod on the first part of power stroke
- 2 Compressive stress on push rod during valve opening
- 3 Clutch lining when the clutch is engaged

3 **Shear stress:** When a material is subjected to two equal and opposite forces acting tangentially across the resisting section, the body tends to be sheared off across the cross section. The stress included is called shear stress. It is represented by τ . The corresponding strain is called shear strain. (Fig 8)



$$\text{Shear stress } (\tau) = \frac{F}{A} \left(\frac{\text{N}}{\text{cm}^2} \text{ or } \frac{\text{Kg}}{\text{cm}^2} \right)$$

Eg.

- 1 Rivets
- 2 Gudgeon Pin
- 3 Spring shackle pin
- 4 Brake rod rivets
- 5 Chassis rivets
- 6 Fly wheel holding bolts
- 7 Swivel pins
- 8 Gear box shaft
- 9 Axle shaft

4 Torsional stress: When a shaft is subjected to the action of two equal and opposite couples acting in parallel planes, then the shaft is said to be in torsion. The stress set up by the torsion is known as torsional shear stress.

Eg.

- 1 Rear axle
- 2 Crank shaft
- 3 Coil springs
- 4 Propeller shaft
- 5 Starter motor armature shaft

Concept on Center of Gravity and Equilibrium of Forces in Plane

The center of gravity (CG) of an object is the point at which weight is evenly dispersed and all sides are in balance. A human's center of gravity can change as he takes on different positions, but in many other objects, it's a fixed location.

There are certain conditions for Coplanar Forces to be in equilibrium. These include: The sum of forces must be zero. The sum of the moments of the forces about a point in the anticlockwise direction is equal to the sum of the moments of the forces about the same point in the clockwise direction.

Equilibrium forces are a set of forces whose resultant is zero. An 'Equilibrant' is the force that brings a group of forces into equilibrium. The equilibrant has the same magnitude as the resulting force but opposite direction. A force comprises both a magnitude (magnitude) and a direction, making it a vector quantity. For any system of coplanar forces to be in equilibrium following condition should be satisfied: The algebraic sum of the horizontal components of all the forces should be zero.

Concept of Moment of Inertia and Torque

Moment of inertia is defined as the quantity expressed by the body resisting angular acceleration which is the sum of the product of the mass of every particle with its square of a distance from the axis of rotation.

Mass moment of inertia, also known as rotational inertia, is a quantity that is used in measuring a body's resistance to a change in its rotation direction or angular momentum. It basically characterizes the acceleration undergone by an object or solid when torque is applied.

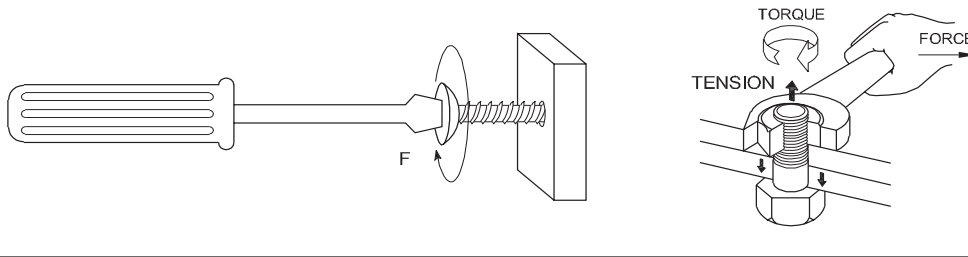
When a bus or a train starts suddenly, the passenger standing inside it falls backward: It happens because the feet of the passenger being in contact with the floor of the bus come in motion along with the bus but the upper part of the body remains at rest due to inertia of rest. Hence the passenger falls backward.

Torque is the measure of the force that can cause an object to rotate about an axis. Force is what causes an object to accelerate in linear kinematics. Similarly, torque is what causes an angular acceleration. Hence, torque can be defined as the rotational equivalent of linear force.

A doorknob turns because a linear, downward force is applied perpendicular to the knob. A coin spins because it is pushed with a linear force that is applied at some angle relative to the edge of the coin.

Torque is the product of force (unit N) and perpendicular distance (unit m) of line of force from the axis. Hence SI unit of torque is Nm.

Fig 9



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Assignment

Ex: 1.

Amit has a cycle mass of 50 kg. How much force should he apply to the cycle so that it should travel with the acceleration of 10 m/s²?

Solution:

Known,

- M (Mass of toy car) = 50 Kg,
- A (Acceleration) = 10 m/s²,

F is Force to be applied : = M × A

$$= 50\text{Kg} \times 10 \text{ m/s}^2 = 500 \text{ Kg m/s}^2 = 500 \text{ N.}$$

Solved Problems

Ex.2. Virat uses 30N of power to push a 2kg box to the left. Rahul uses 40N of force to push the same box to the right. What is the box's net force?

Possible responses:

- 1.33N
- 10N
- 10N
- 0.75N

Ans. We sum together all the forces to get the net force:

$$F_{\text{net}} = F_{\text{virat}} + F_{\text{Rahul}} \quad F_{\text{net}} = F_{\text{virat}} + F_{\text{Rahul}}$$

Since force is a vector, the direction of action is important. We shall turn leftward motion into a negative and rightward motion into a positive. Virat is pushing to the left with 30N

hence his force is 30N. Rahul was pushing to the right with 40N

thus his force will stay 40N.

We can get the net force by summing the individual force together.

$$F_{\text{net}} = -30\text{N} + 40\text{N} \quad F_{\text{net}} = -30\text{N} + 40\text{N}$$

$$F_{\text{net}} = 10\text{N}$$

Ex. 3. A constant force acting on a body of mass 3.0 kg changes its speed from 2.0 m/s to 3.5m/s in 25 s. The direction of the motion of the body does not changes. What is the magnitude and what is the direction of the force?

Solution

Mass of the body, $m = 3 \text{ kg}$

Initial speed of body, $u = 2 \text{ m/s}$

Final speed of body, $v = 3.5 \text{ m/s}$

Time, $t = 25 \text{ s}$

Using the first equation of motion, the acceleration (a) produced in the body can be calculated as:

$$v = u + at$$

$$a = \frac{v - u}{t}$$

$$= \frac{3.5 - 2}{25} = 0.06 \text{ m/s}^2$$

$$F = ma$$

$$= 3 \times 0.06 = 0.18 \text{ N}$$

Since the application of the force does not change the direction of the body, the net force acting on the body goes in the direction of its motion.

Ex. 4. A stream of water flowing horizontally with a speed 15 ms^{-1} of gushes out of a tube of cross-sectional area 10^{-2} m^2 , and hits a vertical wall nearby. What is the force exerts on the wall by the water's impact, assuming it does not rebound?

Solution

Speed of water stream, $v = 15 \text{ m/s}$

The cross-sectional area of the tube, $A = 10^{-2} \text{ m}^2$

The volume of water that comes out through the pipe per second,

$$V = A \times v = 15 \times 10^{-2} \text{ m}^3/\text{s}$$

Density of water, $\rho = 1000 \text{ kg/m}^3$

Mass of water that flows out in the pipe per second = density $\times$ volume $V = 150 \text{ kg/s}$

The water hits the wall and doesn't rebound. Therefore, the force that the water exerts on the wall is given by

Newton's second law of motion as:

$$F = \text{Rate of change of momentum} = \frac{P}{t}$$

$$= \frac{mv}{t}$$

$$= 150 \times 15 = 2250 \text{ N}$$

Example 5. A stream of water flowing horizontally with a speed 15 ms^{-1} of gushes out of a tube of cross-sectional area 10^{-2} m^2 , and hits a vertical wall nearby. What is the force exerts on the wall by the water's impact, assuming it does not rebound?

Solution

Speed of water stream, $v = 15 \text{ m/s}$

The cross-sectional area of the tube, $A = 10^{-2} \text{ m}^2$

The volume of water that comes out through the pipe per second,

$$V = A \times v = 15 \times 10^{-2} \text{ m}^3/\text{s}$$

Density of water, $\rho = 1000 \text{ kg/m}^3$

Mass of water that flows out in the pipe per second = density $\times$ volume $V = 150 \text{ kg/s}$

The water hits the wall and doesn't rebound. Therefore, the force that the water exerts on the wall is given by

Newton's second law of motion as:

$$F = \text{Rate of change of momentum} = \frac{P}{t}$$

$$= \frac{mv}{t}$$

$$= 150 \times 15 = 2250 \text{ N}$$

Assignment:

1. Which of the following is NOT true for an object moving along a straight path in an accelerated motion?

- a. Its velocity always changes
- b. Its speed keeps changing
- c. (d) It always goes away from the Earth
- d. It always goes away from the Earth

Answer: c. A force is always acting on it

Explanation: For the accelerated motion of an object along a straight line, a non-zero force must be acting on the object, which is increasing its velocity and speed. However, the direction of force is not given so it can't be determined whether it is moving away from earth or not.

2. The inertia of an object causes the object to

- a. decrease its speed
- b. Increase its speed
- c. resist any change in the state of its motion
- d. decelerate due to friction

Answer: (c) resist any change in the state of its motion

Explanation: The inertia of an object causes the object to resist any change in the state of its motion.

3. Which of the following is true for the third law of motion?

- a. Action-Reaction pair always acts on the same body.
- b. They act on different bodies in opposite directions
- c. Action-Reaction pairs have the same magnitudes and directions
- d. Act on either body at normal to each other

Answer: (b) They act on different bodies in opposite directions.

Explanation: Action-Reaction always acts on different bodies in opposite direction and are equal in magnitude.

4. Which of the following is the SI units of force?

- a. Kg/s^2
- b. Kg/s
- c. Newton-metre
- d. Newton

Answer: (d) Newton

Explanation: Newton is the SI unit of force.

5. If the mass of the body is doubled and its velocity becomes half, then the linear momentum of the body will

- a. become double
- b. remain the same
- c. become half
- d. become four times

Answer: (b) remain the same

Explanation: If the body's mass is doubled and its velocity becomes half, then the body's linear momentum will remain the same.

6. The linear momentum of an object is 250 g cm/s . If the velocity of the object is 5 m/s , then the mass of the object is

- a. 0.5 g
- b. 5 kg

- c. 0.5 mg
- d. 5 mg

Answer: (a) 0.5 g

Explanation: Given, velocity, $v = 5 \text{ m/s} = 500 \text{ cm/s}$, momentum, $p = 250 \text{ g cm/s}$, mass, $m = ?$

We know that, momentum of a body is given by $p = mv$

or, $m = p/v = 250/500 = 0.5 \text{ g}$

7. Which of the following is true about force?

- a. Force is invisible
- b. Force can move a body
- c. It can deform a body
- d. All of the above

Answer: (d) all of the above

Explanation: All of the given points are true for force.

8. A goalkeeper in a football game pulls his hands backwards after holding the ball shot at the goal. This enables the goalkeeper to

- a. increase the rate of change of momentum
- b. decrease the rate of change of momentum
- c. increase the force exerted by the balls on the hands
- d. exert larger force on the ball

Answer: (b) decrease the rate of change of momentum

Explanation: A goalkeeper in a football game pulls his hands backwards after holding the ball shot at the goal, enabling the goalkeeper to decrease the rate of change of momentum.

9. Which law is also known as the law of inertia?

- a. Newton's first law of motion
- b. Newton's second law of motion
- c. Newton's third law of motion
- d. Law of conservation of momentum

Answer: (a) Newton's first law of motion

Explanation: The inertia of a body is the tendency to not change its static or motional state. Newton's first law of motion says that a static body will remain motionless, and a body in motion will stay in motion until a force acts on it. Therefore, Newton's first law is associated with inertia and is also known as the law of inertia.

10. A passenger in a moving train tosses a coin that falls behind him. It means that the motion of the train is

- a. uniform
- b. accelerated
- c. retarded
- d. along circular tracks

Answer: (b) accelerated

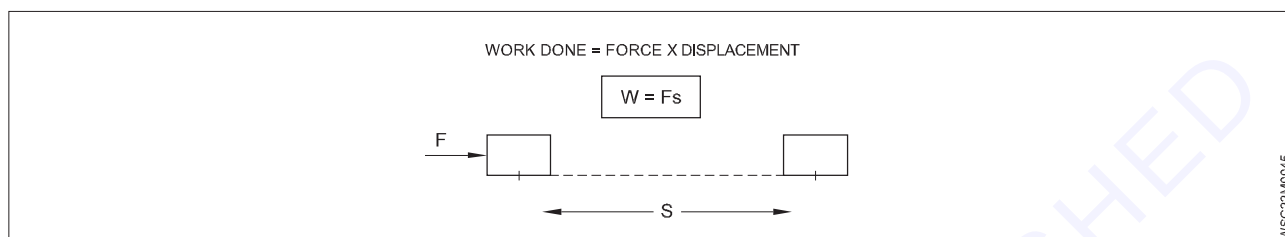
Explanation: A passenger in a moving train tosses a coin that falls behind him. It means that the motion of the train is accelerated.

EXERCISE 5 : Work, power & energy

Definitions: When a force is applied to a body and there is a displacement of that body along in the direction of force then the work is said to be done by that force. The work done is a scalar quantity.

Work done is denoted by W.

$$W = F \times S$$

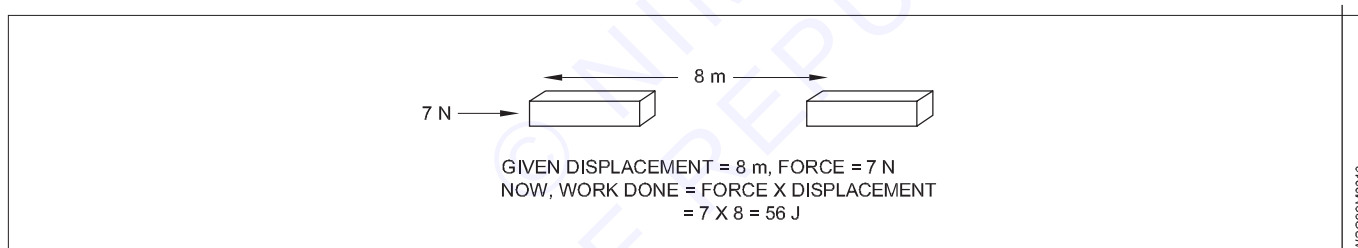


Units, Calculation & Application

The SI unit of work is Joule (J) or N m and the CGS unit is erg. The calorie (cal) is also a unit of work.

$$1 \text{ erg} = 10^{-7} \text{ Joule} = 10^{-7} \text{ N m}$$

$$1 \text{ cal} = 4.186 \text{ Joule}$$



The SI unit of work is joule (J). Joule is defined as the work done by a force of one Newton causing a displacement of one meter. Sometimes, Newton-metre (N-m) is also used for measuring work.

There are many examples of work done in our everyday life. For example, a horse pulling a plow through the field, a father pushing a grocery cart in a shopping mall, or a student lifting a bag on his back on his back or his shoulder full of books and many more.

POWER: Power is the amount of energy that is transferred in a unit of time.

$$\text{Work done} / \text{Time taken} = \text{Force} \times (\text{Displacement} / \text{Time taken})$$

Since Work done / Time taken = Power, and Displacement / Time taken = Velocity, we can simplify the formula to: **Formula:** Power = Force (N) x Velocity in the direction of the force (m/s) Simplified formula: $P = Fv$. SI Unit: Watt (W).

ENERGY: Energy can be defined as the ability to do work.

The equation developed by Albert Einstein, which is usually given as $E = mc^2$, showing that, when the energy of a body changes by an amount E (no matter what form the energy takes), the mass (m) of the body will change by an amount equal to E/c^2 .

There is a significant difference between work and energy. Work is the transferring of an amount of energy with the help of a force covering a particular distance in a direction. Energy is also referred to as the force that works at a certain distance.

Concept of HP, IHP, BHP & FHP – Related Calculations with Mechanical Efficiency. S.I. Unit of Power and their Relations.

Simple terms **BHP= IHP - FP**, where FP is the frictional power loss, Frictional loss is directly proportional to square of the engine speed. Indicated horse power (IHP) - It is the power generated in the engine cylinder and received by the piston. It is the power developed in a cylinder without accounting frictional losses. Brake horse power (BHP) - It is the power delivered by the engine at the end of the crankshaft.

$i hp = P \times L \times A \times N / 33,000$ where P = Mean indicated pressure, in psi L = Length of stroke, in feet A = Effective area of the piston, in square inches N = Number of power strokes per minute 33,000 = Unit of power (one horsepower), or foot pounds per minute.

In the International System of Units (SI), the unit of power is the watt (W), which is equal to one joule per second.

Horsepower (hp) is a unit of measurement of power (the rate at which work is done) It was originally defined as 550 foot-pounds per second (ft-lb/s). A power level of 1 hp is approximately equivalent to 746 watt s (W) or 0.746 kilowatts (kW). To convert from horsepower to watts, multiply by 746. mechanical efficiency, measure of the effectiveness with which a mechanical system performs. It is usually the ratio of the power delivered by a mechanical system to the power supplied to it, and, because of friction, this efficiency is always less than one.

There are three main ways of describing mechanical efficiency during exercise: gross efficiency, net efficiency and mechanical efficiency.

If the useful output energy is 200 J and the total input energy is 400 J, then the mechanical efficiency is $(200/400) \times 100 = 50\%$.

The equation that links efficiency and power can be expressed as $\text{Efficiency} = \text{Output power} / \text{Input power}$. The rate at which energy is transferred is called power and the amount of energy that is usefully transferred is called efficiency.

