LEARNING MATERIAL

FOR

APPLIED PHYSICS

(FOR 1ST YEAR)

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SYLLABUS

APPLIED PHYSICS

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RATIONALE

Applied physics includes the study of a large number of diverse topics all related to things that go on in the world around us. It aims to give an understanding of this world both by observation and by prediction of the way in which objects will behave. Concrete use of physical principles and analysis in various fields of engineering and technology are given prominence in the course content.

Note: Teachers should give examples of engineering/technology applications of various concepts and principles in each topic so that students are able to appreciate learning of these concepts and principles. In all contents, SI units should be followed. Working in different sets of units can be taught through relevant software.

LEARNING OUTCOMES

After undergoing this subject, the students will be able to:

- Identify physical quantities, parameters and select their units for use in engineering solutions.
- Units and dimensions of different physical quantities.
- Represent physical quantities as scalar and vectors.
- Basic laws of motions,
- Analyse and design banking of roads and apply conservation of momentum principle to explain recoil of gun etc.
- Define work, energy and power and their units. Solve problems about work and power
- State the principle of conservation of energy.
- Identify forms of energy, conversion from one form to another.
- Compare and contrast the physical properties associated with linear motion and rotational motion and give examples of conservation of angular momentum.
- Describe the surface tension phenomenon and its units, applications, effects of temperature on surface tension.
- Describe the viscosity of liquids.
- Define stress and strain, modulus of elasticity.
- State Hooke's law.
- Measure temperature in various processes on different scales (Celsius, Kelvin, Fahrenheit etc.)
- Distinguish between conduction, convection and radiation.
- Use equipments like Vernier calliper, screw gauge, Spherometer.
- Differentiate between Transverse and Longitudinal, Periodic and Simple Harmonic

Motion.

- Explain the terms: frequency, amplitude, wavelength, wave velocity, frequency and relation between them.
- Explain various Engineering and Industrial applications of Ultrasonics.
- Apply acoustics principles to various types of buildings to get best sound effect.
- Explain the laws of reflection and refraction of light.
- Explain total internal reflection as applied to optical fibers.
- Define capacitance and its unit and solve simple problems using C=Q/V
- Explain the role of free electrons in insulators, conductors and semiconductors.
- Application of semiconductors as diode, rectifiers, concept of transistors
- Explain electric current as flow of charge, the concept of resistance, heating effect of current.
- State and apply Ohm's law.
- Calculate the equivalent resistance of a variety of resistor combinations.
- Apply the concept of light amplification in designing of various LASER based instruments and optical sources.
- Apply the use of optical fibre in Medical field and optical fibre Communication.
- Concept of nanomaterials

DETAILED CONTENTS

Section A (20%)

1. Units and Dimensions (10 periods)

1.1 Definition of Physics, Physical quantities (Fundamental and derived),
1.2 Units: fundamental and derived units,
1.3 Systems of units: CGS, FPS, MKS, SI
1.4 Definition of Dimensions;
1.5 Dimensional formulae and SI units of physical quantities (distance, displacement, area, volume, velocity, acceleration, momentum, force, impulse, work, power, energy, pressure, surface tension, stress, strain)
1.6 Principle of homogeneity of dimensions
1.7 Dimensional equations, Applications of dimensional equations; checking of correctness of equation, Conversion of system of unit (force, work)

2. Force and Motion (10 periods)

2.1 Scalar and vector quantities –(Definition and examples),
2.2 Addition of Vectors, Triangle & Parallelogram Law (Statement only),
2.3 Scalar and Vector Product (statement and formula only)
2.4 Definition of Distance, displacement, speed, velocity, acceleration
2.5 Force and its units, concept of Resolution of force
2.6 Newton’s Law of motion (Statement and examples),

2.7 Linear Momentum, conservation of momentum (Statement only), Impulse

2.8 **Circular motion**: definition of angular displacement, angular velocity, angular acceleration, frequency, time period; Relation between linear and angular velocity.

2.9 Centripetal and centrifugal forces(definition and formula only)

2.10 Application of centripetal force in Banking of roads (derivation for angle of banking)

Section B (20%)

3. Work, Power and Energy (08 periods)

3.1. Work (Definition, Symbol, Formula and SI units)

3.2. Energy (Definition and its SI units), Examples of transformation of energy.

3.3. Kinetic Energy (Formula, examples and its derivation)

3.4. Potential Energy (Formula, examples and its derivation)

3.5. Law of conservation of mechanical energy for freely falling bodies (With Derivation)

3.6. Power (definition, formula and units)

3.7. Simple Numerical problems based on formula of Power

4 Rotational Motion (04 periods)

4.1 Rotational motion with examples

4.2 Definition of torque and angular momentum and their examples

4.3 Conservation of angular momentum (quantitative) and its examples

4.4 Moment of inertia and its physical significance, radius of gyration (definition, derivation and formula).

5. Properties of Matter (8 periods)

5.1 Definition of Elasticity, Deforming force, Restoring force, example of Elastic and plastic body,

5.2 Definition of Stress and strain with their types,

5.3 Hooke's law, Modulus of Elasticity (Young's, Bulk modulus and shear)

5.4 Pressure (definition, formula, unit), Pascals Law

5.5 Surface tension: definition, its units, applications of surface tension, effect of temperature on Surface tension

5.6 Viscosity: definition, units, effect of temperature on viscosity

5.7 Fluid motion, stream line and turbulent flow.

Section C (60%)

6. Heat and temperature (06 periods)

6.1 Definition of heat and temperature (on the basis of kinetic theory),

6.2 Difference between heat and temperature

6.3 Principles of measurement of temperature.

6.4 Modes of transfer of heat (Conduction, convection and radiation with examples).

6.5 Properties of heat radiation
6.6 Different scales of temperature and their relationship

7. Wave motion and its applications (10 periods)

7.1 Wave motion, transverse and longitudinal wave motion with examples, Terms used in wave motion like displacement, amplitude, time period, frequency, wavelength, wave velocity; relationship among wave velocity, frequency and wave length .
7.2 Simple Harmonic Motion (SHM): definition, examples
7.3 Cantilever (definition, formula of time period (without derivation).
7.4 Free, forced and resonant vibrations with examples
7.5 Acoustics of buildings – reverberation, reverberation time, echo, noise, coefficient of absorption of sound, methods to control reverberation time.
7.6 Ultrasonics: Introduction and their engineering applications (cold welding, drilling, SONAR)

8. Optics (05 periods)

8.1. Reflection and refraction with laws, refractive index, lens formula (no derivation), power of lens (related numerical problems).
8.2. Total internal reflection and its applications, Critical angle and conditions for total internal reflection
8.3. Microscope, Telescope (definition)
8.4. Uses of microscope and telescope.

9. Electrostatics (09 Periods)

9.1. Electric charge, unit of charge, conservation of charge.
9.2. Coulombs law of electrostatics,
9.3. Electric field, Electric lines of force (definition and properties), Electric field intensity due to a point charge.
9.4. Definition of Electric flux, Gauss law (Statement and derivation)
9.5. Capacitor and Capacitance (with formula and units), Series and parallel combination of capacitors (simple numerical problems)

10. Current Electricity (08 Periods)

10.1 Electric Current and its Unit, Direct and alternating current,
10.2 Resistance, Specific Resistance and Conductance (definition and units)
10.3 Series and Parallel combination of Resistances.
10.4 Ohm’s law (statement and formula),
10.5 Heating effect of current, Electric power and its units
10.6 Kirchhoff’s laws (statement and formula)

11 Electromagnetism (04 periods)

11.1. Introduction to magnetism, Types of magnetic materials. Dia, para and ferromagnetic materials with examples.

11.2. Magnetic field, magnetic intensity, magnetic lines of force, magnetic flux and their units

11.3. Electromagnetic induction (definition)

12. Semiconductor physics (09 periods)

12.1. Definition of Energy level, Energy bands,

12.2. Types of materials (insulator, semi conductor, conductor) with examples,

12.3. Intrinsic and extrinsic semiconductors, p-n junction diode and its V-I characteristics

12.4. Diode as rectifier – half wave and full wave rectifier (centre tap only)

12.5. Semiconductor transistor; pnp and npn (Introduction only), symbol.

13. Modern Physics (09 periods)

13.1. Lasers: full form, principle, spontaneous emission, stimulated emission, population inversion, engineering and medical applications of lasers.

13.2. Fibre optics: Introduction to optical fibers (definition, parts), applications of optical fibers in different fields.