Assignment

- Fig 1

m = 55 kg

 - s = 1.82 metres
W = _____ joules
 - s = 1.40 metres
W = _____ joules
 - s = 0.85 metres
W = _____ Joules
- Fig 2

t = 8 secs

 - P = _____ Watts
 - P = _____ Watts
 - P = _____ Watts

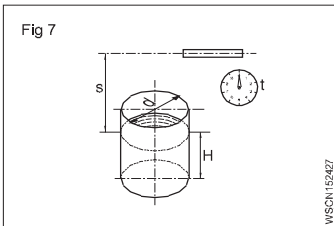
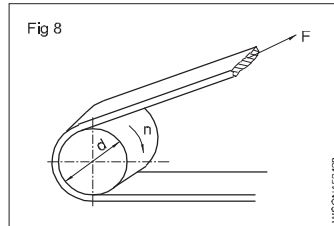
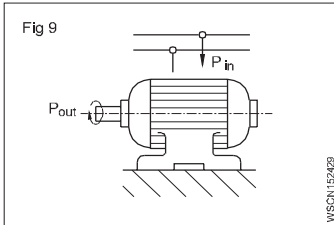
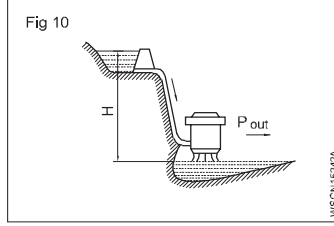
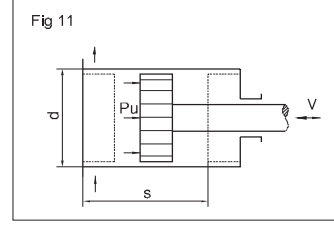
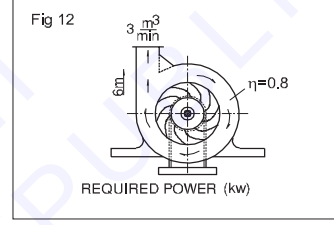
(*W' of a,b,c of Q1)
- Fig 3

W = 1312.5 Joules
m = 350 kg
s = _____ metres
- Fig 4

m = 75 kg
s = 100 metres
t = 12 secs
W = _____ Nm
P = _____ Watts
- Fig 5

V = 1 m³/min
H = 2 m
 $\eta = 0.75$
Power input = _____ kW
- Fig 6

P = 12 kw
s = 4 metres
t = 20 secs
m = _____ kg

- 7  Fig 7
 $d = 3 \text{ metre}$
 $H = 2 \text{ metre}$
 $t = 20 \text{ minutes}$
 $s = 6 \text{ metres}$
 $P = \underline{\hspace{2cm}} \text{ kW}$
 Water filled in the tank. s is the pumping height
- 8  Fig 8
 $d = 200 \text{ mm}$
 $n = 750 \text{ rpm}$
 $F = 700 \text{ N}$
 $P = \underline{\hspace{2cm}} \text{ kW}$
- 9  Fig 9
 $P_{\text{input}} = 4 \text{ kW}$
 $P_{\text{output}} = 3450 \text{ Joules/sec}$
 $\eta = \underline{\hspace{2cm}} \%$
- 10  Fig 10
 Volume of water
 $'V' = 10 \text{ metre}^3$
 $H = 18 \text{ metres}$
 $t = 20 \text{ sec}$
 $\eta = 70 \%$
 $P_{\text{output}} = \underline{\hspace{2cm}} \text{ kW}$
- 11  Fig 11
 $d = 225 \text{ mm}$
 $s = 450 \text{ mm}$
 Piston pressure
 $'P' = 4.5 \text{ bar}$
 $V = 2.5 \text{ metre/sec}$ (piston speed)
 $\eta = 70 \%$
 Power input
 $= \underline{\hspace{2cm}} \text{ kW}$
- 12  Fig 12
 $'V' \text{ of water pumped} = 3 \text{ metre}^3/\text{min}$
 $H = 6 \text{ metre}$
 $\eta = 0.8$
 Power input
 $= \underline{\hspace{2cm}} \text{ kW}$

Potential energy, kinetic energy and related problems

Potential energy

Potential energy is the energy possessed by a body by virtue of its position. A body of mass ' m ' kept at a height ' h ' from a datum possesses a potential energy of mgh or Wh or Fh ; where W or F are the Weight force. When the body is allowed to fall it will be able to do a useful work of Fh .

Example

- Water stored in a Tank
- Coil Spring.

Kinetic energy

It is the energy possessed by a body by virtue of its motion. If a body of mass ' m ' starting from rest attains a velocity of ' v ' after covering a distance of ' s ', by the action of an applied force ' F ', then work done on the body $= F \times s$ But $F = m \times a$. Therefore work done on the body $= m \times a \times s$.

But $a \times s = \frac{V^2}{2}$ because the body is starting from rest.

Therefore Work done on the body $= \frac{1}{2}mv^2$

Since work done on the body = The energy possessed by the body

Kinetic Energy $= \frac{1}{2}mv^2$

Energy possessed by a body = work done on the body

Potential energy $= mgh$

$$\text{Kinetic energy} = \frac{1}{2} mv^2$$

If friction is neglected potential energy = Kinetic energy

Example

- Rolling vehicle
- Rotating fly wheel
- Flowing water
- Falling weight

Potential energy

Hammer head drops from height 'h'. $m = 10 \text{ kg}$.

$$h = 1.4 \text{ m.} \quad u = 0 \frac{\text{metre}}{\text{sec}}$$

$$V^2 = 2 \text{ gs} \quad V = 5.24 \frac{\text{metre}}{\text{sec}}$$

$$V^2 = 2 \times 9.81 \times 1.4$$

$$V^2 = 27.468$$

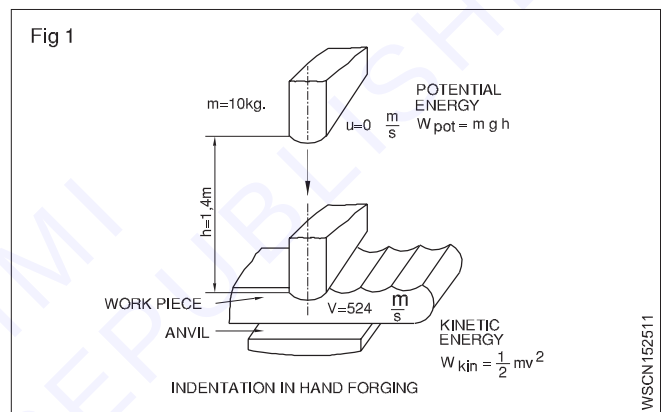
$$V^2 = 5.24 \text{ m/sec}$$

$$\text{P.E} = 10 \text{ kg} \times 9.81 \text{ metre/sec}^2 \times 1.4 \text{ metre (Fig 1)}$$

$$= 137.3 \text{ N metre} \quad (\because 1 \text{ N} = 1 \text{ kg.m/sec}^2)$$

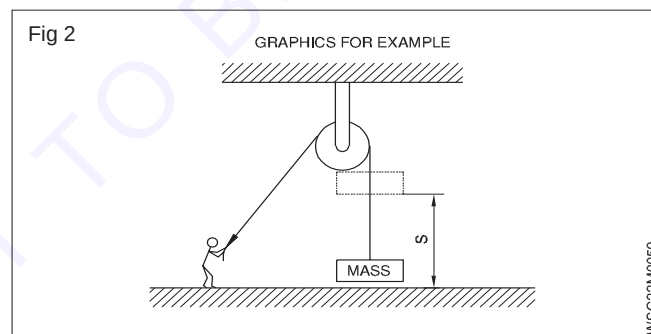
$$\text{K.E} = \frac{1}{2} \times 10 \text{ kg} \times 5.24^2 \frac{\text{metre}^2}{\text{sec}^2}$$

$$= 137.3 \text{ N metre.}$$



Examples

- A pulley is used to lift a mass with a force of 900 N to a height of 10 metres in 2 minutes. Find the work done by the force and also the power.(Fig 2)



$$\text{Work done} = F \times s = 900 \text{ N} \times 10 \text{ metre}$$

$$= 9000 \text{ Nm} = 9000 \text{ joules.}$$

$$\text{Power} = \frac{W}{t} = \frac{9000 \text{ joules}}{120 \text{ sec}}$$

$$= \frac{75 \text{ joules}}{\text{sec}}$$

$$= 75 \text{ watts}$$

- Determine the horse power required to drive a lift in raising a load of 2000 kgf at a speed of 2 metre/sec, if the efficiency is 70%.

Useful workdone to raise the lift in 1 sec

Force = 2000 kgf

Work = F x d

$$\text{Power} = \frac{F \times d}{t} = \frac{2000 \times 2}{1}$$

$$= 4000 \text{ w}$$

Power output = 4000 w

Power input = Power output

$$= \frac{4000}{0.7} = 5714 \text{ w}$$

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

$$P = \frac{5714}{746} = 7.659 \approx 7.6 \text{ HP}$$

Power input = 7.6 HP

- A mass of 100 gm is allowed to fall from a height of 10 metres. Determine the amount of Kinetic energy gained by the body. (Take the value of g as 10 metre/sec²)

Since initial velocity is 0 and distance travelled is 10 metres. final velocity²

$$= V^2 = 2 \times g \times s = 2 \times 10 \times 10 \text{ metre}^2/\text{sec}^2$$

$$\therefore \text{K.E} = \frac{1}{2}mv^2 = \frac{1}{2} \times 100 \text{ gm} \times 200 \text{ metres}^2/\text{sec}^2$$

$$= 10000 \text{ gm metre}^2/\text{sec}^2$$

$$= 10 \times 10^7 \text{ ergs}$$

$$= 10 \text{ Joules.}$$

K.E. developed by the vehicle at a constant speed

- A motor vehicle of one tonne is travelling at 60 km/hr. Calculate K.E of the vehicle at this speed.

$$\text{K.E of the vehicle} = \frac{1}{2}mv^2$$

Where m = one tonne or 1000 kg

v = 60 km/hr

Solution

Changing v into meter/sec we get,

$$V = 60 \times \frac{1000}{60 \times 60} = \frac{50}{3} \text{ m/sec}$$

($\because 1 \text{ km} = 1000 \text{ m}$)
($\because 1 \text{ hour} = 3600 \text{ sec}$)

$$\text{Now K.E. of vehicle} = \frac{1}{2} \times 1000 \times \frac{50}{3} \times \frac{50}{3}$$

$$= 1000 \times \frac{2500}{18}$$

$$= \frac{2500000}{18} \text{ J}$$

K.E. developed by a vehicle during acceleration

- A motor vehicle of 1200 Kg mass is being accelerated from 36 km to 48 km/hr speed. Calculate the increase in K.E during its acceleration.

$$\begin{aligned}
 &= \frac{2500000}{100 \times 18} \text{ KJ} \\
 &= \frac{1250}{9} \text{ KJ} \\
 &= 138.89 \text{ KJ}
 \end{aligned}$$

Solution

Mass of motor vehicle = 1200 kg

K.E. of the vehicle at 36 km/hr speed

$$= \frac{1}{2} \times 1200 \times 36^2 \text{ J} \quad \text{KE} = \frac{1}{2} mv^2 \text{ J}$$

$$v = 36 \text{ km/hr} = 36 \times \frac{1000}{60 \times 60} = 10 \text{ m/sec}$$

K.E of the vehicle at 48 km/hr speed

$$= \frac{1}{2} \times 1200 \times 48^2 \text{ J} \quad (\because 1 \text{ kg.m/sec}^2 = 1 \text{ N})$$

$$(\because 1 \text{ Nm} = 1 \text{ J})$$

$$v = 48 \text{ km/hr} \quad = 48 \times \frac{1000}{60 \times 60} = \frac{40}{3} \text{ m/sec}$$

$$\text{KE} = \frac{1}{2} \times 1200 \times 10 \times 10 = 60000 \text{ J}$$

$$\text{KE} = \frac{1}{2} \times 1200 \times \frac{40}{3} \times \frac{40}{3} = 106666.67 \text{ J}$$

$$\begin{aligned} \text{Increase in K.E of the vehicle} &= 106666.67 \text{ J} - 60000 \text{ J} = 46666.67 \text{ J} \\ &= 46.666 \text{ KJ.} \end{aligned}$$

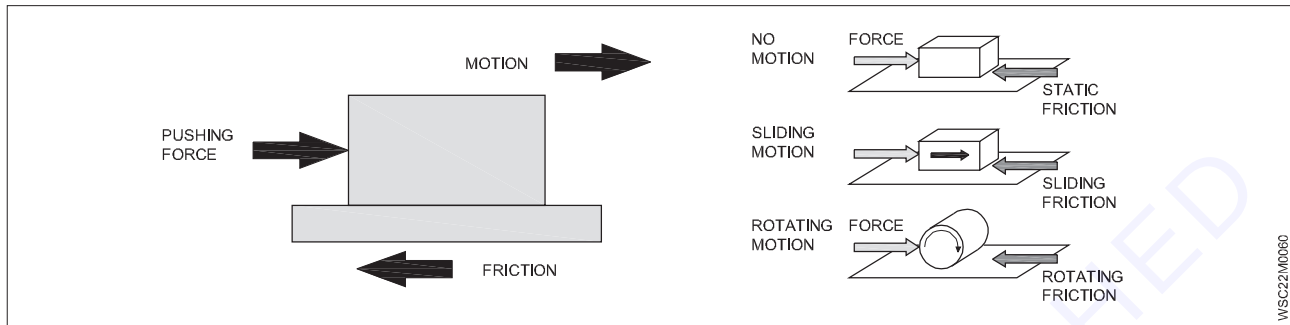
Workdone in vehicle operation

The Mechanical Work performed by the motor vehicle for its propulsion on road can generally be classified into two major categories of work done.

- Workdone by the IC engine in developing full power under all condition of speed and load.
- Workdone by the motor vehicle in performing different operations on road like hill climbing/acceleration/braking/towing and reversing operation.

EXERCISE 6 : Friction

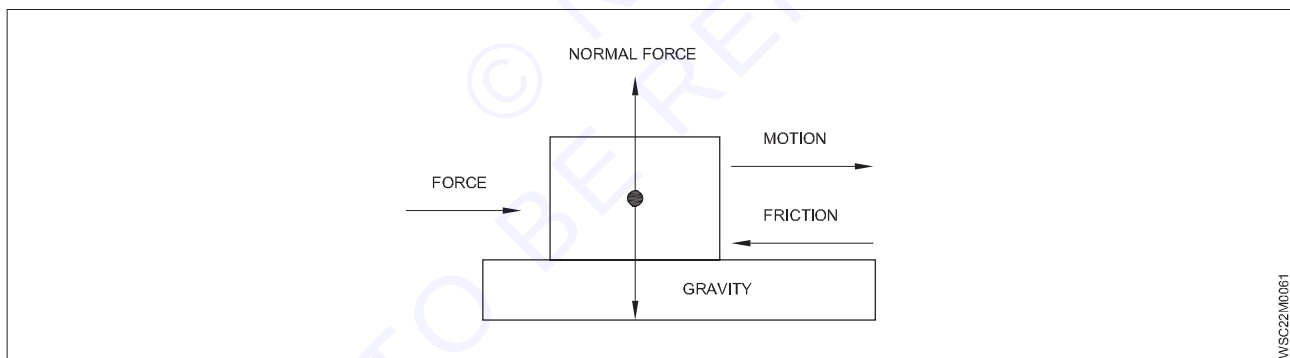
Concept of Friction: Friction is the force that opposes motion between any surfaces that are in contact. There are four types of friction: static, sliding, rolling, and fluid friction. Static, sliding, and rolling friction occur between solid surfaces. Fluid friction occurs in liquids and gases.



Laws of Friction

The laws of friction are

- Friction is proportional to the normal force exerted between the surfaces.
- Friction does not depend on the area of contact.
- Friction force depends on the type of surfaces in contact.
- The coefficient of static friction is greater than the coefficient of kinetic friction.



First Law

"For any object under motion, the friction is proportional and perpendicular to normal load."

Second Law

"The surface characteristics an object comes in contact with determines the friction between them"

Third Law

"For any two objects moving across each other, the area of contact surface does not influence the Frictional force between them."

Fourth Law

"The kinetic friction between two dry objects is independent of the relative surface velocity." Therefore, kinetic friction is independent of velocity.

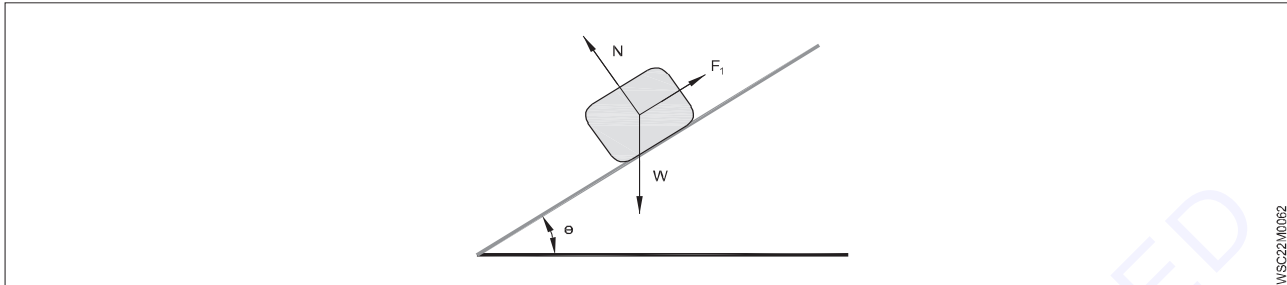
Fifth Law

"The coefficient of static friction is more than the coefficient of kinetic friction."

Limiting Friction

Friction created when two static surfaces come into contact with each other. The limiting frictional force is independent of the area of contact and is proportional to the reasonable reaction between the contacting surfaces.

When the frictional force is at its maximum possible value, friction is said to be limiting. If friction is limiting, yet the book is still stationary, it is said to be in limiting equilibrium. If you push ever so slightly harder, the book will start to move.

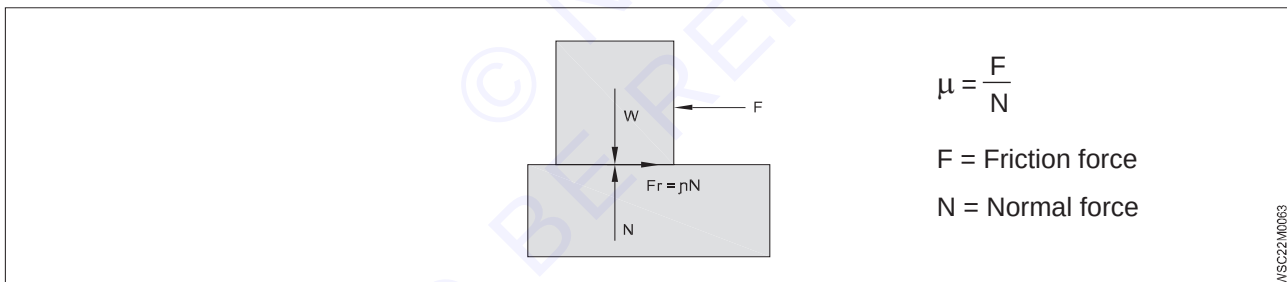


Limiting friction is important in many everyday applications. For example, the limiting friction between your shoes and the floor keeps you from slipping when you walk on the floor. Similar, the limiting friction between your car's tires and the road prevents your car from skidding.

The maximum or limiting value of friction between two surfaces is $F_{MAX} = \mu R$ where μ is the coefficient of friction and R is the normal reaction between the two surfaces.

Coefficient of Friction

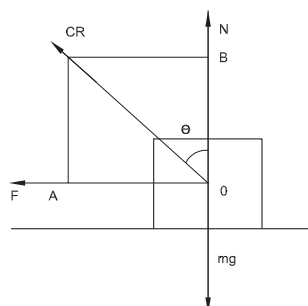
The coefficient of friction, μ , is a measure of the amount of friction existing between two surfaces. A low value of coefficient of friction indicates that the force required for sliding to occur is less than the force required when the coefficient of friction is high. Ratio of the frictional force (F) to the normal force applied.



It is usually symbolized by the Greek letter mu (μ). Mathematically, $\mu = F/N$, where F is the frictional force and N is the normal force.

The value of the coefficient of static friction depends on the objects that are causing friction.

It's value is generally between 0 and 1 but it can be greater than 1. The value equal to 0 means there is no friction between two objects. All objects will have some friction when they come in contact with each other.



We know that,

$$\mu = \frac{F}{N} \quad (1)$$

μ = coefficient of friction

Considers ΔOBC ,

$$\tan \theta = \frac{\text{OPP}}{\text{adj}}$$

$$= \frac{BC}{OB}$$

$$BC = OA$$

$$= \frac{OA}{OB}$$

$$= \frac{F}{N}$$

$$= \frac{\mu N}{N}$$

$$= \mu \quad [\text{From (1)}]$$

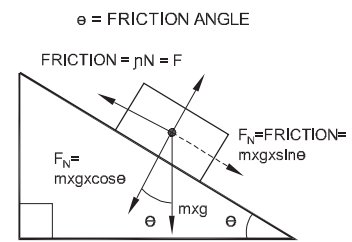
$$\tan \theta = \mu$$

$$\theta = \tan^{-1}(\mu)$$

Angle of friction

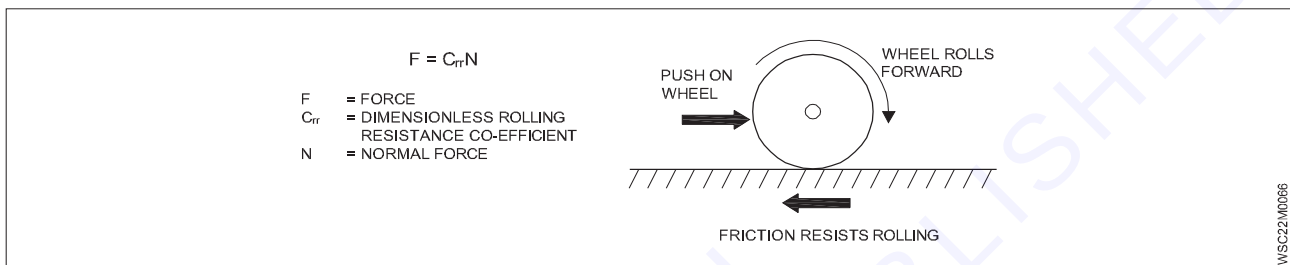
Angle made by the resultant of normal reaction and limiting friction with the normal reaction is called the angle of friction. The coefficient of static friction is equal to the tangent of the angle of friction.

In situations like this, where an object of mass m slides down a slope that makes an angle θ with the horizontal, friction is given by $f_k = \mu_k mg \cos \theta$



Rolling friction & sliding friction

Rolling friction is the resistive force offered by any surface that, opposes the rolling motion of any object that rolls over it, thus causing it slow down and eventually stop. Rolling friction occurs when a spherical or round object rolls across a surface.



Law 1

As the smoothness of the surface increases, the rolling friction decreases.

Law 2

Rolling friction is directly proportional to the load. As the load increases, the rolling friction increases, and as the load decreases, the rolling friction decreases.

Law 3

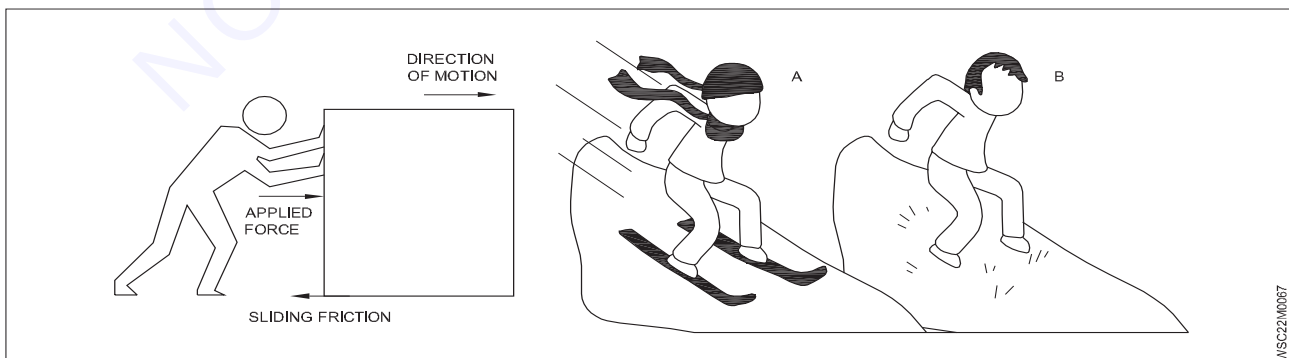
Rolling friction is inversely proportional to the radius of the rolling body. When the radius increases, friction decreases, and when the radius decreases, friction increases.

Examples: Rolling of the football, tennis ball, or any other ball. Less rolling friction allows tires of Heavy-duty trucks to move more quickly. A skateboard set on an inclined surface is said to have resistance caused by the rolling friction. While driving, bike wheels roll with less speed.

Sliding friction

The resistance created by any two objects when sliding against each other. This friction is also known as kinetic friction and is defined as the force that is needed to keep a surface sliding along another surface. Sliding friction takes place when two surfaces are rubbed against each other. Sliding friction takes place due to interlocking between microscopic surfaces.

SI unit of force is newton (N).



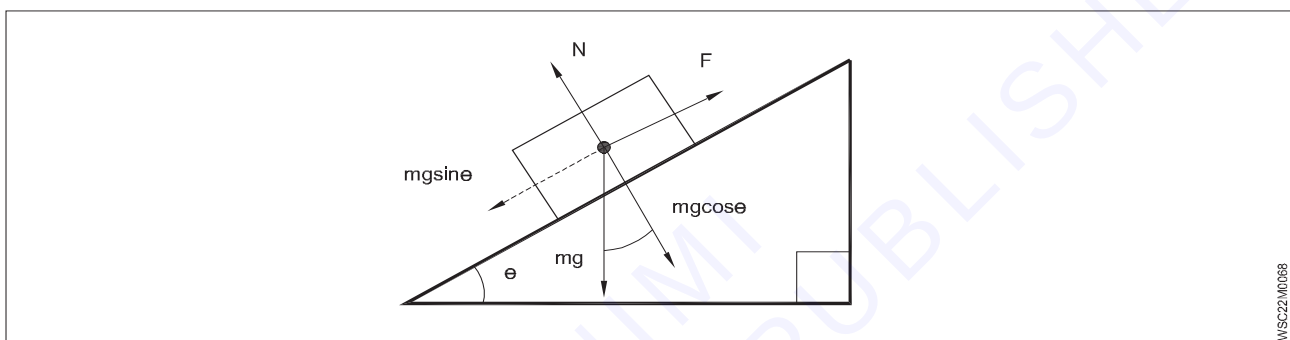
Examples

- Rubbing our hands makes a heat.
- When you go down the slide you create a sliding friction.
- Sand on a icy road.
- When a player falls and slides on the basketball court.
- The player slides against the ground aggressively to get the ball.
- Pushing an object across a surface.

Friction on inclined surfaces

When an object is at rest on an inclined plane as shown in the figure the force of friction is static in nature. The direction of static friction is in upward direction as the block has the tendency to move downwards. As there is relative slipping between the surfaces the force of friction is kinetic in nature.

The normal force can be found using the gravitational, or weight, force and the angle of the inclined plane. It is given by $F = mg \cos \theta$, where m is the mass, g is acceleration due to gravity and θ (theta) is the angle.



Examples

- | | | |
|-------------|------------------|---------------|
| • Ramps. | • Stairs. | • Slides. |
| • Anthills. | • Slanted roofs. | • Escalators. |

Assignment

Examples

- 1 Weight of a machine vice placed on the table of machine tool is 20 kgf. What is the minimum horizontal force needed which will start it sliding, if the coefficient of sliding friction is 0.19

Solution:

Co-efficient of friction $\mu = 0.19$

Normal reaction $R = 20 \sim \text{kgf}$.

Force of friction $= \mu \cdot R$

$$0.19 \times 20 = 3.8 \sim \text{kgf}$$

Minimum horizontal force required $= 3.8 \text{ kgf}$

- 2 A solid weighing 50 kg is placed on a solid surface. How Minimum horizontal force required to move the block when coefficient of friction is 0.25 between the block and the surface.

Solution:

Normal reaction $R = 50 \text{ kg}$

Coefficient of friction $\mu = 0.25$

Force required to move the block $= \mu \cdot R$

$$= 0.25 \times 50 = 12.5 \text{ kg}$$

- 3 A bus with full = $0.25 \times 50 = 12.5$ kg 4500 kg is running on the road. If the coefficient of friction between the tyres and the road is 0.30, then calculate the force of friction.

Solution:

Normal reaction $A = 4500$ kg

Coefficient of friction $\mu = 0.30$

Force of Friction = $\mu \cdot R$

$= 0.30 \times 4500$

$= 1350$ kg

- 4 A glass block of 400 grams has been placed on the table. The glass is connected by a string to a 40 grams scale pan. The string passes over a pulley. When a weight of 60 grams is placed on the scale pan, the block starts sliding. Find out the co-efficient of Induction between wood and glass

Solution:

Scale pan means a small container Weight of 60 grams placed on the scale pan. Weight of scale pan is given as 40 grams. Force required to move the glass block $= 60 \text{ grams} + 40 \text{ grams} = 100 \text{ grams}$

F = Force required to start siding $= 100 \text{ grams}$

R = Normal Reaction weight of glass block $= 400 \text{ grams}$

Let μ co-efficient of friction

We know:

$F = \mu \cdot R$

$\mu = F/R = 100/400 = 0.25$

Co-efficient of friction $= 0.25$ Ans.

EXERCISE 7 : Stress & Strain

Concepts of stress & Strain: Modulus of elasticity, Stress- strain curve. Hook's law, different module of elasticity like Young's modulus, modulus of rigidity, bulk modulus and their relations.

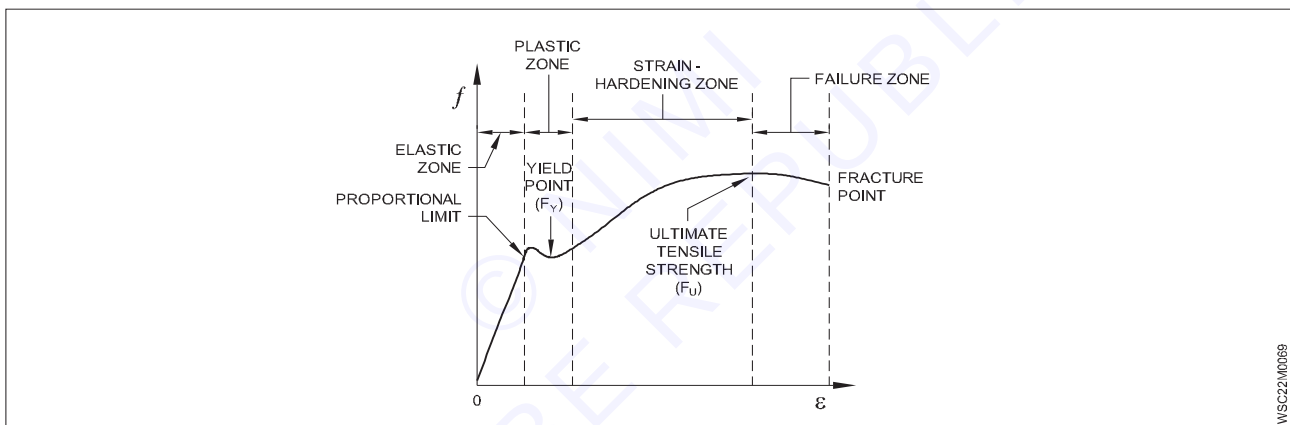
Poisson's ratio: Stress is the force exerted per unit area and strain is the physical change that results in response to that force.

Stress is the ratio of force over area ($S = R/A$, where S is the stress, R is the internal resisting force and A is the cross-sectional area). Strain is the ratio of change in length to the original length, when a given body is subjected to some external force (Strain= change in length ÷ the original length).

There are three types of stress: compression, tension, and shear. Stress can cause strain, if it is sufficient to overcome the strength of the object that is under stress. Strain is a change in shape or size resulting from applied forces (deformation).

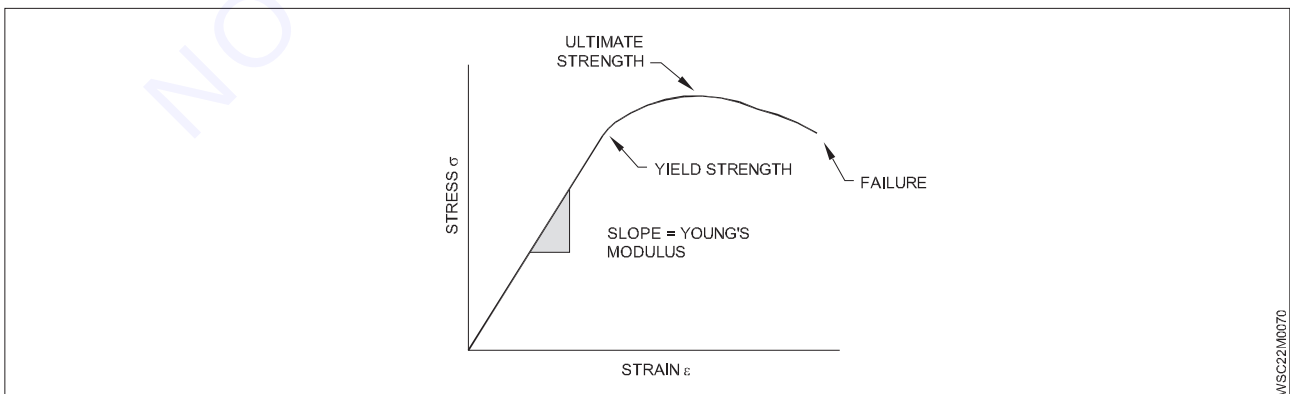
SI unit of stress is N/m^2 or Pa , as expected by the units, stress is given by dividing the force by the area of its generation, and since this area (" A ") is either sectional or axial, the basic stress formula is " $\sigma = F/A$ ".

Hooke's law states that the strain of the material is proportion to the applied stress within the elastic limit of that material. When the elastic materials are stretched, the atoms and molecules deform until stress is applied, and when the stress is removed, they return to their initial state.



Modulus of elasticity

Modulus of Elasticity, also known as Elastic Modulus or simply Modulus, is the measurement of a material's elasticity. Elastic modulus quantifies a material's resistance to non-permanent, or elastic, deformation. The Elastic Modulus is the measure of the stiffness of a material. Elastic modulus, also known as Young's modulus, is a fundamental property of materials that measures their stiffness or resistance to elastic deformation under stress. This property is essential in engineering and materials science, as it determines a material's ability to support loads and maintain its shape.

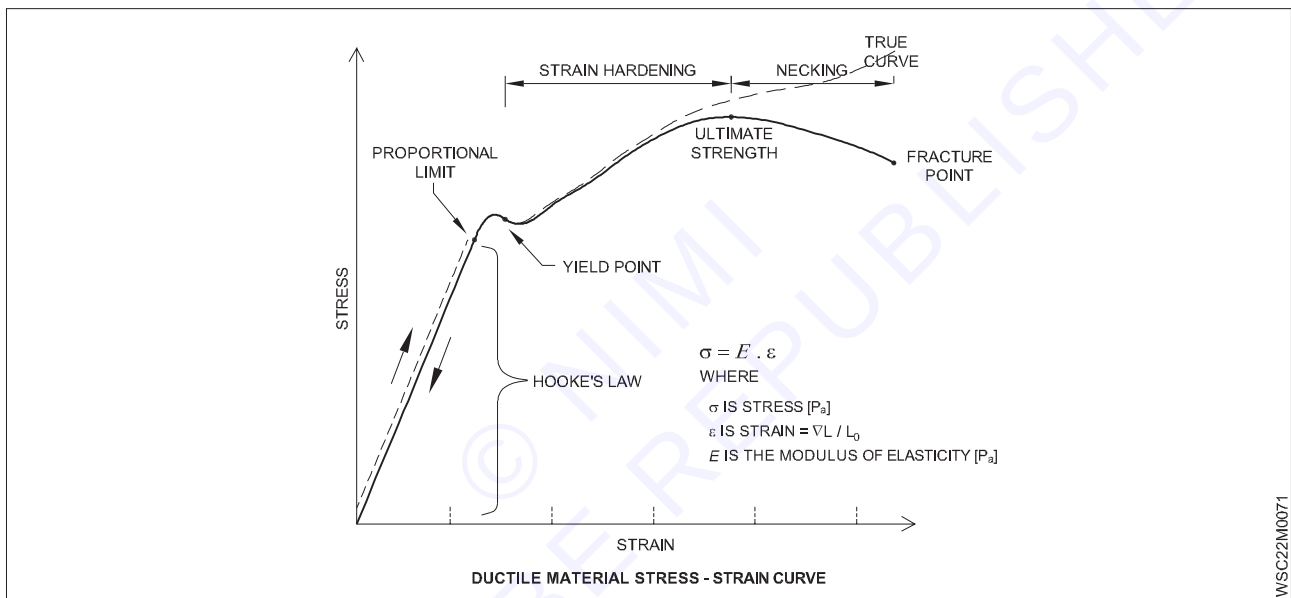


Pascals (Pa)

The units of modulus of elasticity are pressure units, as it is defined as stress (pressure units) divided by strain (dimensionless). Most commonly the units are Pascals (Pa) which is the SI unit, or pounds per square inch (psi) depending on the industry or geographical location.