13.3. Introduction to nanotechnology (definition of nanomaterials with examples) and its applications.

LIST OF PRACTICALS (To perform minimum fourteen experiments)

1. To find diameter of solid cylinder using a vernier calliper
2. To find internal diameter and depth of a beaker using a vernier calliper and hence find its volume.
3. To find the diameter of wire using screw gauge
4. To find thickness of paper using screw gauge.
5. To determine the thickness of glass strip using a spherometer
6. To determine radius of curvature of a given spherical surface by a spherometer.
7. To verify parallelogram law of forces
8. To determine the atmospheric pressure at a place using Fortin's Barometer
9. To determine force constant of spring using Hooke's law
10. Measuring room temperature with the help of thermometer and its conversion in different scale.
11. To find the time period of a simple pendulum
12. To determine and verify the time period of Cantilever
13. To verify ohm's laws by plotting a graph between voltage and current.
14. To verify laws of resistances in series combination.
15. To verify laws of resistance in parallel combination.

16. To find resistance of galvanometer by half deflection method
17. To verify laws of reflection of light using mirror.
18. To verify laws of refraction using glass slab.
19. To find the focal length of a concave lens, using a convex lens
20. To study colour coding scheme of resistance.

INSTRUCTIONAL STATREGY

Teacher may use various teaching aids like models, charts, graphs and experimental kits etc. for imparting effective instructions in the subject. Students need to be exposed to use of different sets of units and conversion from one unit type to another. Software may be used to solve problems involving conversion of units. The teacher should explain about field applications before teaching the basics of mechanics, work, power and energy, rotational motion, properties of matter etc. to develop proper understanding of the physical phenomenon. Use of demonstration can make the subject interesting and develop scientific temper in the students.

MEANS OF ASSESSMENT

- Assignments and quiz/class tests, mid-term and end-term written tests, model/prototype
- Actual laboratory and practical work, exercises and viva-voce

RECOMMENDED BOOKS

1. Text Book of Physics for Class XI (Part-I, Part-II); N.C.E.R.T., Delhi
2. Applied Physics, Vol. I and Vol. II by Dr. HH Lal; TTTI Publications, Tata McGraw Hill, Delhi
3. Concepts in Physics by HC Verma, Vol. I & Vol. II Bharti Bhawan Ltd. New Delhi
4. Engineering Physics by PV Naik, Pearson Education Pvt. Ltd, New Delhi
5. e-books/e-tools/relevant software to be used as recommended by AICTE/ HSBTE/ NITTTR.
6. Practical Physics, by C. L. Arora, S Chand Publication

Websites for Reference:

http://swayam.gov.in

DISTRIBUTION OF SYLLABUS FOR ASSESSMENTS & DISTRIBUTION OF MARKS

Section	Unit	Time Allotted (Periods)	Marks Allotted (%)
A (20 Marks)	1	10	10
	2	12	10
B (20 Marks)	3	8	8
	4	5	4
	5	8	8
C (60 Marks)	6	6	6
	7	10	10
	8	5	5
	9	9	9
	10	9	8
	11	5	4
	12	9	9
	13	9	9
	Total	**105**	**100**

Chapter 1: UNITS & DIMENSIONS

Physics: Physics is the branch of science which deals with the study of nature and properties of matter and energy. The subject matter of physics includes heat, light, sound, electricity, magnetism and the structure of atoms.

For the designing a law of physics scientific method is followed which includes the verifications with experiments. The physics, attempts are made to measure the quantities with the best accuracy .Thus Physics can also be defines as **science of measurement**.

Applied Physics is the application of the Physics to helping human beings and solving their problem, it is usually considered as a bridge or a connection between Physics & engineering.

Physical Quantities: All quantities in terms of which laws of physics can be expressed and which can be measured are called Physical Quantities.

e.g - Distance, Speed, mass, Force etc.

Measurement: In our daily life, we need to express and compare the magnitude of different quantities; this can be done only by measuring them.

Measurement is the comparison of an unknown physical quantity with a known fixed physical quantity.

Unit: The known fixed physical quantity is called unit. OR The quantity is used as standard for measurement is called unit.

For example, when we say that length of the class room is 8 metre. We compare the length of bench with standard quantity of length called metre.

Length of class room = 8 metre

$$\boxed{Q = nu}$$

Physical Quantity = Numerical value x unit

Q = Physical Quantity

n = Numerical value

u = Standard unit

e.g. Mass of stool = 15 kg

Mass = Physical quantity

15 = Numerical value

Kg = Standard unit

Means mass of stool is 15 times of known quantity i.e kg.

Characteristics of Standard Unit: A unit selected for measuring a physical quantity should have the following properties

(i) It should be well defined i.e. its concept should be clear.
(ii) It should not be change with change in its physical condition like temperature, pressure & stress.
(iii) It should be suitable in size i.e. neither too large nor too small.
(iv) It should not change with place of time.
(v) It should be reproducible.
(vi) It should be internationally accepted.

Classification of Units: Units can be classified into two categories.

- **Fundamental**
- **Derived**

Fundamental Quantity: The quantity which are independent on each other. In mechanics, mass, length and time are called fundamental quantity. Units of these fundamental physical quantities are called **Fundamental units.**

e.g. Fundamental Physical Quantity	Fundamental unit
Mass	Kg, Gram, Pound
Length	Metre, Cm, Foot
Time	Second, Minute, Hour

Derived Quantity: Derived quantity is the quantity which is derived from the fundamental quantities e.g. Area is derived quantity.

Area = Length x Breadth

= Length x Length

$= (\text{Length})^2$

Speed =Distance / Time

=Length / Time

The units for derived quantity is called **Derived Units.**

SYSTEM OF UNIT: For measurement of physical quantities, the following system are commonly used:-

(i) C.G.S system: In this system, the units of length is centimetre, the unit of mass is gram and the unit of time is second.

(ii) F.P.S system: In this system, the unit of length is foot, the unit of mass is a pound and the unit of time is second.

(iii) M.K.S: In this system, the unit of length is metre, unit of mass is kg and the unit of time is second.

(iv) S.I System: This version is an improved and extended version of M.K.S system of units. It is called international system of unit.

With the development of science & technology, the three fundamental quantities like mass , length & time were not sufficient as many other quantity like electric current , heat etc. Came up

Therefore, more fundamental units in addition to the units of mass, length and time.

Thus, MKS system was modified with addition of four other fundamental quantities and two supplementary quantities.

Table of Fundamental Units

Sr. No.	Name of Physical Quantity	Unit	Symbol
1	Length	Metre	m
2	Mass	Kilogram	Kg
3	Time	Second	s
4	Temperature	Kelvin	K
5	Electric Current	Ampere	A
6	Luminous Intensity	CCandela	Cd
7	Quantity of Matter	Mole	mol

Table of Supplementary unit

Sr. No	Name of Physical Quantity	Unit	Symbol
1	Plane angle	Radian	rad
2	Solid angle	Steradian	sr

Advantage of S.I. system:

(i) It is coherent system of unit i.e. the derived units of a physical quantity are easily obtained by multiplication or division of fundamental units.

(ii) It is a rational system of units i.e. it uses only one unit for one physical quantity. i.e. It uses as unit Joule (J) for all types of energies (heat, light, mechanical).

(iii) It is metric system of units i.e. its multiples & submultiples can be expressed in power of 10.

Basic and Supplementary unit of S.I:

1. **Metre** (m) : The metre is the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second

2. **Kilogram** (Kg) : The kilogram is the mass of the platinum-iridium prototype which was approved by the Conférence Générale des Poids et Mesures, held in Paris in 1889, and kept by the Bureau International des Poids et Mesures.

3. **Second** (s): The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom.

4. **Ampere** (A) : The ampere is the intensity of a constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2 x 10-7 newton per metre of length.

5. **Kelvin** (K): kelvin is the fraction 1/273,16 of the thermodynamic temperature of the triple point of water.

6. **Candela** (Cd): The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 x 1012 hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

7. **Mole** (mol): The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0,012 kilogram of carbon 12.

Supplementary units:

1. Radian (rad): It is supplementary unit of plane angle. It is the plane angle subtended at the centre of a circle by an arc of the circle equal to the radius of the circle. It is denoted by θ.

$\theta = l / r$

l= length of the arc

r= radius of the circle

2. Steradian (Sr): It is supplementary unit of solid angle. It is the angle subtended at the centre of a sphere by a surface area of the sphere having magnitude equal to the sphere of the radius of the sphere. It is denoted by Ω.

$\Omega = \Delta s / r^2$

SOME IMPORTANT ABBREVIATIONS

Symbol	Prefix	Multiplier	Symbol	Prefix	Multiplier
D	deci	10^{-1}	da	deca	10^{1}
c	centi	10^{-2}	h	hecto	10^{2}
m	milli	10^{-3}	k	kilo	10^{3}
µ	micro	10^{-6}	M	mega	10^{6}
n	nano	10^{-9}	G	giga	10^{9}
P	Pico	10^{-12}	T	tera	10^{12}
f	femto	10^{-15}	P	Pecta	10^{15}
a	atto	10^{-18}	E	exa	10^{18}

Some Important Units of Length:

(i) 1 fermi = 1 fm = 10^{-15} m
(ii) 1 angstrom = 1Å = 10^{-10} m = 10^{-8} cm
(iii) 1 micron = 10^{-6} m = 10^{-4} cm
(iv) 1 Light year = 1 ly = 9.46 x 10^{15}m
(v) 1 Parsec = 1pc = 3.26 light year

Some conversion Factor of mass:

1 kilogram = 202046 pound

1 pound = 453.6 gram

1 kilogram = 1000 gram

1 milligram = 1/1000 gram = 10^{-3} gram

1 centigram = 1/100 gram = 10^{-2} gram

1 decigram = 1/10 gram

1 quintal = 100 kg

1 metric ton = 1000 kilogram

DIMENSIONS

Dimensions: The dimensions of a derived physical quantity are the powers to which the fundamental units of mass, length and time written as M,L and T which include their nature and not their magnitude.

For example Area = Length x Breadth

$= [L^1] \times [L^1] = [L^2] = [M^0L^2T^0]$

Power (0,2,0) of fundamental units are called dimensions of area in mass , length and time respectively.

e.g. Density = mass/volume

$=[M]/[L^3]$

$=[M^1L^{-3}T^0]$

Dimensional Formula: A dimensional formula is an expression along with power of mass, length & time which indicates how derives physical quantity depends upon fundamental physical quantity.

e.g. Speed = Distance/Time

$=[L^1]/[T^1] =[M^0L^1T^{-1}]$

It tells us that speed depends upon L & T. It does not depends upon M.

Dimensional Equation: An equation obtained by equating the physical quantity with its dimensional formula is called dimensional equation.

The dimensional equation of area, density & velocity are given as under-

Area = $[M^0L^2T^0]$

Density = $[M^1L^{-3}T^0]$

Velocity = $[M^0L^1T^{-1}]$

Dimensional formula SI & CGS unit of Physical Quantity

Sr. No.	Physical Quantity	Formula	Dimension	Name of S.I unit	Name of c.g.s unit
1	Force	Mass x acceleration	$[M^1L^1T^{-2}]$	Newton (N)	Dyne
2	Work	Force x distance	$[M^1L^2T^{-2}]$	Joule (j)	Erg
3	Power	Work / time	$[M^1L^2T^{-3}]$	Watt (W)	Erg/s
4	Energy (all form)	Stored work	$[M^1L^2T^{-2}]$	Joule (J)	Erg
5	Pressure,Stress	Force/area	$[M^1L^{-1}T^{-2}]$	Nm^{-2}	Barye
6	Momentum	Mass x velocity	$[M^1L^1T^{-1}]$	$Kgms^{-1}$	
7	Moment of force	Force x distance	$[M^1L^2T^{-2}]$	Nm	
8	Impulse	Force x time	$[M^1L^1T^{-1}]$	Ns	
9	Strain	Change in dimension / original dimension	$[M^0L^0T^0]$	No unit	

10	Modulus of elasticity	Stress / strain	$[M^1L^{-1}T^{-2}]$	Nm^{-2}	
11	Surface energy	Energy / area	$[M^1L^0T^0]$	Joule/m^2	
12	Surface Tension	Force / length	$[M^1L^0T^{-2}]$	N/m	
13	Co-efficient of viscosity	Force x distance/ area x velocity	$[M^1L^{-1}T^{-1}]$	N/m^2	
14	Moment of inertia	Mass x (radius of gyration)^2	$[M^1L^2T^0]$	Kg-m^2	
15	Angular Velocity	Angle / time	$[M^0L^0T1]$	Rad.per sec	
16	Frequency	1/Time period	$[M^0L^0T^{-1}]$	Hertz	
17	Area	Length x Breadth	$[M^0L^2T^0]$	Metre^2	
18	Volume	Length x breadth x height	$[M^0L^3T^0]$	Metre^3	
19	Density	Mass/ volume	$[M^1L^{-3}T^0]$	Kg/m^3	
20	Speed or velocity	Distance/ time	$[M^0L^1T^{-1}]$	m/s	
21	Acceleration	Velocity/time	$[M^0L^1T^{-2}]$	m/s^2	
22	pressure	Force/area	$[M^1L^{-1}T^{-2}]$	N/m^2	

Classification of physical Quantity: Physical Quantity has been classified into following four categories on the basis of dimensional analysis.

1. Dimensional Constant: These are the physical quantities which possess dimensions & have constant (fixed) value.

e.g. Planck's constant, gas constant, universal gravitational constant etc.

2. **Dimensional Variable**: These are the physical quantities which possess dimensions & do not have fixed value.

e.g. velocity, acceleration, force etc.

3. **Dimensionless Constant**: These are the physical quantities which do not possess dimensions but have constant (fixed) value.

e.g. e,π , $numbers\ like$ 1,2,3,4,5 etc.

4. **Dimensionless Variable**: These are the physical quantities which do not possess dimensions & have variable value.

e.g. angle, strain, specific gravity etc.

Q.1 Derive the dimensional formula of following Quantity & write down their dimensions.

(i) Density **(ii) Power**

(iii) Co-efficient of viscosity **(iv) Angle**

Sol. (i) Density = mass / volume

$=[M]/[L^3] = [M^1L^{-3}T^0]$

(ii) Power = work / time

=force x distance/time

$=[M^1L^1T^{-2}] \times [L]/[T]$

$=[M^1L^2T^{-3}]$

(iii) Co-efficient of viscosity = Force x distance /area x velocity

= mass x acceleration x distance/ length^2 x distance / time

$=[M] \times [LT^{-2}] \times [L] /[L^2] \times [LT^{-1}]$

$=[M^1L^{-1}T^{-1}]$

(iv) Angle = arc (length) / radius (length)

= [L]/[L]

$=[M^0L^0T^0]$ = no dimension

Q.2 Explain which of the following pair of physical quantities have the same dimension:

(i) Work & power **(ii) Stress & Pressure**

(iii) Momentum & impulse

Sol. (i) Dimension of work = force x distance = $[M^1L^2T^{-2}]$

Dimension of power = work / time = $[M^1L^2T^{-3}]$

(ii) Dimension of stress = force / area = $[M^1L^1T^{-2}]/[L^2] = [M^1L^{-1}T^{-2}]$

Dimension of pressure = force / area = $[M^1L^1T^{-2}]/[L^2] = [M^1L^{-1}T^{-2}]$

Stress and pressure have the same dimension.

(iii) Dimension of momentum = mass x velocity= $[M^1L^1T^{-1}]$

Dimension of impulse = force x time $=[M^1L^1T^{-1}]$

*Momentum and impulse have the same dimension.

Principle of Homogeneity of Dimensions:

Principle of Homogeneity of Dimensions states that **the dimensions of all the terms on both sides of an equation must be the same**. According to the principle of homogeneity, the comparison, addition & subtraction of all physical quantities is possible only if they are of the same nature i.e., they have the same dimensions.

If the power of M, L and T on two sides of the given equation are same, then the physical equation is correct otherwise not. Therefore, this principle is very helpful to check the correctness of a physical equation**.**

Example: A physical relation must be dimensionally homogeneous, i.e., all the terms on both sides of the equation must have the same dimensions.

In the equation, $S = ut + ½ at^2$

The length (S) has been equated to velocity (u) & time (t) , which at first seems to be meaningless, But if this equation is dimensionally homogeneous, i.e , the dimensions of all the terms on both sides are the same, then it has physical meaning.

Now, dimensions of various quantities in the equation are :

Distance, $S = [L^1]$

Velocity, $u = [L^1T^{-1}]$

Time, $t = [T^1]$

Acceleration, $a = [L^1T^{-2}]$

½ is a constant and has no dimensions. Thus, the dimensions of the term on L.H.S. $S=[L^1]$ and dimensions of term s on R.H.S .

$$ut + ½ at^2 = [L^1T^{-1}]\,[T^1] + [L^1T^{-2}]\,[T^2] = [L^1] + [L^1]$$

Here, the dimensions of all the terms on both sides of the equation are the same. Therefore, the equation is dimensionally homogeneous.

Dimensional Analysis: A careful examination of the dimensions of various quantities involved in a physical relation is called dimensional analysis. The analysis of the dimensions of a physical quantity is of great help to us in a number of ways as discussed under the uses of dimensional equations:

Uses of dimensional equation: The principle of homogeneity & dimensional analysis has put to the following uses:

(i) Checking the correctness of physical equation.
(ii) To convert a physical quantity from one system of units into another.
(iii) To derive relation among various physical Quantities.