There are three different types of elastic modulus

- young's modulus.
- shear modulus.
- bulk modulus.
- The greatest known modulus of elasticity (Young's modulus) is found in diamonds. ...
- The elasticity of a material is determined by its modulus of elasticity, commonly referred to as elastic modulus or simply modulus.
- A material's resistance to elastic, or non-permanent, deformation is measured by its elastic modulus.



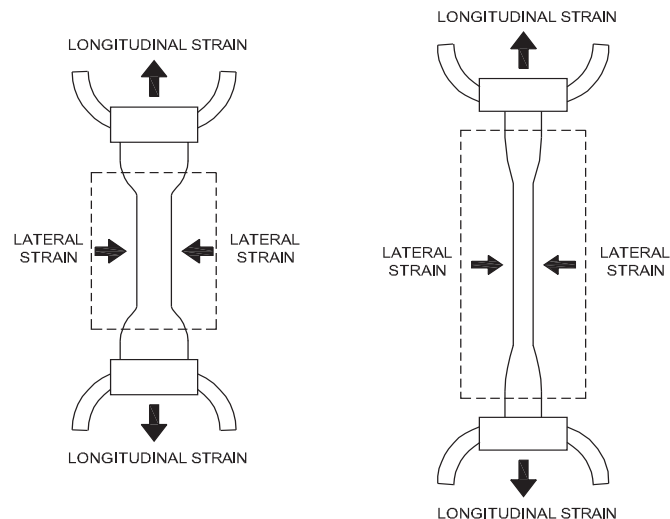
The symbol of absolute value is represented by the modulus symbol, '| |', with the numbers between it. For example, the absolute value of 9 is denoted as |9|.

Poisson ratio is the ratio of transverse contraction (or expansion) strain to longitudinal extension strain in the direction of stretching force. Tensile deformation is considered positive and compressive deformation is considered negative.

Formula	Poisson's ratio = – Lateral strain / Longitudinal strain
Range	-1.0 to +0.5
Units	Unit less quantity
Scalar / Vector	Scalar quantity

Rubber has one of the highest values of Poisson's ratio at 0.4999, which is evident in its physically noticeable reaction to axial stretching.

The equation for calculating Poisson's ratio is given as $\nu = (-\epsilon_{\text{trans}}) / \epsilon_{\text{axial}}$. Transverse strain (ϵ_{trans}) is measured in the direction perpendicular to the applied force, and axial strain (ϵ_{axial}) is measured in the direction of the applied force.



WSC22M0072

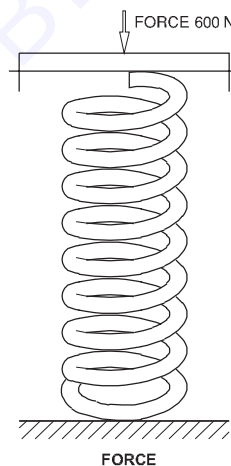
Assignment

- 1 A steel rod used for brake operation is 1.50 m long. When it is subjected to a tensile force the extension produced is 0.5 mm. Find the strain in the rod.

$$= \frac{0.5}{1.5 \times 1000} \left(\frac{\text{mm}}{\text{mm}} \right)$$

Strain in the brake rod = 0.0003

- 2 A helical spring is loaded with a force of 600 Newton and is compressed by 30mm. What would be the load required to compress it to 10 mm.



WSC22M0073

Solution

$$= \frac{600}{30} \left(\frac{\text{N}}{\text{mm}} \right) = 20 \left(\frac{\text{N}}{\text{mm}} \right)$$

Load required to compress the spring by 10 mm
 = spring stiffness x deflection
 = 20 (N/mm) x 10(mm)

Load required = 200 N

3 Helical spring is loaded with a force of 400 Newton and it is compressed by 18 mm. What would be the load required to compress it to 6 mm?

Given force = 400 Newton
 Deflection = 18 mm
 Spring Stiffness = Force / Compressed length
 = 400 / 18
 = 22.22 Newton / mm
 Load required = 22.22 x 6
 = **133.32 N**

4 Calculate the tensile strain when a force of 3.2 kN is applied to a bar of original length 2.8 m extends the bar by 0.5 mm.

Force F = 3.2 kN
 Original length L = 280 cm
 Increased length(Δl) = 0.5 mm = 0.05 cm
 Tensile strain = ?
 Strain = $\frac{\Delta l}{L}$
 = $\frac{0.05}{280}$
 = **0.0001786**

Example

1 A steel rod of 10 mm diameter and 175 mm long is subjected to a tensile load of 15 kN. If $E = 2 \times 10^5$ N/mm², calculate the change in length.

Tensile load = 15 kN = 15000 N
 Area of cross section = $(\pi r^2) = \frac{\pi}{4} \times 10 \times 10 \text{ mm}^2 = 78.57$
 $\therefore$ Stress = $\frac{15000 \text{ N}}{78.57 \times 100 \text{ mm}^2} = 191 \text{ N/mm}^2$
 Young's modulus $E = \frac{\text{Stress}}{\text{Strain}}$
 $E = 2 \times 10^5 \text{ N/mm}^2 = \frac{191 \text{ N/mm}^2}{\text{Strain}}$
 $\therefore$ Strain = $\frac{191}{2 \times 10^5}$
 Change in length = $\frac{175 \times 191}{2 \times 10^5} \text{ mm}$
 = **0.167 mm.**

2 A bar of steel 2.5 cm diameter was subjected to compressive load of 4500 kg. The compression in a length of 20 cm was found to be 0.008 cm. Find the Young's modulus of elasticity of bar.

Solution

Diameter of bar $d = 2.5 \text{ cm}$

Force applied i.e. compressive load = 4500 kg

Original length of bar = 20 cm

Change in length = 0.008 cm

$$\therefore \text{Area of original cross-section} = \frac{\pi}{4} d^2$$

$$= \frac{\pi}{4} \times 2.5^2$$

$$= \frac{\pi \times 6.25}{4}$$

$$= \text{cm}^2$$

$$\therefore \text{Stress} = \frac{\text{Force applied}}{\text{Area of original cross section}}$$

$$= \frac{4500}{\frac{\pi \times 6.25}{4}}$$

$$= \frac{4500 \times 4}{\pi \times 6.25}$$

$$= \frac{2880}{\pi}$$

$$\therefore \text{Stress} = \frac{2880}{\pi} \text{ Kg/cm}^2$$

$$\therefore \text{Strain} = \frac{\text{Change in length}}{\text{Original length}}$$

$$= \frac{0.008}{20} = \frac{8/1000}{20}$$

$$= \frac{8}{20 \times 1000} = \frac{4}{10000}$$

$$\therefore \text{Strain} = \frac{4}{10000}$$

$$\therefore \text{Young's modulus} = \frac{\text{Stress}}{\text{Strain}}$$

$$= \frac{2880}{\pi} \div \frac{4}{10000}$$

$$= \frac{2880}{\pi} \times \frac{10000}{4}$$

$$= \frac{7200000}{\pi}$$

$$= 2292000 \text{ Kg/cm}^2$$

$$= 2.292 \times 10^6 \text{ Kg/cm}^2$$

- 3 A force of 10 tonnes is applied axially on a rod of 12 cm dia. the original length is 100 mm. If modulus of elasticity is 2×10^{12} kg/cm². Calculate stress and strain developed in the rod.

Solution

$$\begin{aligned}\text{Force applied} &= 10 \text{ tonnes} = 10 \times 1000 \text{ kg} \\ &= 10^4 \text{ kg}\end{aligned}$$

$$\text{Diameter (d)} = 12 \text{ mm} = 1.2 \text{ cm}$$

$$\text{Young's modulus (E)} = 2 \times 10^{12} \text{ kg/cm}^2$$

$$\text{Stress} = \frac{\text{Force applied}}{\text{Area of original cross section}}$$

$$\begin{aligned}&= \frac{10^4}{\frac{\pi}{4} \times \frac{12}{10} \times \frac{12}{10}} \\ &= \frac{10^4 \times 4 \times 10 \times 10}{\pi \times 12 \times 12} \\ &= \frac{10^6}{36\pi}\end{aligned}$$

$$= 8841 \text{ kg/cm}^2$$

$$\therefore \text{Stress} = 8841 \text{ kg/cm}^2$$

We know

$$\begin{aligned}\frac{\text{Stress}}{\text{Strain}} &= \text{Young's modulus} \\ \text{Strain} \times \text{Young's modulus} &= \text{Stress} \\ \text{Strain} &= \frac{\text{Stress}}{\text{Young's Modulus}}\end{aligned}$$

$$\begin{aligned}&= \frac{8841}{2 \times 10^{12}} \\ &= \frac{4420.5}{10^{12}} \\ &= 4420.5 \times 10^{-12}\end{aligned}$$

$$\text{Stress} = 8841 \text{ kg/cm}^2$$

$$\text{Strain} = 4420.5 \times 10^{-12}$$

- 4 A bar of 100 cm elongates to 101.36 cm when a load of 15000 kg is applied to it. Take the area of cross section of bar as 10 cm². Find the stress, strain and young's modulus.

$$L_1 = 100 \text{ cm}$$

$$L_2 = 101.36 \text{ cm}$$

$$\begin{aligned}\Delta L &= L_2 - L_1 \\ &= 101.36 - 100 = 1.36 \text{ cm}\end{aligned}$$

$$F = 15000 \text{ kg}$$

$$A = 10 \text{ cm}^2$$

$$\text{Stress} = \frac{\text{Force(F)}}{\text{Area(A)}}$$

$$= \frac{15000}{10}$$

$$= 1500 \text{ kg/cm}^2$$

$$\text{Strain} = \frac{\Delta \ell}{L}$$

$$= \frac{1.36}{100}$$

$$= 0.0136$$

$$\text{Young's modulus} = \frac{\text{Stress}}{\text{Strain}}$$

$$E = \frac{1500}{0.0136}$$

$$= 110300 \text{ kg/cm}^2$$

- 5 What force is required to stretch a steel wire of 10 mm long and 10 mm dia. to double its length. E of steel is 205 KN/cm².

$$d = 10 \text{ mm} = 1 \text{ cm}$$

$$r = 0.5 \text{ cm}$$

$$L_1 = 1 \text{ cm}$$

$$L_2 = 2 \text{ cm}$$

$$\Delta \ell = L_2 - L_1 = 2 - 1 = 1 \text{ cm}$$

$$E = 205 \text{ KN/cm}^2$$

$$\text{Strain} = \frac{\Delta \ell}{L} = \frac{1}{1} = 1$$

$$E = \frac{\text{Stress}}{\text{Strain}}$$

$$205 = \frac{\text{Stress}}{1}$$

$$\text{Stress} = 1 \times 205 = 205 \text{ KN/cm}^2$$

$$\text{Stress} = \frac{\text{Force}(F)}{\text{Area}(A)}$$

$$205 = \frac{\text{Force}}{3.14 \times 0.5 \times 0.5}$$

$$\text{Force} = 205 \times 3.14 \times 0.5 \times 0.5$$

$$= 161 \text{ KN}$$

- 6 A wire of 1.6 cm diameter is subjected to a tensile load of 2000 Kg. Find the stress and strain if young's modulus = $2 \times 10^6 \text{ kg/cm}^2$.

$$F = 2000 \text{ kg}$$

$$d = 1.6 \text{ cm}$$

$$r = 0.8 \text{ cm}$$

$$E = 2 \times 10^6 \text{ Kg/cm}^2$$

$$\begin{aligned}
 \text{Stress} &= \frac{F}{A} \\
 &= \frac{2000}{\pi r^2} \\
 &= \frac{2000}{3.14 \times 0.8 \times 0.8} \\
 &= \frac{2000}{2.0096} \\
 &= 995.2 \text{ kg/cm}^2
 \end{aligned}$$

$$\text{Young's modulus} = \frac{\text{Stress}}{\text{Strain}}$$

$$2 \times 10^6 = \frac{995.2}{\text{Strain}}$$

$$\begin{aligned}
 \text{Strain} &= \frac{995.2}{2 \times 10^6} \\
 &= 0.0005
 \end{aligned}$$

- 7 A tensile load of 2000 kg is applied on a rectangular rod of 2 cm x 1 cm whose length is 2 metres. Calculate the elongation in length as $E = 2 \times 10^6 \text{ Kg/cm}^2$.

$$F = 2000 \text{ Kg.}$$

$$L_1 = 2 \text{ m} = 200 \text{ cm}$$

$$E = 2 \times 10^6 \text{ kg/cm}^2$$

$$\text{Rectangular rod length} = 2 \text{ cm}$$

$$\text{Breadth} = 1 \text{ cm}$$

$$\begin{aligned}
 \text{Stress}(\sigma) &= \frac{\text{Force}(F)}{\text{Area}(A)} = \frac{\text{Force}}{l \times b} \\
 &= \frac{2000}{2 \times 1} \\
 &= 1000 \text{ kg/cm}^2
 \end{aligned}$$

$$E = \frac{\text{Stress}}{\text{Strain}}$$

$$2 \times 10^6 = \frac{1000}{\text{Strain}}$$

$$\begin{aligned}
 \text{Strain} &= \frac{1000}{2 \times 10^6} \\
 &= 0.0005
 \end{aligned}$$

$$\frac{\Delta l}{L_1} = \text{Strain}$$

$$\frac{\Delta l}{200} = 0.0005$$

$$\begin{aligned}\Delta l &= 200 \times 0.0005 \\ &= 0.1 \text{ cm}\end{aligned}$$

$\therefore$ **Elongated length = 0.1 cm**

Stress

- 1 Calculate the intensity of stress in the material if a copper rod of 40 mm diameter is subjected by tensile load of 4000 Newton's.
- 2 Calculate the intensity of stress if a mild steel rod having a cross sectional area of 40 mm² is subjected to the load of 1000 kg.
- 3 Calculate the tensile stress if a square rod of 10 mm side is tested for a tensile load of 1000 kg.
- 4 Calculate the maximum stress if a bar of 9 cm² cross sectional area 300 cm long carries a tensile load of 3500 kg.
- 5 Find out the stress on the rod. if a load of 500 kg is placed on a M.S.rod of dia. 35 mm.
- 6 A metallic bar of 8 cm diameter is under stress carrying a load of 8620 N. Calculate the intensity of stress.
- 7 A steel wire 2 mm diameter is loaded in tension with a weight of 20 kg. Find out the stress developed.
- 8 A rod having a cross sectional area of 25 mm² is subjected to a load of 1500 kg. Find out stress on the rod.
- 9 A square rod of 10 mm side is tested for a tensile load of 2500 kg. Calculate the tensile stress of the rod.

Strain

- 1 Find the compressive strain if a metal bar is 150 cm long. When 2.5 KN is applied, its length becomes 148.6 cm.
- 2 Calculate the strain if a metallic bar is 150 cm long. When 2500 kg is applied its length becomes 150.5 cm.
- 3 Find the strain it causes if a load of 300 kg hanging from a rod of 3 metres length and 5 mm diameter extends it by 4 mm.
- 4 A tensile force of 10 kg is applied on a copper wire of diameter 1 cm. So that the length of wire increases by 5 mm. If the original length of wire was 2 metres, find out the strain.
- 5 A steel rod whose diameter is 1 cm and 60 cm in length. This rod is pulled at both ends by a force of 700 kg. If modulus of elasticity of steel is 2.1×10^6 kg/cm², find out increase in length of rod and strain produced in it.
- 6 A steel rod 1.5 metres long and of 30 mm diameter is pulled at both ends by a force of 1500 kg. If modulus of elasticity of steel is 2.4×10^6 kg/cm², determine increase in length of rod and strain produced in it.
- 7 Calculate the change in length of a rod of dia 16 mm and 160 mm long when it carries a load of 40KN. Take $E = 200000$ N/mm².
- 8 A hollow C.I. column with a wall thickness of 2 cm is subjected to an axial compressive load of 80 tonnes. If the maximum stress is not to be exceeded 1 tonne per cm², determine the internal diameter of column. Calculate compressive strain, if $E = 950$ tonnes per cm².

Young's modulus

- 1 A piece of wire 2 m long, 0.8 mm² in cross section increases its length by 1.6 mm on suspension of 8 kg weight from it. Calculate the stress, strain and young's modulus.
- 2 A wire of 16 mm dia. is subjected to a tensile load of 2000 kg. Find the stress and strain if young's modulus $E = 2 \times 10^{16}$ kg/cm².
- 3 A wire is of 2 metres long and its area of cross section is 0.78 mm². If 78 kg weight is suspended on this wire, then the length of the wire is increased by 1.4 mm. Find out stress, strain and young's modulus of elasticity.
- 4 A wire 2800 mm long is stretched by 0.5 mm, when a weight of 9 kg is hung on it, its diameter is 2 mm. Calculate stress and young's modulus for the substance of the wire.