1. **To check the correctness of Physical relations** : According to principle of Homogeneity of dimensions a physical relation or equation is correct , if the dimensions of all the terms on both sides of the equation are the same.If the dimensions of even one term differs from those of others , the equation is not correct.

Example 3. Check the correctness of the following formulae by dimensional analysis.

(i)$F=mv^2/r$ (ii)$t=2\pi\sqrt{l/g}$

Where all the letters have their usual meanings.

Sol. $F = mv^2 / r$

Dimensions of the term on L.H.S

Force, $F = [M^1L^1T^{-2}]$

Dimensions of the term on R.H.S

$Mv^2/ r = [M^1][L^1T^{-1}]^2 / [L]$

$=[M^1L^2T^{-2}] / [L]$

$=[M^1L^1T^{-2}]$

The dimensions of the term on the L.H.S are equal to the dimensions of the term on R.H.S. Therefore, the relation is correct.

(ii) $t = 2\pi\sqrt{l/g}$

Here, Dimensions of L.H.S $t = [T^1] = [M^0L^0T^1]$

Dimensions of the terms on R.H.S

(i) Dimensions of (length) = $[L^1]$

(ii) Dimensions of g (acc due to gravity) = $[L^1T^{-2}]$

2π being constant have no dimensions.

Hence, the dimensions of terms $2\pi\sqrt{l/g}$ on R.H.S

$= (L^1/ L^1T^{-2}])^{1/2} = [T^1] = [M^0L^0T^1]$

Thus, the dimensions of the terms on both sides of the relation are the same i.e., $[M^0L^0T^1]$.Therefore, the relation is correct.

Example 4. Check the correctness of the following equation on the basis of dimensional analysis, V = $\sqrt{\frac{E}{d}}$ V is the velocity of sound, E is the elasticity and d is the density of the medium.

Sol. Here, Dimensions of the term on L.H.S

$$V = [M^0L^1T^{-1}]$$

Dimensions of elasticity, E = $[M^1L^{-1}T^{-2}]$

& Dimensions of density, d = $[M^1L^{-3}T^0]$

Therefore, Dimensions of the terms on R.H.S

$$\sqrt{\frac{E}{d}} = [M^1L^{-1}T^{-2}/ M^1L^{-1}T^{-2}]^{1/2} = [M^0L^1T^{-1}]$$

Thus, dimensions on both sides are the same, therefore the equation is correct.

Example 5. Using Principle of Homogeneity of dimensions, check the correctness of equation, h = 2Td /rgcos θ.

Sol. The given formula is , h = 2Td /rgcos θ.

Dimensions of term on L.H.S

Height (h) = $[M^0L^1T^0]$

Dimensions of terms on R.H.S

T= surface tension = $[M^1L^0T^{-2}]$

D= density = $[M^1L^{-3}T^0]$

r=radius = $[M^0L^1T^0]$

g=acc .due to gravity = $[M^0L^1T^{-2}]$

cos θ = $[M^0L^0T^0]$= no dimensions

So,

Dimensions of 2Td /rgcos θ= $[M^1L^0T^{-2}]$ x $[M^1L^{-3}T^0]$ / $[M^0L^1T^0]$ x $[M^0L^1T^{-2}]$

= $[M^2L^{-5}T^0]$

Dimensions of terms on L.H.S are not equal to dimensions on R.H.S. Hence, formula is not correct.

Example 6. Check the accuracy of the following relations :

(i) E = mgh + ½ mv^2 ; (ii) v^3-u^2 = 2as^2.

Sol. (i) E = mgh + ½ mv^2

Here. Dimensions of the term on L.H.S

Energy , E = $[M^1L^2T^{-2}]$

Dimensions of the terms on R.H.S,

Dimensions of the term , mgh = [M] x $[LT^{-2}]$ x [L] = $[M^1L^2T^{-2}]$

Dimensions of the term , ½ mv^2= [M] x $[LT^{-1}]^2$= $[M^1L^2T^{-2}]$

Thus, dimensions of all the terms on both sides of the relation are the same, therefore, the relation is correct.

(ii) The given relation is,

$$v^3 - u^2 = 2as^2$$

Dimensions of the terms on L.H.S

$$v^3 = [M^0] \times [LT^{-1}]^3 = [M^0L^3T^{-3}]$$

$$u^2 = [M^0] \times [LT^{-1}]^2 = [M^0L^2T^{-2}]$$

Dimensions of the terms on R.H.S

$$2as^2 = [M^0] \times [LT^{-2}] \times [L]^2 = [M^0L^3T^{-2}]$$

Substituting the dimensions in the relations ,$v^3 - u^2 = 2as^2$

We get, $[M^0L^3T^{-3}] - [M^0L^2T^{-2}] = [M^0L^3T^{-2}]$

The dimensions of all the terms on both sides are not same, Therefore, the relation is not correct.

Example 7 . The velocity of a particle is given in terms of time t by the equation

v = At + b / t+c

What are the dimensions of a, b and c ?

Sol. Dimensional formula for L.H,.S

$$\mathbf{V} = [L^1T^{-1}]$$

In the R.H.S dimensional formula of At

$$[T] = [L^1T^{-1}]$$

$$A = [LT^{-1}] / [T^{-1}] = [L^1T^{-2}]$$

t +c = time , c has dimensions of time and hence is added in t.

Dimensions of t + c is [T]

Now, $b / t + c = v$

$$b = v\,(t + c) = [LT^{-1}]\,[T] = [L]$$

There dimensions of a = $[L^1T^{-2}]$, Dimensions of b = [L] and that of c = [T]

Example 8. In the gas equation $(P + a/v^2)(v - b) = RT$, where T is the absolute temperature , P is pressure and v is volume of gas. What are dimensions of a and b?

Sol. Like quantities are added or subtracted from each other i.e.,

$(P + a/v^2)$ has dimensions of pressure = $[ML^{-1}T^{-2}]$

Hence, a/v^2 will be dimensions of pressure = $[ML^{-1}T^{-2}]$

$$a = [ML^{-1}T^{-2}]\,[\text{volume}]^2 = [ML^{-1}T^{-2}]\,[L^3]^2$$

$$a = [ML^{-1}T^{-2}]\,[L^6] = [ML^5T^{-2}]$$

Dimensions of a = $[ML^5T^{-2}]$

(v – b) have dimensions of volume i.e., b will have dimensions of volume i.e., $[L^3]$

$$b = [L^3] = [M^0L^3T^0]$$

2. **To convert a physical quantity from one system of units into another.**

Physical quantity can be expressed as

$$Q = nu$$

Where n_1u_1 represent the numerical value and unit of a physical quantity in one system and n_2u_2 in the other system.

If for a physical quantity Q;$M_1L_1T_1$ be the fundamental unit in one system and $M_2L_2T_2$ be fundamental unit of the other system and dimensions in mass, length and time in each system can be respectively a,b,c.

$$U_1 = [M_1^aL_1^bT_1^c]$$

and $$U_2 = [M_2^aL_2^bT_2^c]$$

as we know

$$n_1u_1 = n_2u_2$$

$$n_2 = n_1u_1/u_2$$

$$n_2 = n_1[M_1^aL_1^bT_1^c]/[M_2^aL_2^bT_2^c]$$

$$= n_1[M_1/M_2]^a[L_1/L_2]^b[T_1/T_2]^c$$

While applying the above relations the system of unit as first system in which numerical value of physical quantity is given and the other as second system

$$n_2 = n_1[M_1/M_2]^a[L_1/L_2]^b[T_1/T_2]^c$$

Thus knowing $[M_1L_1T_1]$, $[M_2L_2T_2]$ a,b,c and n , we can calculate n_2.

Example 8 : Convert one newton into dyne.

Sol. Newton is the unit of force in SI system, and its dimensional formula is $[M^1L^1T^{-2}]$,

Hence a = 1,b =1, c = -2 on comparing $[M^a L^b T^u]$

System (SI)	(CGS System)
N_1=1	n_2=?
M_1 =1kg = 10^3 gm	M_2 = 1g
L_1 = 1 m = 100 cm	L_2 = 1cm
T_1 = 1 S	T_2 = 1S

$$h_2 = n_1[M_1/ M_2]^a[L_1/ L_2]^b[T_1/ T_2]^c$$

$$=1 [1kg/1g]^1 [1m/1cm]^1[1s/1s]^{-2}$$

$$= 1 [10^3g /1g][100cm/1cm]^1[1]^{-2}$$

$$= 10^3x10^2 =10^5$$

Hence $= 1N =10^5$dyne.

Example 9: Convert the value of 25 joule into ergs using dimensional equations.

Sol. Conversion is of work from SI to CGS System. Dimensional formula work

$$= [M^1L^2T^{-2}]$$

a = 1, b = 2 and c = -2

Given System

SI (MKS System)	CGS System
N_1 = 25	n_2 = ?
M_1= 1kg = 10^3 gm	M_2 = 1g
L_1 = 1m =100 cm	L_2 = 1cm
T_1 = 1s	T_2 = 1s

Now substituting the values in equation:

$N2 = n1[M_1/ M_2]^a[L_1/ L_2]^b[T_1/ T_2]^c$

$= 25 [1kg/1g]^1 [1m/1cm]^2[1s/1s]^{-2}$

$= 25 [100g /1g][100cm/1cm]^2 \times [1]^{-2}$

$= 25 \times 1000\times 1000 \times 1 = 25\times 10^7$

Work of 1 Joule= 25×10^7 ergs Answer.

Example 10: Find the value of force 1 dyne on a system based on a metre, kilogram and minute as fundamental units.

Sol . Dyne is the unit of force in cgs system.

Dimensional formula of force=$[MLT^{-2}]=[M^a L^b T^c]$,(say)

a = 1, b = 1, c = 2

cgs System	New System
M_1 =1g	M_2 = 1kg
L_1 = 1 cm	L_2 = 1m
T_1 = 1s	T_2 = 1min
N_1=1	n_2=?

Using the relation

$N2 = n1[M_1/ M_2]^a[L_1/ L_2]^b[T_1/ T_2]^c$

$= 1 \times [1g/1kg]^1 [1cm/1m]^2[1s/1min]^{-2}$

$= 1 \times [1g /1000g][1cm/100cm][1s/60s]^{-2}$

$=1 \times 1/1000\times 1 \times 100 \times 3600$

$= 3.6 \times 10^{-2}$

The value of force 1 dyne in a new system is equal to 3.6×10^{-2}.

Limitations of Dimensional Equation: The method of dimensions has the following limitations:

1. It does not help us to find the value of dimensionless constants involved in various physical relations. The values, of such constant have to be determined by some experiments or mathematical investigations.
2. This method fails to derive formula of a physical quantity which depends upon more than three factors. Because only three equations are obtained by comparing the powers of M, L and T.
   However, in SI units formula for physical quantities depending upon more than three quantities can be derived because there are seven base units.
3. This method is applicable only in case of power functions. It fails to derive relations of quantities involving exponential and trigonometric functions.
4. The method cannot be directly applied to derive relations which contain more than one terms on one side or both sides of the equation, such as $v = u + at$ 0r $s = ut + ½ at^2$ etc. However, such relations can be derived indirectly.
5. A dimensionally correct relation may not be true physical relation because the dimensional equality is not sufficient for the correctness of a given physical relation.

LET US SUM UP

- **Physics –** Physics is the branch of science which deals with the study of nature and natural phenomenon (like repetition of day & night, light , motion of bodies etc.)
- **Physical Quantity –** Any quantity which can be measured is called a physical quantity.
- **Unit –** The quantity used as standard of measurement is called unit.
- **Measurement –** The physical quantity to be measured is compared with a known fixed unit quantity of the similar nature. The known fixed quantity is called the unit.
- **Fundamental & Derived unit –** Units of mass, length, time, temperature, current, amount of substance & luminous intensity are called as fundamental units. Derived units are the units which are derived from the fundamental units (either by multiplication or divisions).
- **System of units-**
  (i) C.G.S system (centimetre, gram, second system)
  (ii) F.P.S system (Foot , Pound, Second system)
  (iii) M.K.S system (Metre, Kilogram, Second system)
- **Dimensions** – Dimensions of a physical quantity are powers to which the fundamental units to be raised in order to represent that quantity.

- **Dimensional Formula** – An expression alongwith power of mass, length and time which indicates how derived physical quantity depends upon fundamental physical quantity.
- **Dimensional Equation** – An equation obtained by equating the physical quantity with its dimensional formula is called dimensional equation.
- **Coherent system of unit** – The system in which the derived units of physical quantity are easily obtained by multiplication or division of fundamental units.
- **Principle of Homogeneity** – The dimensions of all the terms on both the sides of an equation must be same dimensions.
- **Application of Dimensional Analysis –**
  (i) To convert one system of unit into another system
  (ii) To check the correctness of a given relation
  (iii) To derive the expression for physical quantities

SHORT ANSWER QUESTIONS [2 MARKS]

1. Define Physics.
2. What do you mean by physical quantity?
3. Differentiate between fundamental & derived unit.
4. Write full form of the following system of unit
   (i) CGS (ii) FPS (iii) MKS
5. Write definition of Dimensions.
6. What is the suitable unit for measuring distance between sun & earth?
7. Write the dimensional formula of the following physical quantity - **[4marks]**
   (i) Momentum (ii) Power (iii) Surface Tension (iv) Strain
8. What is the principle of Homogeneity of Dimensions?
9. Write the S.I & C.G.S unit of the following physical quantities-
   (a) Force (b) Work
   (i) P = hdg (ii) V = $\sqrt{\frac{E}{d}}$ **[4marks]**
10. What are the uses of dimensions?

LONG ANSWER QUESTIONS

1. Check the correctness of the relation λ = h /mv where λ = wavelength , h = Planck's constant , m = mass of the particle , v = velocity of the particle.
   (Ans. Correct)
2. Explain different type of system of unit,
3. Check the correctness of the following relation by using method of dimensions
   (i) V = u + at

(ii) $F = mv / r^2$

(iii) $V^2 - u^2 = 2as$

4. What are the limitations of Dimensional analysis?
5. Convert 25 newton of force into FPS system of unit.
6. Convert an acceleration of 100 m/s^2 into km/hr^2.

Chapter 2: Force and Motion

2.1 SCALAR QUANTITIES

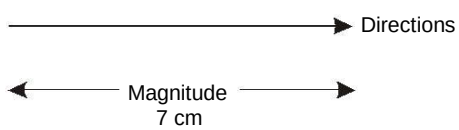
Scalar quantities are those quantities which are having only magnitude but no direction.

Examples: Mass, length, density, volume, energy, temperature, electric charge, current, electric potential etc.

Vector Quantities: Vector quantities are those quantities which are having both magnitude as well as direction.

Examples. Displacement, velocity, acceleration, force, electric intensity, magnetic intensity etc.

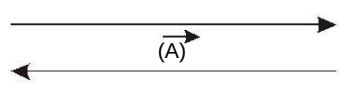
Representation Vector: A vector is represented by a straight line with an arrow head. Here, the length of the line represents the magnitude and arrow head gives the direction vectors.



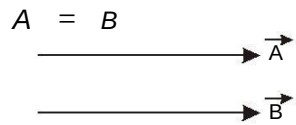
TYPES OF VECTORS

1. Negative Vectors: The negative of a vector is defined as another vector having same magnitude but opposite in direction.

i.e., any vector A and its negative vector [$-A$] are as shown.



2. Equal Vector: Two or more vectors are said to be equal, if they have same magnitude and direction. If A and B are two equal vectors then



3. Unit Vector: A vector divided by its magnitude is called a unit vector. It has a magnitude one unit and direction same as the direction of given vector. It is denoted by A.

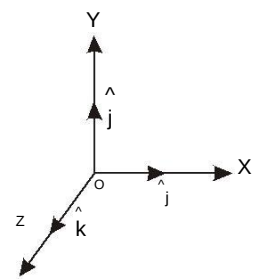
$$\hat{A} = \frac{\vec{A}}{A}$$

Unit vector along the three mutually perpendicular axis are represented by $\hat{i}, \hat{j}, \hat{k}$

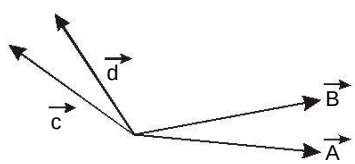
$\hat{i}$ is the unit vector along *x*–axis

$\hat{j}$ is the unit vector along *y*-axis

$\hat{i}$, $\hat{j}$ and $\hat{k}$ are mutually perpendicular to each other, *i.e*, angle between any pair 90°.



Co-Initial Vector: Two or more vectors having same initial point are called co-initial vectors.

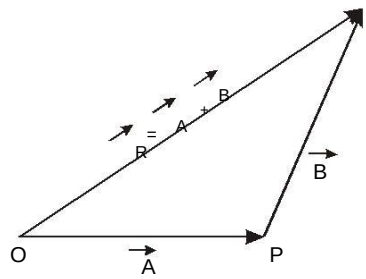


Collinear Vectors: Two or more vectors having equal or unequal magnitudes, which act either along the same line of along the parallel lines are called collinear vectors.

Zero Vector: A vector having zero magnitude and arbitrary direction (be not fixed) is called zero vector. It is denoted by $\vec{O}$.

2.2 ADDITIONAL VECTORS

Triangle Law of Vector: If two vectors can be represented in magnitude and direction by two sides of a triangle taken in the same order than their resultant is represented in magnitude and direction by third side of triangle taken in opposite order.