- 5 A force of 1000 kg is applied axially on rod of 12 mm diameter the original length is 100 mm. If modulus of elasticity is 2×10^{12} kg/cm². Calculate the stress and strain developed in the rod.
- 6 A steel wire 3.2 mm diameter and 3.65 metre long stretches by 2.03 mm under the load of 115 kg. Calculate the stress and young's modulus of elasticity.
- 7 A mass of 10 kg is hung from a vertical wire 300.25 cm long and 0.0005 sq. cm cross section. When the load is removed the wire is found to be 300 cm long. Find the modulus of elasticity for the wire material.
- 8 A steel rod of 1.5 cm diameter and 8 metres long pulled by a force of 80 kg at both ends. Find out the expansion and strain on the rod. The coefficient of elasticity $E = 2.10 \times 10^6$ kg/cm².
- 9 A wire of length 3.5 m and diameter 0.35 mm is stretched by a force of 2kg weight. If the elongation is 4 mm. Calculate the young's modulus of the material of wire.
- 10 A mass of 1kg is suspended from a metal wire 100 cm long and 0.5 mm diameter. An increase in length of wire equal to 2 mm is observed. Calculate the young's modulus of wire.
- 11 A 4 metre long copper wire of diameter 3 mm is used to support a mass of 50kg. What will be the elongation of the wire. Young's modulus of elasticity for copper is 7×10^{10} N/mm².

EXERCISE 8 : Simple machines

A simple machine is a mechanical device that changes the direction or magnitude of a force. In general, they can be defined as the simplest mechanisms that use mechanical advantage (also called leverage) to multiply force. Usually the term refers to the six classical simple machines that were defined as follows:

Level: A lever is a simple machine consisting of a beam or rigid rod pivoted at a fixed hinge, or fulcrum.

Wheel and axle: The wheel and axle is a simple machine consisting of a wheel attached to a smaller axle so that these two parts rotate together in which a force is transferred from one to the other.

Pulley: A pulley is a wheel on an axle or shaft enabling a taut cable or belt passing over the wheel to move and change direction, or transfer power between itself and a shaft.

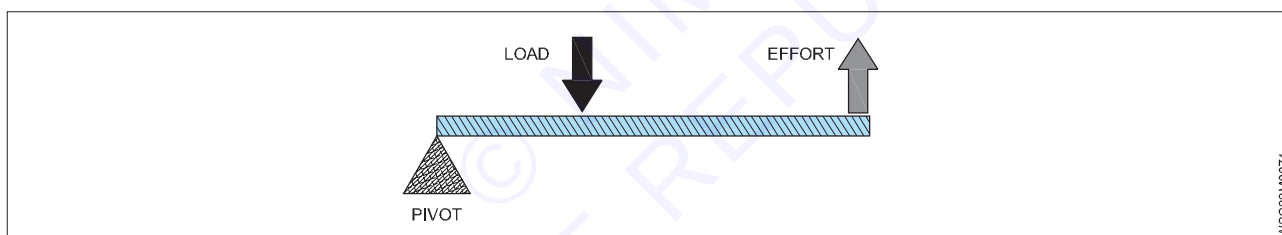
Inclined plane: An inclined plane, also known as a ramp, is a flat supporting surface tilted at an angle from the vertical direction, with one end higher than the other, used as an aid for raising or lowering a load.

Wedge: A wedge is a triangular shaped tool, a portable inclined plane, and one of the six simple machines. It can be used to separate two objects or portions of an object, lift up an object, or hold an object in place.

Screw: A screw is a mechanism that converts rotational motion to linear motion, and a torque (rotational force) to a linear force. It is one of the six classical simple machine.

Concept of Mechanical Advantage:

Mechanical advantage is a measure of the ration of output force to input force in a system, used to analyze the forces in simple machines like levers and pulleys.



Mechanical advantage is also defined as the force created by the machine to the for applied to it. The formula of mechanical advantage is given as: $MA = FB/FA$.

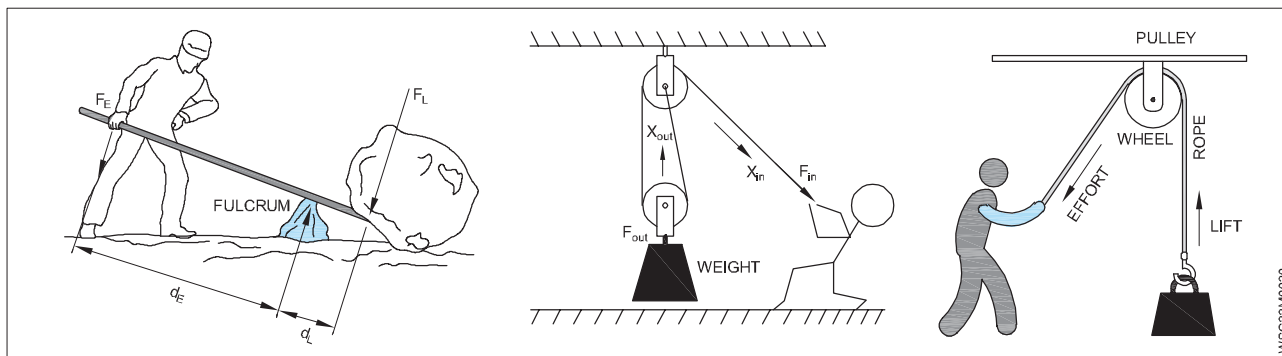
The ideal mechanical advantage (IMA), or theoretical mechanical advantage, is the mechanical advantage of a device with the assumption that its components do not flex, there is no friction, and there is no wear.

If the input effort on a lever is 10 Newtons and the output load is 50 Newtons, what is the mechanical advantage? The lever helps to multiply a person's effort to lift the object by almost 5 times. Hence, by using a lever the object now becomes easier to lift. Also, for example in steering system, the driver applies a relatively small force to steering wheel and this results in much larger steering force at wheels. Mechanical advantages allows humans to perform tasks much easier in terms of the force they need to apply,

Velocity Ratio: Velocity ration is the ration of the velocity at which effort is applied on a machine to the velocity at which load moves.

The ratio of the velocity of effort to the velocity of the load is called Velocity Ratio (VR) i.e., $\text{Velocity Ratio (VR)} = (\text{Velocity of effort}) / (\text{Velocity of load})$ So, $\text{Velocity ratio (VR)} = V_1/V_2$.

The ratio of the distance moved by the point at which the effort is applied in a simple machine to the distance moved by the point at which the load is applied, in the same time. In the case of an ideal (frictionless and weightless) machine, velocity ratio = mechanical advantage.



Efficiency and Their Relations: The efficiency output of a machine is simply the output work divided by the input work, and is usually multiplied by 100 so that it is expressed as a percent. A machine cannot be 100 per cent efficient because the output of a machine is always less than the input. A certain amount of work done on a machine is lost to overcome friction and to lift some moving parts of the machine. If a machine is supplied with 100 joules of energy and it manages to convert 80 joules into useful work, then the efficiency of the machine would be $(80/100) \times 100\% = 80\%$. The remaining 20% of the energy is wasted, often as heat due to friction or sound.

Hence, the relationship between mechanical advantage, velocity ratio, and efficiency is $\eta = \text{MA} \times \text{VR} \times 100\%$.

Mechanical advantage is the ratio of load to effort of machine or we can say it is the ratio of output of machine to the input of the machine.

Velocity ratio is also defined as velocity of effort to the velocity of load.

Let a machine overcome a load 'L' by the application of an effort E. In time 't'. Let the displacement of effort be dE and displacement of load be dL

Thus, the mechanical advantage of the machine is equal to the product of its efficiency and Velocity ratio.

Note:

Mechanical Advantage (M.A.), efficiency (η) and velocity ratio are interconnected with each other. Basically mechanical Advantage of machine is equal to the product of its efficiency and velocity Ratio. Therefore, $\text{M.A.} = \text{V.R.} \times \eta$.

$$\text{Work input} = \text{Effort} \times \text{displacement of effort} = E \times dE$$

$$\text{Work output} = \text{Load} \times \text{displacement of load} = L \times dL$$

$$\text{Efficiency } (\eta) = \frac{\text{Work output}}{\text{Work input}}$$

$$= \frac{L \times dL}{E \times dE} \text{ ----- 1}$$

$$\text{Also, Mechanical Advantage, (M.A.)} = \frac{\text{Load (L)}}{\text{Effort (E)}} \text{ ----- 2}$$

$$\text{And velocity Ratio (V.R.)} = \frac{dE}{dL} \text{ ----- 3}$$

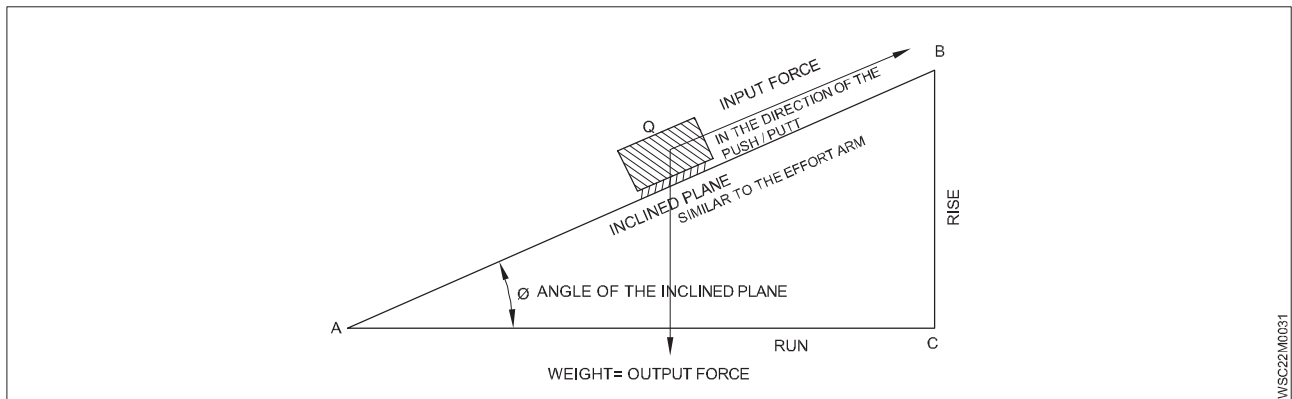
By equation 1, 2 and 3

$$\text{Efficiency } (\eta) = \frac{\text{M.A.}}{\text{V.R.}}$$

$$\text{M.A.} = \text{V.R.} \times \eta$$

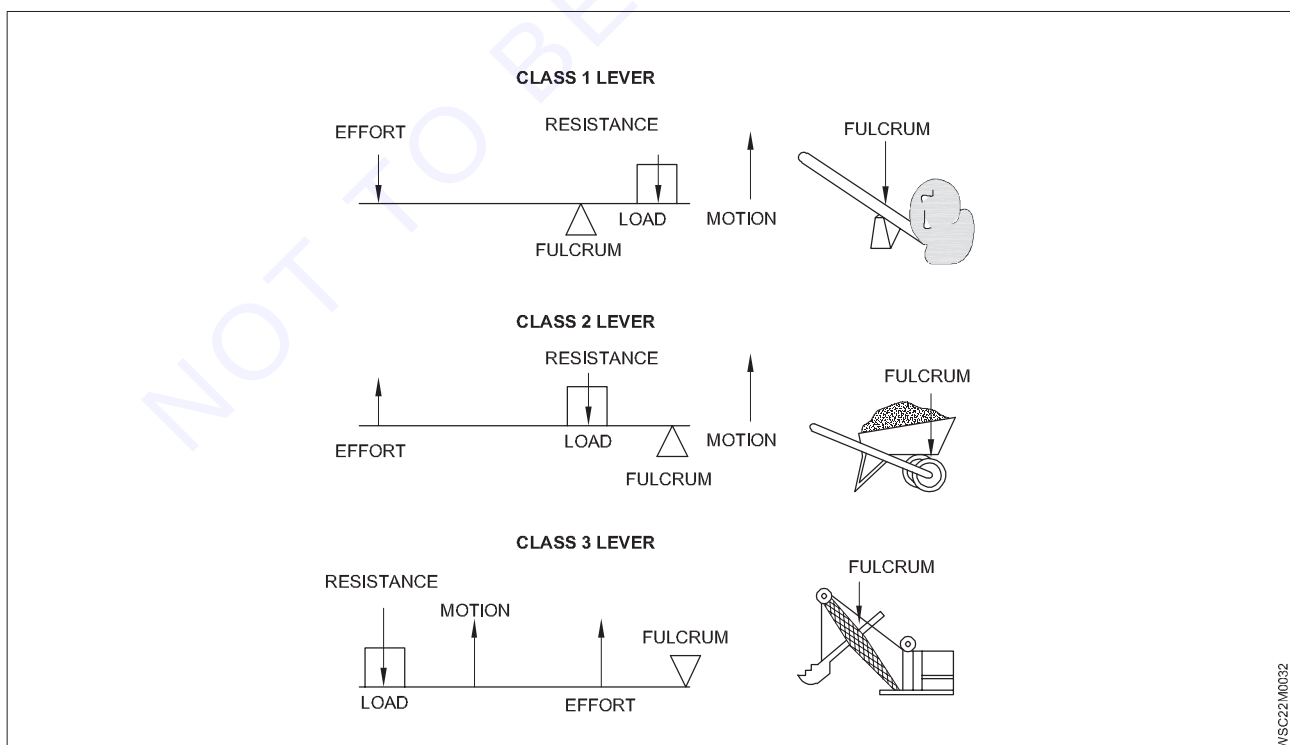
Working Principles of Inclined Plane:

Inclined plane, simple machine consisting of a sloping surface, used for raising heavy bodies. The force required to move an object up the incline is less than the weight being raised, discounting friction. The steeper the slope, or incline, the more nearly the required force approaches the actual weight.



Lever: A lever is a simple machine consisting of a beam or rigid rod pivoted at a fixed hinge, or fulcrum. A lever is a rigid body capable of rotating on a point on itself. On the basis of the locations of fulcrum, load and effort, the lever is divided into three types. It is one of the six simple machine identified by Renaissance scientists. A lever amplifies an input force to provide a greater output force, which is said to provide leverage, which is mechanical advantage gained in the system, equal to the ratio of the output force to the input force. As such, the lever is a mechanical advantage device, trading off force against movement.

- **Class I** - Fulcrum is located between the effort and the resistance: The effort is applied on one side of the fulcrum and the resistance (or load) on the other side. For example, a seesaw, a crowbar, a pair of scissors, a balance scale, or a claw hammer (pulling a nail). With the fulcrum in the middle, the lever's mechanical advantage may be greater than, less than, or even equal to 1.
- **Class II** - Resistance (or load) is located between the effort and the fulcrum: The effort is applied on one side of the resistance and the fulcrum is located on the other side, e.g. a wheelbarrow, a nutcracker, a bottle opener, or the brake pedal of a car. Since the load arm is smaller than the effort arm, the lever's mechanical advantage is always greater than 1. It is also called a force multiplier lever.
- **Class III** - Effort is located between the resistance and the fulcrum: The resistance (or load) is applied on one side of the effort and the fulcrum is located on the other side, e.g. a pair of tweezers, a hammer, a pair of tongs, a fishing rod, or the mandible of a human skull. Since the effort arm is smaller than the load arm, the lever's mechanical advantage is always less than 1. It is also called a speed multiplier lever.



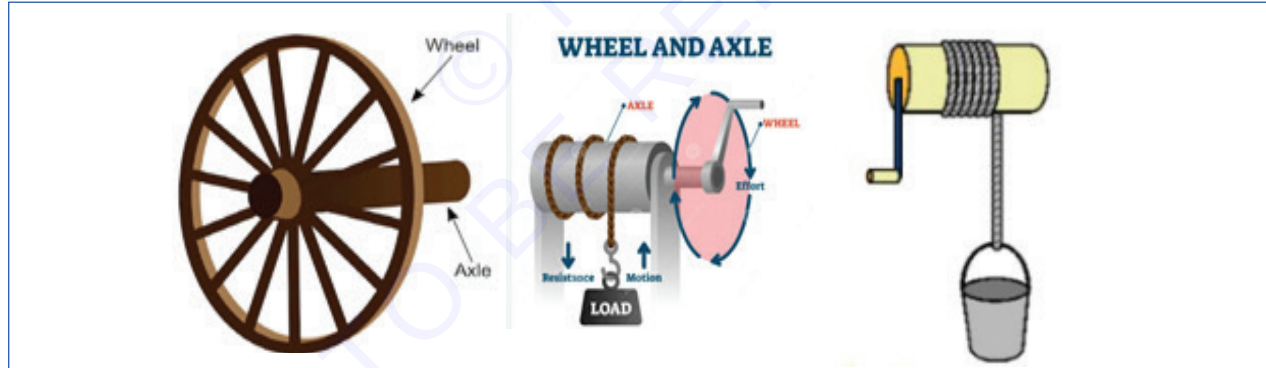
Screw Jack: A jack screw jack or jackscrew is a mechanical device used as a lifting device to lift heavy loads by applying minimal forces. A hydraulic jack uses hydraulic power. The most common form is a car jack floor jack or garage jack which lifts vehicles so that maintenance can be performed.

A jackscrew, or screw jack, is a type of jack that is operated by turning a lead screw. It is commonly used to lift moderate and heavy weight, such as vehicles; to raise and lower the horizontal stabilizers of aircraft; and as adjustable supports for heavy loads, such as the foundations of houses.



A screw jack is a gearbox assembly (either worm gear or bevel gear) and a transmission product (lead screw, ball screw or roller screw) which through use of a motor is used to convert rotary into linear motion. They can be used to push, pull, tension, lock, unlock, tilt, pivot, roll, slide and lift or lower loads, anything from a few kilos to thousands of tonnes. Screw jack material: Aluminium AC43100, cast iron G25 UNI 5007, cast iron GS400 UNI 4544, stainless steel AISI 316 (ASTM A 351 CF8M).

Wheel and Axle: The wheel and axle is a type of simple machine used to make tasks easier in terms of manipulating force by applying the concept of mechanical advantage.



The wheel and axle consists of a round disk, known as a wheel, with a rod through the centre of it, known as the axle.

Describe

Two rounded objects that move together

The larger object is the **Wheel**

The smaller object is the **Axle**

The larger the wheel, The longer the distance and the greater the MA.