Parallelogram Law of Vector: It states that If two vectors can be represented in magnitude and direction by two adjacent sides of a parallelogram drawn from any point; then their resultant is represented in magnitude and direction by the diagonal of the parallelogram passing through the same point.

MULTIPLICATION OF VECTORS

Vectors can be multiplied by scalars to get a different vector or can also be multiplied by or more vectors. Accordingly there are various multiplication procedure for vectors like multiplication of vectors by a scalar, Dot product, cross product, triple product, multiple vector products etc. Let us discuss them in brief.

(*a*) Multiplication of a Vector by Scalar: Multiplication of a vector by a real number *n* gives a new vector whose magnitude is *n* times the magnitude of the given vector and direction is same as that of the given vector, when *n* is +ve real number.

Consider a vector *A* which is multiplied by a real number *n*, then the new or resultant vector is $n\,A$.

Example: If $n = 2$, then resultant vector becomes $2\,A$, which is a vector, acting in the direction of *A* and having magnitude twice as that of *A* . If $n = -2$, then new vector becomes $-2\,A$, which is also a vector, acting in the opposite direction of *A* and having magnitude twice as that of *A* .

2.3 SCALAR PRODUCT (DOT PRODUCT)

When resultant of product of two vectors is a scalar quantity then it is called scalar product of vectors. It is written by $A \cdot B = AB \cos \theta$, which is a scalar quantity.

Scalar product is commutative *i.e.* $A \cdot B = B \cdot A$

Example. 1. Work is a scalar product of force and displacement.

$$W = F \cdot S \quad W$$
$$= FS \cos \theta$$

If displacement is in same direction $\theta = 0$

So $W = FS$ (which is maximum)

If displacement is $\perp$ to force, $\theta = 90°$

$$W = FS \times 0 \text{ as } \cos 90° = 0$$

So $W = 0$ Zero Work

2. Power is a dot product of force and velocity

$$P = F \cdot v$$

VECTOR PRODUCT (CROSS PRODUCT)

When multiplication of two vectors gives a new vector, it is called vector product of vectors. It is written with a sign of cross (×) between multiplying vectors so called cross product.

$$A \times B = (AB \sin \theta)\, \hat{n}$$

where $\hat{n}$ is the unit vector in the direction of new vector.

Cross product is not commutative because changing order of vectors, changes direction of vector.

$$A \times B = -B \times A$$

Example: Torque is a cross product of force and radius vector

$$\tau = F \times r$$

2.4 DISTANCE

How much ground an object has covered during it motion. Distance is a scalar quantity SI unit is meters.

DISPLACEMENT

The direct distance between two points (minimum distance) is called displacement. It is a vector quantity SI unit is meter.

Dimension formula (L)

SPEED

The rate of change of distance is called speed. Speed is a scalar quantity.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

SI unit is ms^{-1}

VELOCITY

The rate of change of displacement is called velocity. Velocity is a vector quantity

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time}}$$

SI unit is ms^{-1}

ACCELERATION

It is defined rate of change of velocity. Acceleration is vector quantity

$$\text{Acceleration} = \frac{\text{Velocity}}{\text{Time}}$$

SI unit is ms^{-2}

Dimension formula = $[LT^{-2}]$

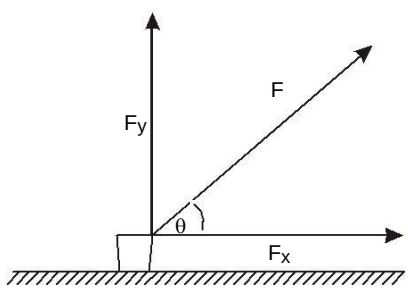
2.5 FORCE

Force may be defined as a pull or a push which produces or tends to produce, stops or tends to stop the motion of a body e.g.

(*i*) To move a football, we have to exert a push i.e., kick on the football

(*ii*) To stop football or a body moving with same velocity, we have to apply push in a direction opposite to the direction of the body.

Resolution of Forces: The process of splitting a single force into two forces (component) is called resolution of force. Two parts are known as the resolved parts of components of the force.



Consider a block being pulled by a constant force F, making an angle θ with the horizontal. The force F can be resolved into two components.

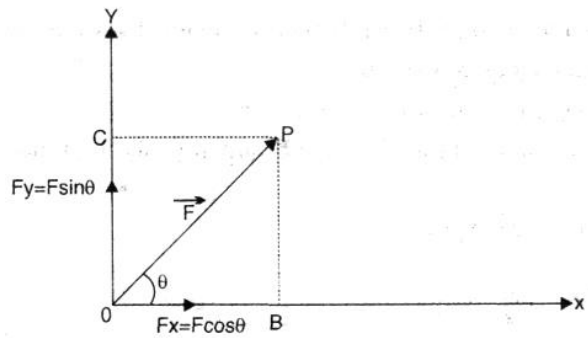
(*i*) The horizontal component (F_X) tending to displace the block.

(*ii*) The vertical component (F_Y) tending to lift the block or to decrease its weight. When the force is resolved into two components at right angles to each other, the components are called rectangular components.

Resolution of a Force Into Rectangular Components: Let a force F be represented by the projections OB and OC and X-axis and Y-axis respectively.

$$F_X = OB$$

and $$F_Y = OC$$



$$\frac{PB}{OP} = Sin\theta$$

or $\quad PB = OP \sin\theta$

or $\quad \boxed{Fy = F \sin\theta}$

Also $\quad \cos\theta = \frac{OB}{OP}$

or $\quad OB = OP \cos\theta$

or $\quad \boxed{Fx = F \cos\theta}$

Therefore, rectangular components of force F are F cosθ and F sinθ.

Composition of Forces: The process of finding are the resultant of a number of forces acting on a body is called composition of forces.

Resultant Force: If number of forces are acting simultaneously on a body, then a single force can produce the same effect in body as is done by all force together is called resultant force (R).

2.6 NEWTON'S LAW OF MOTION

Newton's First Law of Motion: Every body continues to remain in its state of rest or in uniform motion in a straight line until no external force is applied on the body.

eg. The book lying on a table will not move at its own. It does not change its position from the state of rest until no external force is applied on it.

Newton's Second Law of Motion: The rate of change of linear momentum is directly proportional to the applied force.

i.e., $\quad \frac{dp}{dt} \alpha F$

where $\quad \frac{dp}{dt}$ = Rate of change of momentum.

F= Applied force.

Determination of Force Equation from Newton's II law: Newton's II law gives the measurement of force consider m is mass of a body.

u = initial velocity

v = final velocity

$$p_1 = m \times u = \text{initial momentum}$$

$$p_2 = m \times v = \text{Final momentum.}$$

Rate of change of momentum = $\dfrac{mv - mu}{t}$

According to definition of IInd law

Rate of change of momentum is directly proportional to applied force.

i.e., $$F \propto \frac{mv - mu}{t}$$

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

$$= kma \qquad \left(\text{Acceleration } (a) = \frac{v - u}{t}\right)$$

where k = constant of proportionality

If $k = 1$ then F = ma

i.e., Force may be defined as the product of mass and acceleration of a body.

(*iii*) Newton's Third Law of Motion: To every action there is always an equal (in magnitude) and opposite (in direction) reaction.

e.g. when a rubber ball is struck against the wall, it jumps back due to reaction of the wall.

Derivation of Newton's 1st Law and 3rd Law From 2nd Law:

Or

Newton's 2nd Law is the Real law of Motion:

Newton's 2nd law of motion is the real law of motion because both first and third laws of motion can be derived from it. So we will prove that both first and third laws of motion are contained in Newton's 2nd law of motion.

By 2nd law

$$F = ma$$

If no external force acts on the body *i.e.,* $F = 0$, Then

$ma = 0$, but mass of a body can never be zero.

$\Rightarrow$ $$a = 0,$$

$\Rightarrow$ $$\frac{v - u}{t} = 0$$

or $$v - u = 0$$

$\Rightarrow$ $$v = u$$

i.e., When no external force is applied on the body, acceleration produced in it is zero. ***Or***

The body will remain in the rest or uniform motion until some external force is applied on it which is Newton's Ist law of motion. Hence Newton's 1st law is contained in 2nd law.

To prove that Newton's third law is contained in 2nd law of motion:

Consider a system of two bodies A and B mutually interacting with each other, such that no external force acts on the system. Suppose that the body A exerts force F_{AB} on body B and body B exerts force F_{BA} on body A. If $\frac{dp_1}{dt}$ and $\frac{dp_2}{dt}$ are rate of change of the bodies A and B respectively due to forces F_{BA} and F_{AB} acting on them,

$$F_{BA} = \frac{dp_1}{dt}$$

and

$$F_{AB} = \frac{dp_2}{dt}$$

Adding the two equations, we get

$$F_{BA} + F_{AB} = \frac{dp_1}{dt} + \frac{dp_2}{dt} = \frac{d}{dt}(p_1 + p_2)$$

Since no external force is acting on the system the total momentum of the system must be constant.

i.e., rate of change of momentum of the system shall be zero. Therefore, the equation (*i*) becomes

$$F_{BA} + F_{AB} = 0$$

or

$$F_{BA} = -F_{AB}$$

$mu + Mv$ i.e. action and reaction are equal and opposite which is third law. Hence, Newton's second law is the real law.

Equation of Motions: When a body moves in a straight line with uniform acceleration the velocity and the distance travelled can be represented by simple relations. These relations are called the equation of motion. Equation is

(*i*) $V = u + at$

(*ii*) $S = ut + \frac{1}{2}at^2$

(*iii*) $V^2 - u^2 = 2$ as

(*iv*) $S_n = u + \frac{a}{2}(2n - 1)$

2.7 CONCEPT OF MOMENTUM

Momentum: The quantity of motion possessed by a moving body is called momentum. It is measured by the product of mass and velocity of the body.

$\therefore$ Momentum = mass × velocity

or $M = m \times v$

Dimensional formula of momentum is $[M^1 L^1 T^{-1}]$ and its CGS unit is g cm s^{-1} and SI unit is Kg ms^{-1}

CONSERVATION OF MOMENTUM

Principal of Conservation of Momentum: If external force acting on a system of bodies is zero then the total linear momentum of bodies before collision and after collision will be same.

Recoil of the Gun: When a bullet is fired with a gun the bullet moves in forward direction and gun is recoiled/Pushed backwards.

The gun and gullet forms an isolated system So the total momentum of gun and bullet before firing = 0

m = mass of bullet

u = velocity of bullet

M = mass of gun

v = velocity of gun

Total momentum of gun and bullet after firing

$$= mu + Mv$$

Using law of conservation of momentum

$$= 0$$

$$Mv = -mu$$

$$v = \frac{-mu}{M}$$

This is the expression for recoil velocity of gun.

Here negative sign shows that motion of the gun is in opposite direction to that of the bullet. Also velocity of gun is inversely proportional to its mass. Lesser the mass, larger will be the recoil velocity of the gun.

IMPULSE

Impulse: Impulse is defined as the total change in momentum produced by the impulsive force.

O R

Impulse may be defined as the product of force and time and is equal to the total change in momentum of the body.

$$F.t = p_2 - p_1 = \text{total change in momentum}$$

Example. *A kick is given to a football or blow is made with hummer.*

The negative sign indicates that the gun recoils in the backward direction.

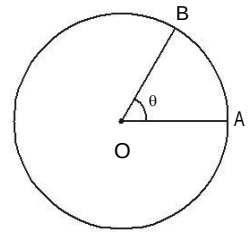
2.8 CIRCULAR MOTION

The motion of a body in a circle of fixed radius is called circular motion. e.g., The motion of a stone tied to a string when whirled in the air is a circular motion.

Angular Displacement: The angle described by a body moving in a circle is called angular displacement.

Consider a body moves in a circle, starting from A reaches B so that $\angle BOA = \theta$

θ is called angular displacement



SI unit of angular displacement is radian (rad.)

Angular Velocity: Angular velocity of a body moving in a circle is the rate of change of angular displacement with time. It is denoted by ω(omega). If θ is the angular displacement in time t then.

$$w = \frac{\theta}{t}$$

SI unit of angular velocity is rad/s.

Time Period: Time taken by a body moving in a circle to complete one revolution is called time period. It is denoted by T

In time $t = T$, angle described, $\theta = 2\pi$

$$\omega = \frac{\theta}{t}$$

or

$$\omega = \frac{2\pi}{T}$$

Frequency: The number of revolutions completed by a body moving in a circle is called frequency.

In T seconds, number of revolutions completed = 1

$\therefore$ In 1 second number of revolutions completed

$$n = \frac{1}{T}$$

$$\therefore \quad \omega = 2\pi n$$

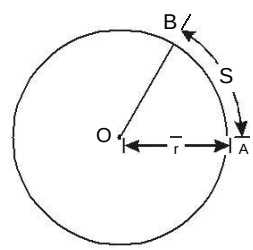
Angular Acceleration: The rate of change of angular velocity of a body with time is called its angular acceleration. It is denoted by α. Let angular velocity of a body moving in a circle change from ω_1 to ω_2 in time t, then

$$\alpha = \frac{\omega_2 - \omega_1}{t}$$

SI unit of a is rad/s^2

RELATIONSHIP BETWEEN LINEAR AND ANGULAR VELOCITY

Consider a body moving in a circle of radius r Let it start from A and B after t, so that $\angle BOA = \theta$



Now $\quad \text{angle} = \dfrac{\text{arc}}{\text{radius}}$

$\therefore \quad \theta = \dfrac{AB}{OA} = \dfrac{S}{r}$

or $\quad S = r\theta$

Dividing both sides by t, we get

$$\frac{S}{t} = r\left(\frac{\theta}{t}\right)$$

Here, $\quad \dfrac{S}{t}$ = linear velocity (v)

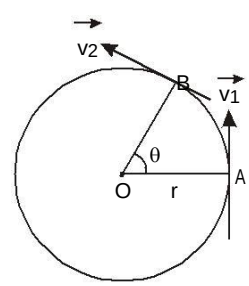
and $\quad \dfrac{\theta}{t}$ = angular velocity (ω)

thus $\quad v = r\omega$

Linear velocity = Radius × angular velocity

RELATION BETWEEN LINEAR ACCELERATION AND ANGULAR ACCELERATION

Consider a body moving in a circle of radius r. Let w_1 be the angular velocity at A and w_2 be the angular velocity at B after time t_1 then by definition.



Angular acceleration, $\quad \alpha = \dfrac{\omega_2 - \omega_1}{t}$

If v_1 and v_2 are the linear velocities of the body at A and B respectively, then;

$$v_1 = r\omega_1$$

or $\quad \omega_1 = \dfrac{v_1}{t}$

and similarly, $\omega 2 = \frac{v2}{r}$

Thus, $\alpha = \frac{v2 - v1}{rt} = \frac{a}{r}$

Where, $a = \frac{v2 - v1}{t}$

is the linear acceleration of the body.

Hence $a = r \propto$

RELATION BETWEEN FREQUENCY (*n*) AND TIME PERIOD (T)

n is the frequency and is equal to the number of revolutions per second. T is the time period and is equal to the time taken to complete one revolution (rotation).

If a body has a frequency of revolutions = 1 second

$\therefore$ Time taken to complete 1 revolution = $\frac{1}{n}$ second.

But time taken to complete one revolution is time period

$\therefore$ $T = \frac{1}{n}$

or $n = \frac{1}{T}$

$nT = 1$

2.9 CENTRIPETAL FORCE

The force acting along the radius towards the centre of circle to keep a body moving with uniform speed in a circular path is called centripetal force. It is denoted by F_C.

$$F_C = \frac{mv^2}{r}$$

e.g. A stone tied at one end of a string whose other end is held in hand, when while round in the air, the centripetal force is supplied the tension in the string.

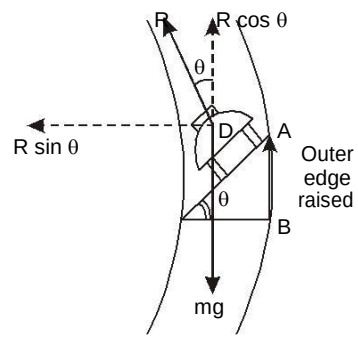
Centrifugal Force: A body moving in circle with uniform speed experience a force in a direction away from the centre of the circle. This force is called centrifugal force.

e.g., (*i*) Cream is separated from milk by using centrifugal force when milk is rotated in cream separator, cream particle in the milk being lighter, experience less centrifugal force.

Banking of Roads: When the outer edge of circular road is raised slightly above than the inner edge of road is called banking of roads.

Angle of Banking: The angle through which the outer edge of circular road is raised above the inner edge of circular roads.

2.10 APPLICATION OF CENTRIPETAL FORCE IN: BANKING OF ROADS



Let m = mass of vehicle

r = radius of circular road

v = uniform speed (velocity) of vehicle when it take turns

θ = angle of banking

D = position of centre of gravity.

At the point D two forces act.

(*i*) Weight (mg) of vehicle vertically downwards.

(*ii*) Normal reaction (*R*) along DR.

R makes an angle θ and divides the forces into two components.

(*i*) $R \sin\theta$ towards the centre

(*ii*) $R \cos\theta$ vertically upwards and balance by weight of (mg) vehicle.