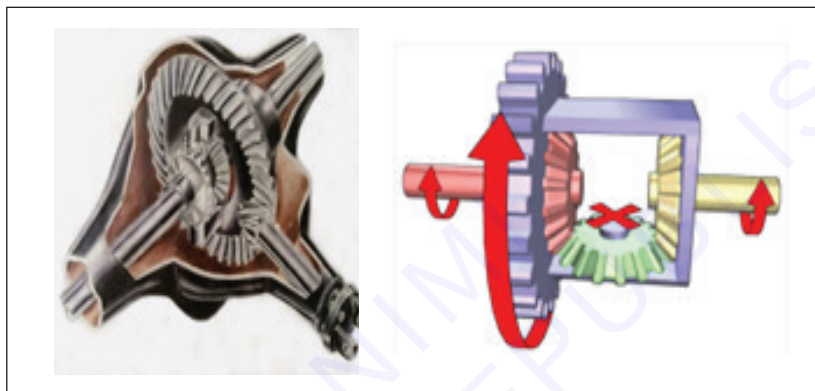
Various examples of what a wheel and axle is used for in our everyday life include:

- Car tires.
- Bicycle.
- Ferris wheel.
- Electric fan.

- Rotary Phone.
- Screwdriver.
- Drill.
- Wheelbarrow.

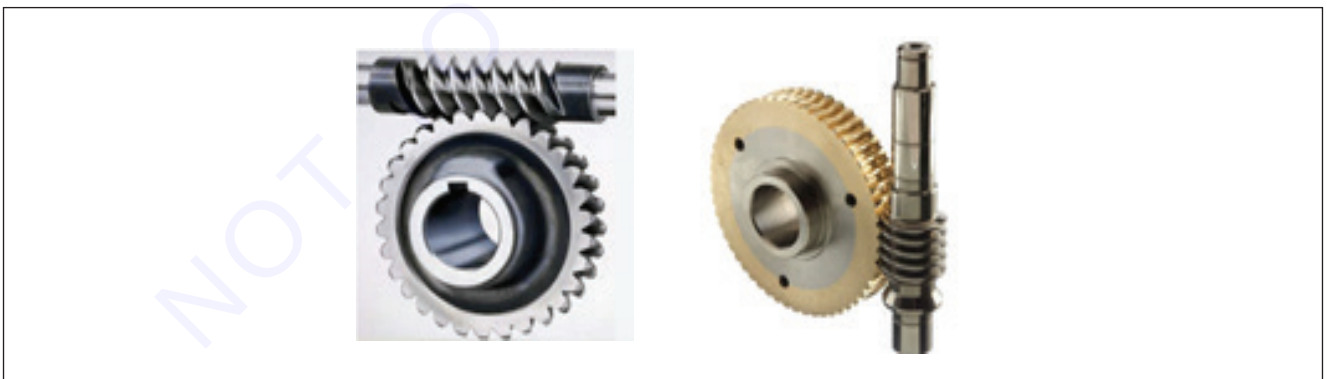
Differential wheel and Axle: The wheel and differential axle are secured to a shaft that runs in bearings within a study wall mounting bracket. The necessary cords and Load hangers are provided and weights are included. The three pulleys are fixed together to form a compound pulley.

A differential is a gear train with three drive shafts that has the property that the rotational speed of one shaft is the average of the speeds of the others. A common use of differentials is in motor vehicles, to allow the wheels at each end of a drive axle to rotate at different speeds while cornering. Other uses include clocks and analog computers. Differentials can also provide a gear ratio between the input and output shafts (called the “axle ratio” or “diff ratio”). For example, many differentials in motor vehicles provide a gearing reduction by having fewer teeth on the pinion than the ring gear.



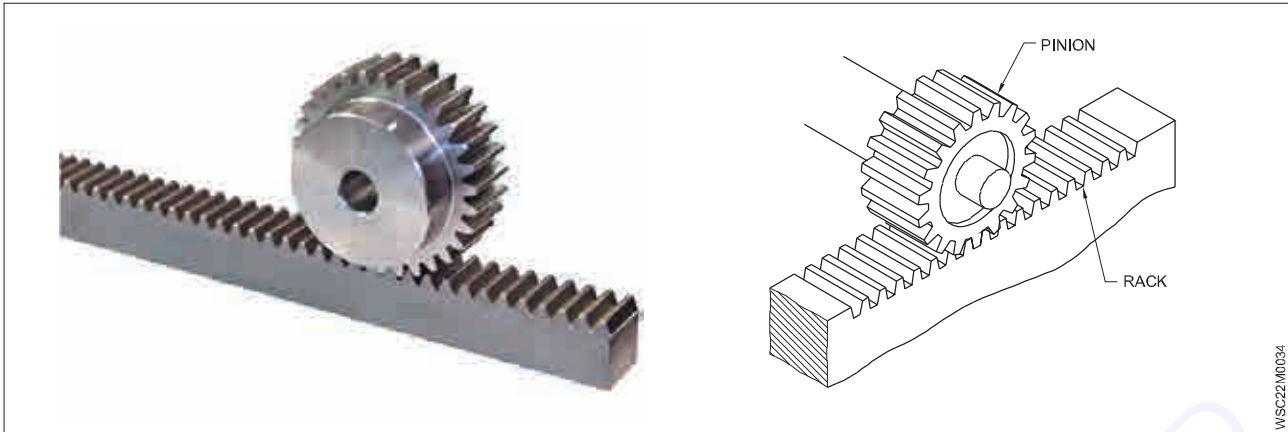
Worm and worm wheel: A worm gear is a thread cut into a round bar, and a worm wheel is a gear that meshed with the worm with the worm at a shaft angle of 90 degrees. The set of a worm and worm wheel is called a worm gear.

Worm gears are known to run smoothly and quietly, as long as they are properly mounted and lubricated. Due to these features, typical worm gear applications include presses, small engines, lifts and elevators, rolling mills, conveying engineering, mining industry machines, on rudders, and worm drive saws.



Rack and Pinion: Rack and pinions are used for lifting mechanisms (vertical movement), horizontal movement, positioning mechanisms, stoppers and to permit the synchronous rotation of several shafts in general industrial machinery. On the other hand, they are also used in steering systems to change the direction of cars.

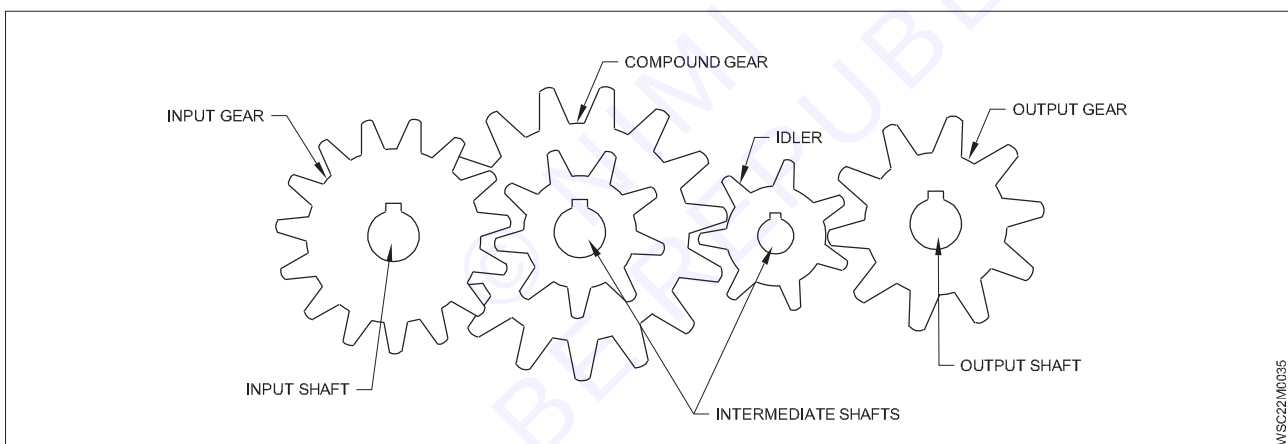
The rack and pinion, also known as the steering rack, is an assembly in your vehicle that allows your wheels to rotate from side to side when you turn your steering wheel.



Gear train

A gear train is a mechanical arrangement of gears that transmit rotational motion and torque from one part of a machine or system to another. It consists of two or more gears meshed together, forming a series of interconnected rotating elements.

Gear train is an arrangement of gears meshing with each other in order to achieve some level of torque conversion between the driving and driven shaft. Gearbox is the housing in which all these are enclosed.



The teeth on gears are designed so the gears can roll on each other smoothly (without slipping or jamming). In order for two gears to roll on each other smoothly, they must be designed so the velocity at the point of contact of the two pitch circles (represented by v) is the same for each gear.

Mathematically, if the input gear G_A has the radius r_A and angular velocity ω_A and meshes with output gear G_B of r_B and angular velocity ω_B then:

$$v = r_A \omega_A = r_B \omega_B$$

The number of teeth on a gear is proportional to the radius of its pitch circle, which means the ratios of the gears' angular velocities, radii, and number of teeth are equal. Where N_A is the number of teeth on the input gear and N_B is the number of teeth on the output gear, the following equation is formed:

$$\frac{\omega_A}{\omega_B} = \frac{r_B}{r_A} = \frac{N_B}{N_A}$$

This shows that a simple gear train with two gears has the gear ratio R given by: $R = \frac{\omega_A}{\omega_B} = \frac{N_B}{N_A}$

This equation shows that if the number of teeth on the output gear G_B is larger than the number of teeth on the input gear G_A then the input gear G_A must rotate faster than the output gear G_B .

- 1 Simple gear train.
- 2 Compound gear train.
- 3 Reverted gear train.
- 4 Planetary or epicyclic gear train.

Planetary gear train (PGT) has been widely used in the transmissions of helicopters, automobiles, wind turbine, aircraft engines, etc. The main advantages of this transmission are its high efficiency, its compactness, its large transmission ratio and its large power-to-weight ratio, etc.

A gearbox, also known as a gear drive, has three main functions: to increase torque from the driving equipment (motor) to the driven equipment, to reduce the speed generated by the motor, and/or to change the direction of the rotating shafts.

Assignment

Examples

A load of 1200 kg is lifted using a simple machine having a velocity ratio of 5 . Find out efficiency of machine, if effort applied is 300 kg

Solution: $MA = \text{LOAD}/\text{EFFORT}$
 $= 1200/300$
 $= 4$

Velocity Ratio = 5 (given)

Efficiency if machine $= (\text{Mechanical Advantage})/(\text{Velocity Ratio})$
 $= 4/5 = 0.8 = 80\%$

A load of 75 kg is lifted using a simple machine having a velocity ratio of 4 . Find out efficiency of machine, if effort applied is 25 kg

Solution: $MA = \text{LOAD}/\text{EFFORT}$
 $= 75/25$
 $= 3$

Velocity Ratio = 4 (given)

Efficiency if machine
 $= (\text{Mechanical Advantage})/(\text{Velocity Ratio})$
 $= 3/4$
 $= 0.75$
 $= 75\%$

Examples

- 1 According to figure the lever has to support a 100 kg load with a 17 kg equivalent force supplied to it. Find the distance between the load and point of force.

Solution: Load = 100 kg; Effort = 17 kg
 Load arm = 50 cm
 Let effort arm = x cm
 As per principle of levers:

Effort x Effort arm = Load x Load arm

$$17(x) = 100 \times 50$$

$$100 \times 50 = 17x$$

$$x = \frac{100 \times 50}{17} = 294.1 \text{ cm}$$

$$= 294.1 \text{ cm}$$

: Distance between the load and point of force

$$= 294.1 - 50$$

$$= 244.1 \text{ cm}$$

$$= 2.4410 \text{ m} \quad \text{Ans}$$

2 A simple screw jack having pitch = 1 cm and the effective length of the lever = 50 cm. What shall be the velocity ratio? A force of 5 kg is applied on lever and lifts a load of 1100 kg. What is its efficiency?

Solution

Length of level / = 50 cm

Pitch of screw $p = 1 \text{ cm}$

Load lifted = 1100 kg

Effort applied = 5 kgs

EXERCISE 9 : Electricity

Electricity is the flow of electrical power or charge. It is a secondary energy source which means that we get it from the conversion of other sources of energy, like coal, natural gas, oil, nuclear power and other natural sources, which are called primary sources.

There are basic types of sources used in electricity are Fossil fuels, Renewable energy, Mainly hydroelectric, Nuclear power. Talking about the SI unit of electricity, it is represented by the unit of power which is Watt.

The formula for electrical energy is $E = V \cdot I \cdot t$ joules, where V is the potential difference, I is the current and t is the time. The formula for electrical power is Power (P) = $V \cdot I$ watts, where V is the potential difference and I is the current.

An ampere is a unit of measure of the rate of electron flow or current in an electrical conductor. One ampere of current represents one coulomb of electrical charge (6.24×10^{18} charge carriers) moving past a specific point in one second. One Volt is defined as energy consumption of one joule per electric charge of one coulomb. $1V = 1J/C$. One volt is equal to the current of 1 amp times the resistance of 1 ohm. Ohm's Law is $V = IR$, where V = voltage, I = current, and R = resistance.

Basic definitions like EMF:

Electromotive force is defined as the electric potential produced by either an electrochemical cell or by changing the magnetic field. EMF is the commonly used acronym for electromotive force. Electromotive force is the characteristic of any energy source capable of driving electric charge around a circuit. It is abbreviated E in the international metric system but also, popularly, as emf . EMF formula can be expressed as, $e = IR + Ir$ or $e = V + Ir$, where, e is the electromotive force (Volts), I = current (A), R = Load resistance, r is the internal resistance of the cell measured in ohms.

Current: Electric current is defined as the rate of flow of electrons in a conductor. The SI Unit of electric current is the Ampere. Electric current refers to flow of electricity in an electronic circuit, and to the amount of electricity flowing through a circuit. It is measured in amperes (A). The larger the value in amperes, the more electricity is flowing in the circuit. The SI unit of current is ampere which measures the flow of electric charge across a surface at the rate of one coulomb per second.

Voltage: Voltage is the force that makes electrons flow. It's difference in potential energy between two different points in a circuit.

Current: Current is the rate of the flow of electrons. It's measured in amperes, which are also called amps. Power (Watts): The power used in a circuit is measured in watts.

Resistance: Resistance to electricity—that is, electrical resistance—is a force that counteracts the flow of current. In this way, it serves as an indicator of how difficult it is for current to flow. Resistance values are expressed in ohms (Ω).

$$V = I \times R$$

$$R = V/I$$

R = Resistance, V = Volt, I = Current.

Potential difference: Electric potential difference is a measure of the amount of potential energy at a given location in a circuit. The concept is also known as "voltage" and is typically measured in "volts." One can think of electric potential difference (and voltage) as a measure of electron pressure.

voltage is called potential difference because it is a measure of the difference in potential energy between two points in a circuit. This potential difference, or voltage, is present even when a circuit is not switched on, similar to how a brick held in the air has gravitational potential energy.

The S.I. Unit of potential difference is Volt. The potential difference between two points is said to be 1 volt if work is done in transferring 1 coulomb of charge from one point to other point is 1 Joule.

Uses of Electricity: A large amount of electricity is currently being used for street lighting in almost every country. More uses in sectors as follows:

- Entertainment.
- Healthcare.
- Engineering.
- Transport and Communication.
- Outdoors.
- Household.
- Commercial.
- Office.

It is used for heating, lighting, cooling, refrigeration, household appliance, transportation, electronic appliances, industrial machinery, etc. The usage of electricity is not limited to a certain point it has unlimited uses in the modern era of today.

Difference between ac and dc

In alternating current (AC), the voltage periodically changes from positive to negative and from negative to positive, and the direction of the current also periodically changes accordingly. DC stands for direct current means it has a fixed amplitude and no frequency. It has polarity of + and -. Current produced by generators or Turbine are AC currents and the current we get from our HOME power sockets are AC current. Mostly Electrical appliances like FAN, Bulb, AC, Motors are works on AC current.

Primary DC is generated by batteries and electrochemical of photovoltaic cells. Power loss during transmission is more in direct current as compared to alternating current. In direct current, the voltage is always constant, and the electricity flows in a certain direction. AC electricity is more dangerous to work with due to these reasons: The human body has a higher impedance to DC currents than AC; humans can withstand higher voltages of DC electricity than AC. AC is less expensive and easy to generate than DC. AC can be transmitted across long distances without much energy loss, unlike DC.

Safety devices

An electric fuse is a safety device, which is used to limit the current in an electric circuit. The use of fuse safeguards the circuit and appliances connected in that circuit from being damaged. An alloy of lead and tin is used as a material of fuse because it has low melting point and high resistivity. The ground-fault circuit interrupter, or GFCI, is designed to shut-off electric power if a ground fault is detected, protecting the user from a potential electrical shock. The GFCI is particularly useful near sinks and wet locations.

5 tips for electrical safety

- 1 Avoid contact with power lines.
- 2 Ground electrical equipment.
- 3 Take care with power tools.
- 4 Wear protective clothing.
- 5 Stay on top of housekeeping

MCBs and MCCBs are circuit breakers with varying current ratings, suited for different load capacities. RCB, RCD, RCCB, and RCBO, on the other hand, focus on protecting against residual currents and electric shock. MCB (Miniature Circuit Breaker) is for basic protection device to limit the current and fault in a circuit whereas ELCB (Earth Leakage Circuit Breaker) is advanced one which responds only when the circuit leaks current to earth. RCCBs are designed to detect and trip when a current imbalance is detected, which can indicate an electric shock.

Rubber insulating gloves are the preferred choice as they are generally designed to protect against electrical hazards.

Difference between conductors and semiconductors and Resistors

- Conductors are materials that readily allow the flow of electric current. They typically have low resistance and high conductivity. The properties of conductors can be attributed to the following factor. Conductors have loosely bound valence electrons that are free to move within the material. This electron mobility enables efficient electric current flow.

Most conductors are metals, such as copper, silver, and aluminum, due to their high electron mobility. Conductors are used in a wide range of applications, including power transmission lines, electrical wiring, and electronic components.

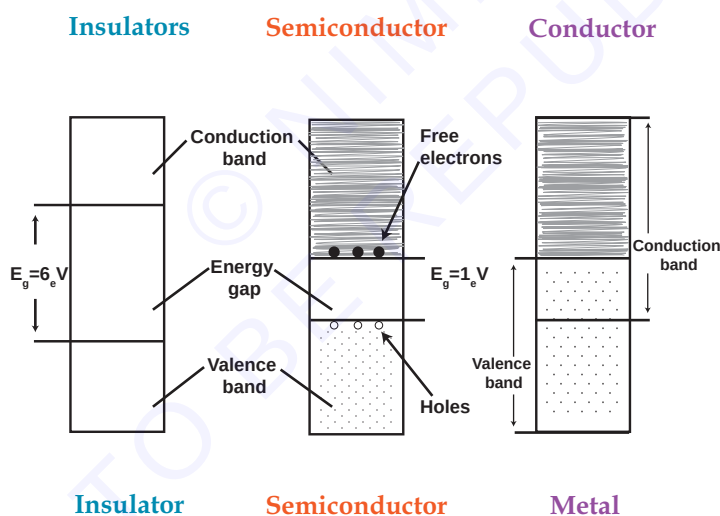
- Semiconductors are materials that exhibit intermediate electrical properties between conductors and insulators. They possess unique characteristics that make them crucial for modern electronics. The conductivity of semiconductors increases with temperature, as thermal energy generates additional charge carriers.

Semiconductors can be intentionally doped with impurities to control their conductivity and create either n-type (electron-rich) or p-type (hole-rich) materials. Semiconductors are the foundation of modern electronics, used in transistors, diodes, integrated circuits, and solar cells. Silicon and germanium are the most widely used semiconductor materials

- Insulators are materials that oppose the flow of electric current, exhibiting high resistance and low conductivity. The characteristics of insulators include. Insulators have tightly bound valence electrons, preventing the free movement of electrons and hindering electric current flow. Most insulators are nonmetals or compounds, such as plastics, ceramics, glass, and rubber. Insulators are used to prevent the flow of electric current, such as in electrical insulation, circuit board substrates, and cable jackets.

In summary, conductors, semiconductors, and insulators are materials distinguished by their ability to conduct electric current. Conductors allow easy current flow, semiconductors exhibit intermediate conductivity with unique properties, and insulators hinder current flow. These classifications play a crucial role in the design and function of electrical systems and electronic devices.

Classification of solids into three types, according to their band structure



Sl. No.	Conductors	Semiconductors	Insulators
1	Conductor easily conducts the electrical current	A semiconductor conducts the electric current less than conductor and greater than insulator	An insulator does not conduct any current
2	Conductor has one valence electron in its outer most orbit	Semiconductor has 4 valence electrons in the outer most orbit	Insulator has 8 valence electrons in the outer most orbit

3	Valance and conduction bands are overlapped	Valance and conductor bands are separated by forbidden energy gap of 1.1 ev	Forbidden energy gap of 6 to 10 ev
4	Conductor formed using metallic bonding	Semiconductor are formed due to covalent bonding	Insulators are formed due to ionic bonding
5	Resistance is very small	Resistance in high	Resistance is very high
6	It has positive temperature coefficient	It has negative temperature coefficient	It has negative temperature coefficient
7	Example:- Copper, Aluminum etc.	Example:- Germanium, Silicon etc	Example:- Mica, Paper etc

Materials Used For Conductors, Semiconductors & Resistors

- Conductors are those materials that easily conduct electricity, materials with high electrical conductivity and low electrical resistivity such as copper, iron, gold, aluminum, and silver are the best materials for conducting electricity. Also Mercury, Steel, Iron & Seawater.

Semiconductor is that Materials with an electrical conductivity value that falls between that of a conductor and that of an insulator such as antimony, arsenic, boron, carbon, germanium, selenium, silicon, sulfur and tellurium. Silicon is the best known of these, forming the basis of most ICs. Common semiconductor compounds include gallium arsenide, indium antimonide and the oxides of most metals.

- Resistors are commonly made by winding a metal wire, usually nichrome, around a ceramic, plastic, or fiberglass core. The ends of the wire are soldered or welded to two caps or rings, attached to the ends of the core. Such as.
 - Wire wound (WW)
 - Carbon Composition (CCR)
 - Carbon Film.
 - Metal Film.
 - Metal Oxide Film.
 - Foil.

Ohm's Law

Ohm's Law states that the current flowing through a conductor is directly proportional to the voltage applied across it, while inversely proportional to its resistance. In simpler terms, it relates how voltage, current, and resistance are interconnected within an electrical circuit.

$$V \propto I$$

$$\text{or, } V = I \times R$$

Where:

V represents the voltage (in volts V)

I denotes the current (in amperes A)

R signifies the resistance (in ohms Ω).

Some common applications of Ohm's Law:

In fuses

- To know the power consumption.
- To control the speed of fans.
- For deciding the size of resistors.
- To determine the voltage, resistance, or current of an electric circuit.

Example 1: If the resistance of an electric coil is 60Ω and a current of 3.2 A flows through the resistance. Find the voltage between two points.

Solution: According to the question, Resistance = 60Ω

Current = 3.2 A

So in order to calculate the voltage we can use the formula, $V = IR$

$$V = I \times R$$

$$V = 3.2 \text{ A} \times 60 \Omega = 192 \text{ V}$$

So the Voltage between the two points in the electric coil is 192 V .

Example 2: An EMF source of 10.0 V is connected to a purely resistive electrical appliance (a light bulb). An electric current of 5.0 A flows through the bulb. Consider the conducting wires to be resistance-free. Calculate the resistance of the appliance.

Solution: According to the question, the Voltage of the source = 10 V

Current = 5.0 A

So in order to calculate the resistance we can use the formula, $R = V/I$

$$R = V/I$$

$$R = 10 \text{ V} / 5 \text{ A}$$

$$R = 2 \Omega.$$

Series, Parallel and Series-Parallel Combination of Resistances

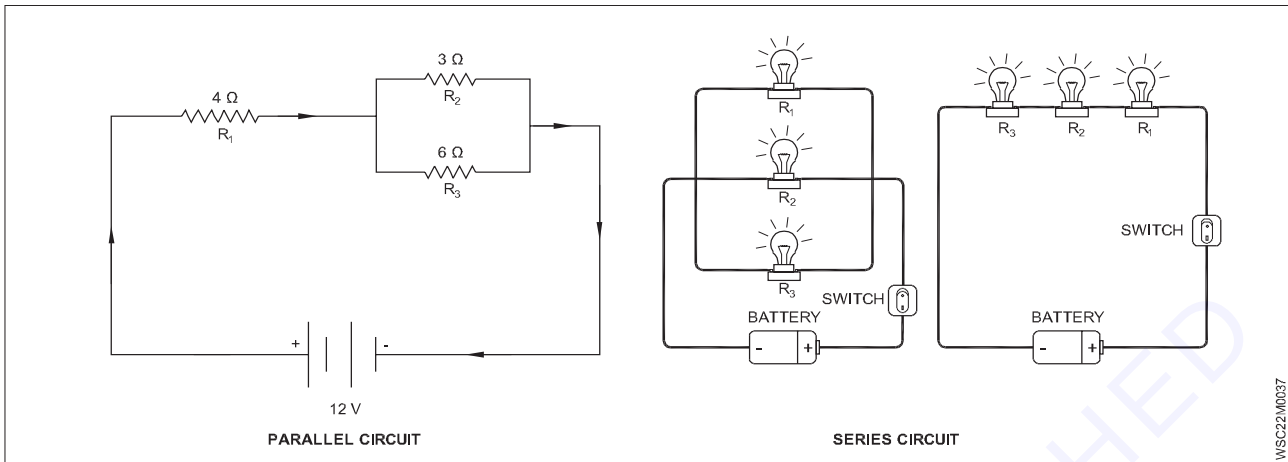
In a series combination, resistances are connected by an end to end such that the current flowing through all of them is equal. Whereas in a parallel combination, the resistances are connected in such a manner that they get an equal voltage. In a series circuit, the same amount of current flows through all the components placed in it. On the other hand, in parallel circuits, the components are placed in parallel with each other due to which the circuit splits the current flow.

Concept, Definitions and Units of Electrical Work, Power and Energy With Related Problems

Electrical work is equal to the amount of charge multiplied by the voltage difference. It describes the effort put in to move a charge between two points. This principle is embodied in the formula $W = QV$, where W represents work, Q charge, and V voltage.

Electric power is the rate at which work is done or energy is transferred in an electrical circuit. Simply put, it is a measure of how much energy is used in a span of time. SI unit of power is the watt (W), which is equal to one joule per second. Electric energy is generated from potential differences in a circuit, causing current to flow. The SI unit of energy is joule.

Fluid mechanics, science concerned with the response of fluids to forces exerted upon them. It is a branch of classical physics with applications of great importance in hydraulic and aeronautical engineering, chemical engineering, meteorology, and zoology.



WSC22-M037

Example 1: A current of 0.8 A flows through the resistor, The potential difference is given as 16 Volts. What is the resistance of the resistor?

Given:

Electric current(I) = 0.8A

Potential difference(V)= 16 v

To find: Resistance (R)

Formula:

$V = IR$

Solution:

Therefore, the resistance of the resistor is 20 ohms.

Example 2: How much current will an electric bulb draw from a 120 V source, if the resistance of the bulb filament is 1000 Ω ?

Given:

Resistance (R) = 1000

Potential difference (V) = 120

To find: Electric current (I)

Formula:

$V = IR$

Solution:

Therefore, the electric bulb will draw 0.12 Ampere of current.

Example 3: How much current will an electric heater coil draw from a 120 V source, if the resistance of the heater coil is 100 Ω ?

Given:

Resistance (R) = 100 Ω

Potential difference (V) = 120 V

To find: Electric current (I)

Formula: $V = IR$

Solution:

Therefore, the electric bulb will draw 1.2 Ampere of current.

Assignment

- 1 What current flows through the bulb of a 3.00-V flashlight when its hot resistance is 3.60Ω ?

Solution

0.833 A

- 2 What is the resistance of a 20.0-m-long piece of 12-gauge copper wire having a 2.053-mm diameter?

Solution

0.104 Ω

- 3 What is the effective resistance of a car's starter motor when 150 A flows through it as the car battery applies 11.0 V to the motor?

Solution

$7.33 \times 10^{-2}\Omega$

- 1 What will be the resistance if 10 resistors of 10 ohm each is connected in series

(A) 100 ?

(B) 1 ?

(C) 0.1 ?

(D) 10 ?.

ANSWER-A

- 2 Resistivity of a wire depends on

(A) length

(B) material

(C) cross section area

(D) All of the above.

ANSWER-B

- 3 Which of the following is not the same as watt?

(A) joule/sec

(B) amperes/volt

(C) amperes x volts

(D) (amperes)² x ohm.

ANSWER-B

- 4 Ohm's law is not applicable to

(A) DC circuits

(B) high currents

(C) small resistors

(D) semi-conductors.

ANSWER-D

- 5 A wire of resistance R has its length and cross-section both doubled. Its resistance will become

(A) 4 R

(B) 2 R

(C) R

(D) R / 4.

ANSWER-C

6 The rating of fuse wire is expressed in terms of

- (A) Ohms
- (B) Mhos
- (C) Amperes
- (D) Watts.

ANSWER-C

7 For maximum transfer of power, internal resistance of the source should be:

- (A) Equal to load resistance
- (B) Less than that of the load
- (C) More than that of the load
- (D) Zero

ANSWER-A

8 Thevenin's theorem can be applied to network containing

- (A) Passive elements only
- (B) Active elements only
- (C) Linear elements only
- (D) All of these

ANSWER-D

9 Which of the following theorems helps in simplifying computations when the load across a circuit is varying?

- (A) Superposition
- (B) Norton's
- (C) Thevenin's
- (D) Maximum power transfer

ANSWER-D

10 When maximum power transfer takes place, the efficiency of power transfer of the circuit is

- (A) 100%
- (B) 75%
- (C) 50%
- (D) 25%

ANSWER-C

11 The superposition theorem requires as many circuits to be solved as there are:

- (A) Nodes
- (B) Sources
- (C) Nodes and Sources
- (D) Nodes, Sources and Mesh

ANSWER-B

12 An ideal voltage source should have:

- (A) Zero source resistance
- (B) Infinite source resistance
- (C) Terminal voltage is proportional to current
- (D) Open-circuit voltage nearly equal to voltage of the load current

ANSWER-A

13 In which figure the relationship between voltage V and current I is in accordance with Ohm's law ?

- (A) Figure A
- (B) Figure B
- (C) Figure C
- (D) Figure D.

ANSWER-B

14 A passive element in a circuit is one which

- (A) Receives energy
- (B) Supplies energy
- (C) both supplies and receives energy
- (D) none

ANSWER-A

15 Unit of electric potential

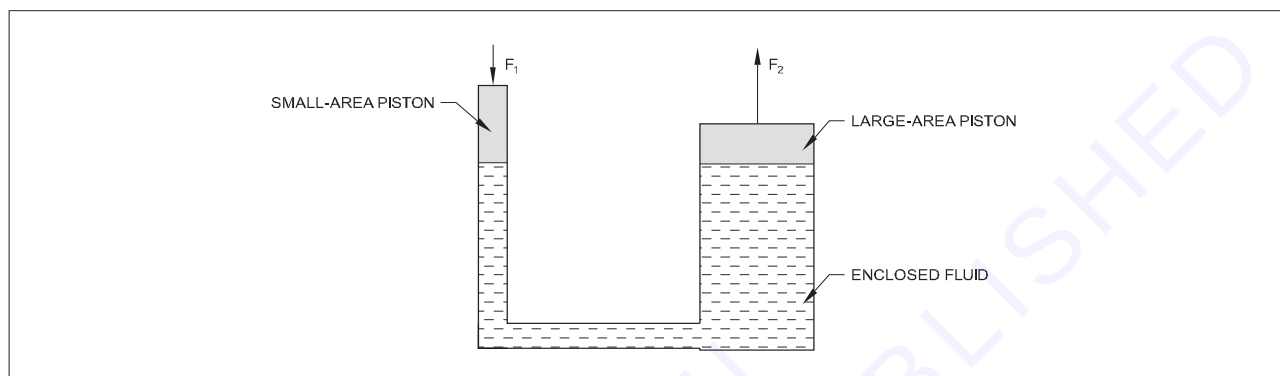
- (A) Ampere
- (B) Volts
- (C) coulomb
- (D) Volt-ampere

ANSWER-B

EXERCISE 10 : Fluid Mechanics

Fluid mechanics is the study of fluid behavior (liquids, gases, and plasmas) at rest and in motion. Fluid mechanics has a wide range of applications in mechanical and chemical engineering, in biological systems, and in astrophysics.

(1) Fluid statics (fluid at rest), (2) Momentum and energy analyses (fluids in motion), and (3) Viscous effects and all sections considering pressure forces (effects of fluids on boundaries).



Properties of Fluid (Density, Viscosity, Specific Weight, Specific Volume, Specific Gravity) With Their Units:

The density of a fluid is defined as the ratio of the mass of the fluid its volume. The density of gases is dependent on pressure and temperature, while the density of liquid remains constant. The density of water is $1000 \text{ kg} \cdot \text{m}^{-3}$ while density of air is $1.225 \text{ kg} \cdot \text{m}^{-3}$. Fluid Density is the mass per unit volume and is denoted by the Greek letter ρ (rho). The old English system of units uses the slug for the unit of mass and feet for the unit of length.

The liquid which has the highest density is mercury, It has a density of about $13.546 \text{ grams per cubic centimeter}$.

Substance	Density	
Air (pair) pair	1.2 kg/m^3	1.2 kg per m^3
Water (pwater) pwater	1000 kg/m^3	1000 kg per m^3
Mercury (pHg)pHg	13600 kg/m^3	13600 per m^3

Liquid has lowest density is Petrol.

- Petrol is a transparent liquid that is used primarily as a fuel in internal combustion engines.
- It consists mostly of organic compounds obtained by the fractional distillation of petroleum.

Viscosity: Viscosity is a measure of a fluid's resistance to flow. The SI unit of viscosity is Poiseuille (PI). Its other units are Newton-second per square meter (Ns m^{-2}) or Pascal-second (Pa s .) The dimensional formula of viscosity is $[\text{ML}^{-1}\text{T}^{-1}]$.

A highly viscous fluid tends to be thick, like honey or cold maple syrup. Compared to a relatively non-viscous fluid, such as water, highly viscous liquids flow much more slowly. Viscosity is represented by the symbol η "eta", and the use of the Greek letter μ (μ) is also common.

Hence, the SI unit of Viscosity is ($\text{N} \cdot \text{s/m}^2$).

Specific weight: In fluid mechanics, specific weight represents the force exerted by gravity on a unit volume of a fluid. For this reason, units are expressed as force per unit volume (e.g., N/m³ or lb/ft³). Specific weight can be used as a characteristic property of a fluid. To find the specific weight of an unknown fluid using a manometer, The specific weight can then be calculated using the formula: specific weight = pressure/density. The SI unit for specific weight is [N/m³]. The imperial unit is [lb/ft³].

Specific volume: Specific volume is a property of materials, defined as the number of cubic meters occupied by one kilogram of a particular substance. The standard unit is the meter cubed per kilogram (m³/kg or m³·kg⁻¹). There are three common formulas used to calculate specific volume (v): $v = V/m$ where V is volume and m is mass. $v = 1/\rho = \rho^{-1}$ where ρ is density. $v = RT/PM = RT/P$ where R is the ideal gas constant, T is temperature, P is pressure, and M is the molarity.

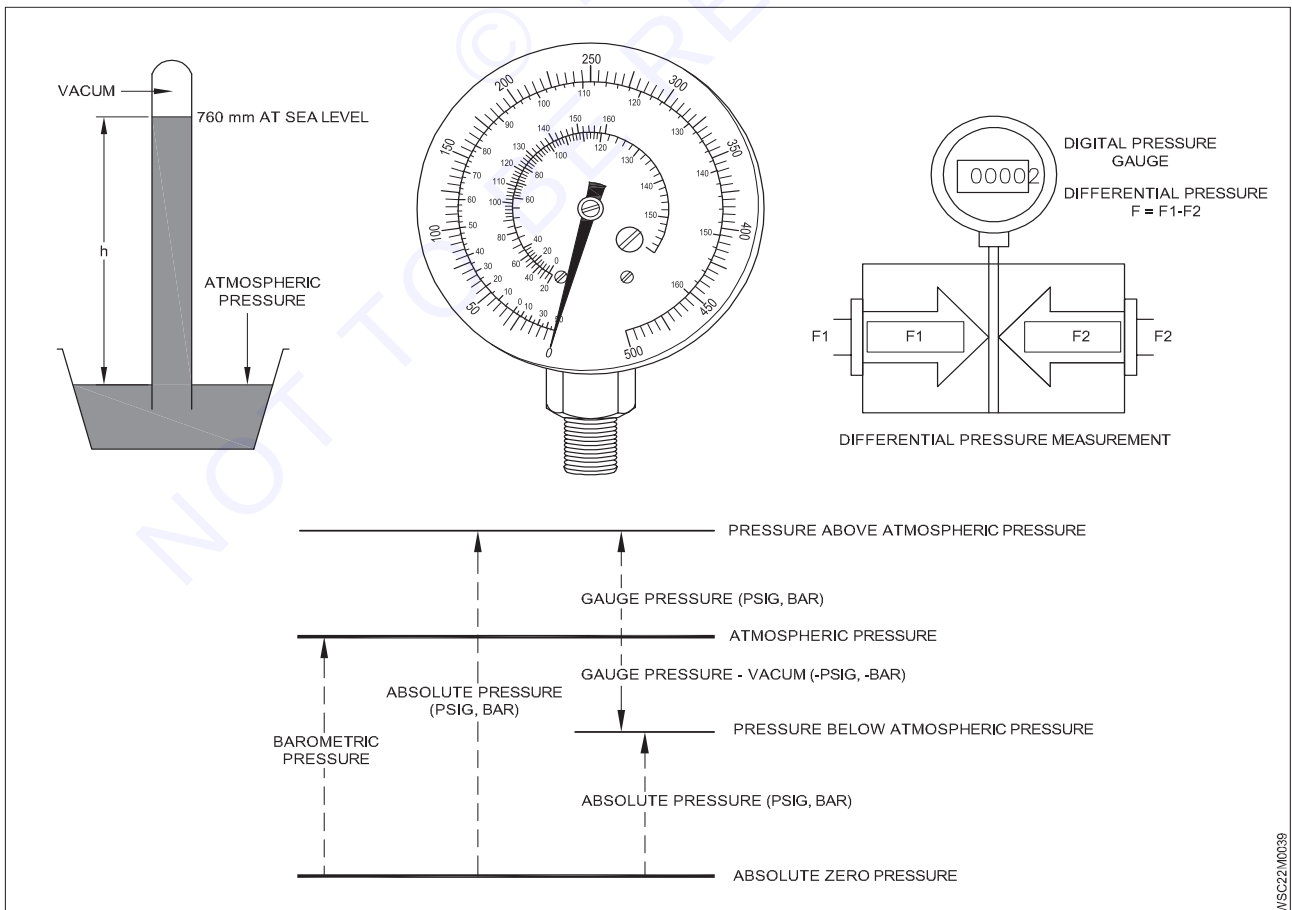
Specific Gravity: The specific gravity of a liquid is the relative weight that liquid compare to an equal volume of water. The specific gravity of water is de facto 1. Liquids that are lighter than water have a specific gravity less than 1 and those heavier than water have a specific gravity greater than 1.

Specific gravity is determined by dividing the density of a material by the density of water at 4 degrees Celsius. The ratio of the density of a substance to the density of some substance (as pure water) taken as a standard when both densities are obtained by weighing in air. Since specific gravity is a ratio, so it has no units.

Concept of Atmospheric Pressure: That pressure is called atmospheric pressure, or air pressure. It is the force exerted on a surface by the air above it as gravity pulls it to Earth. Atmospheric pressure is commonly measured with a barometer. In a barometer, a column of mercury in a glass tube rises or falls as the weight of the atmosphere changes. The SI unit of atmospheric pressure is Pascal (Pa). Another unit of atmospheric pressure is atm and 1 atm = 101325 Pa.

Air pressure is the pressure exerted by the air around us while Atmospheric pressure is the pressure exerted by the atmospheric on the earth. Air pressure is measured by tore gauge while atmospheric pressure is measured using mercury barometer. Where the air pressure is assumed to be zero, is called the Kármán line, which is located 100 km (62 mi) up.

Gauge Pressure, Absolute Pressure, Vacuum & Differential Pressure:



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Types of Pressure

- Absolute pressure.
- Gauge pressure.
- Differential pressure.
- Sealed pressure or vacuum pressure.

Gauge pressure is the pressure relative to atmospheric pressure. Gauge pressure is the pressure relative to atmospheric pressure. Gauge pressure is positive for pressures above atmospheric pressure, and negative for pressures below it. In fact, atmospheric pressure does add to the pressure in any fluid not enclosed in a rigid container. This happens because of Pascal's principle.

Absolute pressure is the sum of gauge pressure and atmospheric pressure. The definition of absolute pressure is the pressure of having no matter inside a space, or a perfect vacuum. Measurements taken in absolute pressure use this absolute zero as their reference point. The best example of an absolute referenced pressure is the measurement of barometric pressure.

Vacuum pressure (Figure 2 labeled C) is a measure of the pressure of a gas in a space where the pressure is lower than atmospheric pressure. It is expressed as a negative gauge pressure, often in units of millimeters of mercury (mmHg) or Pascals (Pa).

Differential pressure is essentially the difference in pressure between two given points. It is a type of pressure measured within different industries using differential pressure sensors. There are 3 common types of pressure;

- Differential Pressure.

Example

A liquid gives force of 100 N over an area of 2 m^2 . What is the pressure?

Force = 100 N

Area = 2 m^2

Pressure = ?

$$P = \frac{F}{A} = \frac{100}{2} = 50\text{ N/m}^2$$

Unit of pressure N/m^2 , $1\text{ N/m}^2 = 1\text{ pascal}$.

This unit is too small (Pressure of a fly on a area of 1 cm^2). Hence 'bar' is introduced as the unit of pressure. $1\text{ bar} = 10^5\text{ pascal}$.

$$10^5\text{ Pa} = 10^5 \frac{\text{N}}{\text{m}^2} = 10 \frac{\text{N}}{\text{cm}^2} = 1\text{ bar}$$

$1\text{ bar} = 1000\text{ mbar}$. [SI unit of Pressure is Pascal (Pa) and Metric unit of Pressure is bar]

Pressure gauges

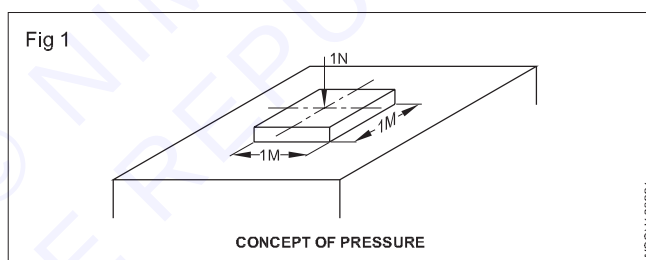
They are instruments or devices used to measure the pressure of liquid steam or gas contained in a vessel. There are also known as manometers.

Types of manometers

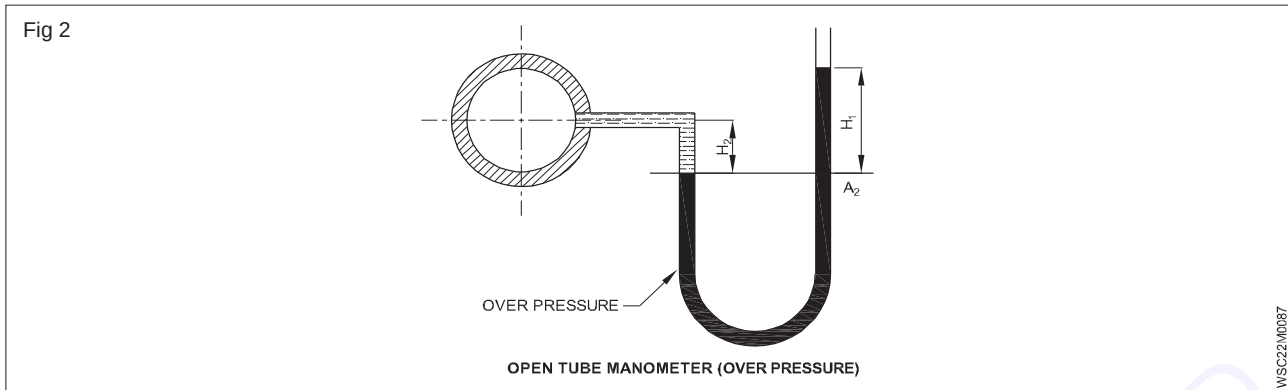
- Open tube
- Closed tube
- Differential type
- Inverted type

Mechanical pressure gauges

- Bourden's pressure gauges
- Diaphragm pressure gauges
- Dead weight pressure gauges



Open tube manometer (Fig 2)

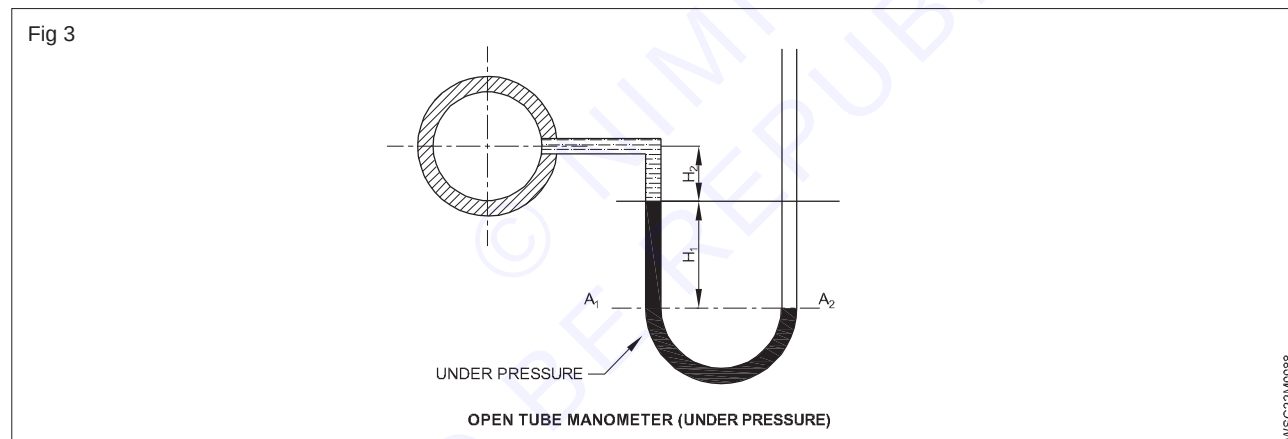


It is more suitable to measure pressure in vessels which are having little variation to atmospheric pressure. It is a 'u' shaped tube containing mercury having its one end connected to the vessel container in which the liquid is there whose pressure is to be determined. The other end is open. The manometer will show a difference in both the limbs of the tube when the pressure inside the vessel is more or less than the air pressure outside.

For a barometer reading with reference to an atmospheric pressure of 1 bar we have

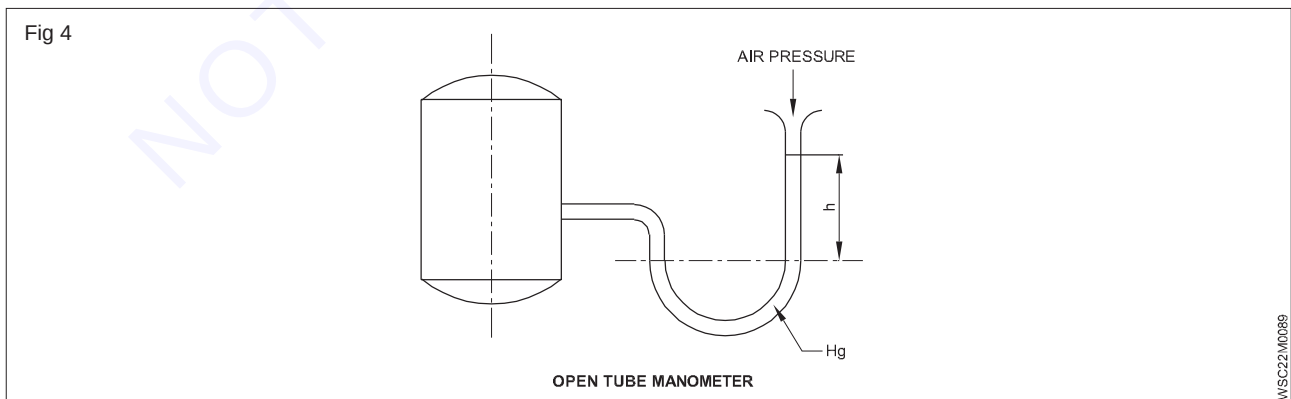
$$P_a = 1 + P_o \text{ (shown in Fig 2)}$$

$$P_a = 1 - P_u \text{ (shown in Fig 3)}$$



Example (Fig 4)

A manometer is connected to an air pressure tank and it indicates an over pressure of 615 mm pressure head. The external air pressure is 1015 mbar. Calculate the absolute pressure in bar and in Pascal (Fig 4).



Absolute Pressure = External Air Pressure + Over Pressure

$$P_a = 1015 \text{ mbar} + 100 \text{ mbar} \times 615 \text{ mm} / 750 \text{ mm}$$

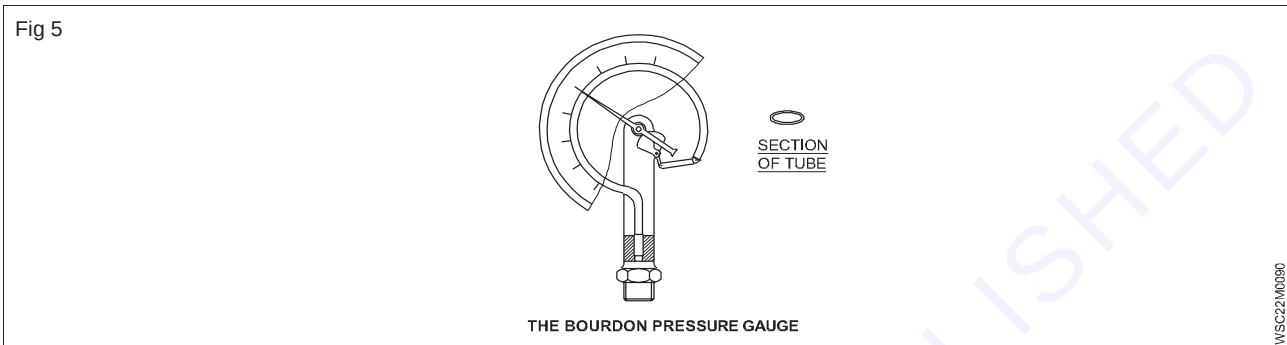
$$= 1835 \text{ mbar}$$

$$P_a = 1.835 \text{ bar} = 1.835 \times 10^5 \text{ Pascal}$$

If the barometer reading is in mm, it is always necessary to convert into m bar.

Pressure and Vacuum gauges

Bourdon tube pressure gauges (Fig 5)



In I.C. Engines, Bourdon tube pressure gauges are widely employed for measurement of pressure, temperature and vacuum. In these gauges, a Bourdon tube which is a tempered, one is used and it attempts to straighten out under pressure and temperature and contract under vacuum.

The working is briefly described here refer to figure. A phosphor bronze tube or elliptical cross section is used and bent to an arc of a circle. The free end of the tube is sealed under internal pressure (or temperature), it attempts to straighten out. During this process, it operates sector, pinion and needle which indicates pressure or temperature over a calibrated dial. The entire unit is mounted on a casing and covered with glass and frame and around it.

Vacuum gauges

These are also of Bourdon tube type gauges where the tube attempts to contract under vacuum thus recording vacuum of the engine in mm Hg (millimeters of mercury)

A reading of 760 mm Hg is perfect vacuum (zero absolute pressure)

A zero of say 300 mm Hg means to say that 300 mm of vacuum is equivalent to (760-300) 460 mmHg absolute pressure.

- Vacuum gauges are often used by service mechanics to find out the mechanical condition of the engine and whether valves, ignition timing and carburetor setting are correct and carry out fine adjustments to obtain the best performance of the engine.
- **Vacuum in Diesel Engine governors:** This is measured by water column methods in fuel injection test bench

Assignment

- 1 Find the pressure at the depth of 40 metres below the surface of a lake in dynes per sq. cm., the atmospheric pressure being neglected.

Solution:

Depth of water level $p = 40 \text{ m} = 4000 \text{ cm}$

Density of water $d = 1 \text{ gram/cc}$

Acceleration due to gravity $g = 980 \text{ cm/sec}^2$

Pressure below the surface of lake is given by the formula
 $= \rho \cdot d \cdot g$.

$$\begin{aligned}\text{Pressure} &= \rho \cdot d \cdot g \\ &= 4000 \times 1 \times 980 \\ &= 3920000 \text{ dynes per sq. cm.}\end{aligned}$$

- 2 At 5 atmospheric pressure 0.2 cu. metre air is filled in a container. If the same air is filled at constant temperature in a 1 cu. metre volume of container then calculate the air pressure in the container.

Solution: At constant temperature the gas follows Boyle's Law

$$P_1 V_1 = P_2 V_2$$

Here, $P_1 = 5$, $V_1 = 0.2 \text{ cu. metre}$, $V_2 = 1 \text{ cu. metre}$

$$\begin{aligned}P_1 V_1 &= P_2 V_2 \\ 5 \times 0.2 &= P_2 \times 1.0 \\ P_2 &= \frac{22}{7} \times 1. = 1\end{aligned}$$

Air pressure in the container = 1 atmospheric.

- 3 The volume of a gas at 770 mm pressure is 403 cc. Find the pressure when the volume is reduced to 341 cc.

As per Boyles Law

$$\begin{aligned}P_1 V_1 &= P_2 V_2 \\ 770 \times 403 &= P_1 \times 341\end{aligned}$$

$$P_1 =$$

Pressure when volume is reduced = **910 mm**