$R \sin\theta$ provides the necessary centripetal force $\left(\frac{mv^2}{r}\right)$

$$R \sin\theta = \frac{mv^2}{r} \quad \text{...(i)}$$

$$R \cos\theta = mg \quad \text{...(ii)}$$

Dividing equation (i) by equation (ii) we get

$$\frac{R \sin\theta}{R \cos\theta} = \frac{mv^2}{r \times mg}$$

$$\tan\theta = \frac{v^2}{rg}$$

$$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$$

VERY SHORT ANSWER TYPE QUESTIONS [2 Marks]

1. What do you mean by circular motion? Give examples?

2. What do you mean by banking of roads?

3. What are scalar and vector quantities? Give examples? [HSBTE Dec. 2012]

4. Define resolution and composition of forces.

5. Newton law of motion. [HSBTE May, June, 2013, Dec. 2012]

6. What is impulse?

SHORT ANSWER TYPE QUESTIONS [4 Marks]

1. What is difference between centripetal and centrifugal forces?

[HSBTE March 2013, Dec. 2012]

2. Derive a relation between linear velocity and angular velocity.

[HSBTE May, June 2013, Dec. 2013]

3. Derive a relation between linear acceleration and angular acceleration.

[HSBTE Dec. 2012]

4. An artificial satellite takes 90 minutes to complete its revolution around the earth.
Calculate the angular speed of satellite. [Ans. 2700 rad/sec]

5. At what maximum speed a racing car can transverse an unbanked curve of 30 m radius? The co-efficient of friction between types and road is 0.6. [Ans. 47.8]

6. State and Explain Newton's law of motion.

7. Justify the statement that Newton's second law is the real law of motion.

8. Define Force. Give its units. State parallelogram law of Vector.

[HSBTE May, June 2013]

9. Define the following.

(*i*) Triangle law of vector addition

(*ii*) Parallelogram law of vector addition. [HSBTE March 2013]

LONG ANSWER TYPE QUESTIONS [10 Marks]

1. Explain Newton's Law of Motion.

2. Explain Banking of Roads.

Chapter 3: Work, Power and Energy

3.1 WORK

Work is said to be done when the force applied on a body displaces it through certain distance in direction of applied force

$$W = F \times S = \text{Force} \times \text{Displacement}$$

It is measured as the product of the magnitude of force and the distance covered by the body in the direction of the force.

UNITS OF WORK

SI unit of work is joule(J)

In CGS system. unit of work is erg.

$$1 \text{ J} = 10^7 \text{ ergs}$$

Dimension of work = $[M^1L^2T^{-2}]$

Example 1. *What work is done is dragging a block 10 m horizontally when a 50 N force is applied by a rope making an angle of 30° with the ground?*

Sol. Here,

$$F = 50 \text{ N}$$
$$S = 10 \text{ m}$$
$$Q = 30$$
$$W = \text{FS cos}$$
$$W = 50 \times 10 \times \cos 30°$$
$$W = 50\text{x}10\text{x}\sqrt{3/2}$$
$$= 250\sqrt{3}J$$

Example 2. *A man weighting 50 kg supports a body of 25 kg on head. What is the work done when he moves a distance of 20 m.*

Solution. Total mass = 50 + 25 = 75 kg

= 90°

Distance = 20 m

W = FS cos (cos 90 = 0)

W = 0

Work done is zero.

Example 3. *A man weighting 50 kg carries a load of 10 kg on his head. Find the work done when he goes (i) 15 m vertically up (i) 15 m on a levelled path on the ground.*

Solution. Mass of the man, m_1 = 50

kg Mass carried by a man m_2 = 10 kg

Total mass $M = m_1 + m_2 = 50 + 10 = 60$

kg (*i*) When the man goes vertically up.

Height through which rises, h = 15 m

$$W = Mgh = 60 \times 9.8 \times 15 = 8820 \text{ J}$$

When the man goes on a levelled path on the ground.

$$W = F \cos \times S$$

Here, $= 90°$

$$\cos = \cos 90° = 0; S = 15 \text{ m}$$

$$W = F \times 0 \times 15 = 0$$

3.2 ENERGY

Energy of a body is defined as the capacity of the body to do the work. Like work, energy is also a scalar quantity.

Dimensional Formula:

Same as that of work *i.e.,* $[ML^2 T^{-2}]$.

Unit:

SI system–Joule

CGS system–erg

TRANSFORMATION OF ENERGY

The energy changes from one form to another is called transformation of energy. For example.

(*i*) In a heat engine, heat energy changes into mechanical energy

(*ii*) In an electric bulb, the electric energy changes into light energy.

(*iii*) In an electric heater, the electric energy changes into heat energy.

(*iv*) In a fan, the electric energy changes into mechanical energy which rotates the fan.

(*v*) In the sun, mass changes into radiant energy.

(*vi*) In an electric motor, the electric energy is converted into mechanical energy.

(*vii*) In burning of coal, oil etc., chemical energy changes into heat and light energy.

(*viii*) In a dam, potential energy of water changes into kinetic energy, then K.E rotates the turbine which produces the electric energy.

(*ix*) In an electric bell, electric energy changes into sound energy.

(*x*) In a generator, mechanical energy is converted into the electric energy.

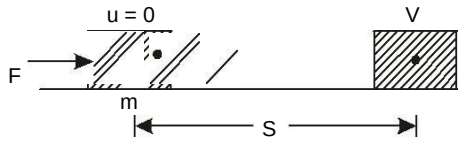
Types of Energy:

Kinetic energy: (K.E.):

Energy possessed by the body by virtue of its motions is called K.E. Examples. (*i*) running water (*ii*) Wind energy work on the K.E. of air (*iii*) Moving bullet has K.E.

EXPRESSION FOR KINETIC ENERGY

Consider F is the force acting on the body at rest (*i.e.,* u = 0), then it moves in the direction of force of distance (s).



Let v be the final velocity.

Using $v^2 - u^2 = 2as$

$$a = \frac{v^2 - u^2}{2s}$$

$$= \frac{v^2 - o^2}{2s}$$

$$a = \frac{v^2}{2s} \quad ...(1)$$

Work done $W = FS$

$W = ma \cdot S$ (using $F = ma$) ...(2)

By equation (1) and (2)

$$W = m \frac{v^2}{2s} s$$

$W = \frac{1}{2} mv^2$ This work done is stored in the body as kinetic energy.

So kinetic Energy (K.E.) = $\frac{1}{2} mv_2$

2. Potential Energy (P.E.): Energy possessed by the body by virtue of its position is called potential energy Example.

(*i*) Water stored in a dam

(*ii*) Mango hanging on the branch of a tree

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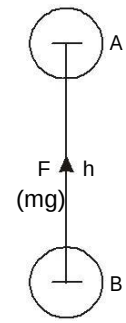
3.4 EXPRESSION FOR POTENTIAL ENERGY (P.E)



It is defined as the energy possessed by the body by virtue of its position above the surface of earth.

$$W = F \times S$$

$$\text{Workdone} = \text{Force} \times \text{height}$$

$$= mg \times h = mgh$$

This work done its stored in the form of gravitational potential energy.

$$\text{Potential energy} = mgh.$$

3.5 LAW OF CONSERVATION OF ENERGY

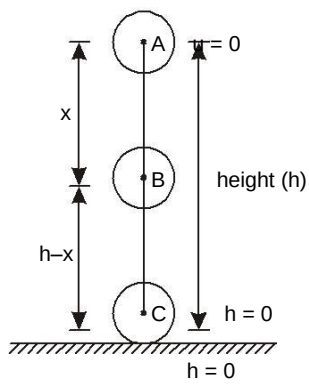
The principal of conversion of energy states that:

"Energy can neither be created nor be destroy but may be converted from one form to another".

This is the fundamental law of physics.

Conservation of Mechanical Energy of a Free Falling body

Let us consider K.E., P.E. and total energy of a body of mass m falling freely under gravity from a height *h* from the surface of ground.



According to diagram

At position A:

$$\text{Initial velocity} = u = 0$$

$$\text{K.E} = \frac{1}{2}mv^2 = 0$$

$$\text{P.E} = mgh$$

$$\text{Total Energy} = \text{K.E} + \text{P.E}$$

$$= 0 + mgh$$

$$= mgh \qquad ...(1)$$

At position B

$$\text{Potential energy} = mgh(h - x)$$

From equation of motion

$$v_b^2 - u^2 = 2as$$

$$v_b^2 - 0 = 2as$$

$$v_b^2 = 2gx$$

$$\text{kinetic energy} = \frac{1}{2}mv_b^2$$

so that

$$\text{K.E} = \frac{1}{2}m(2gx)$$

$$= mgx$$

$$\text{Total energy} = K.E. + P.E$$

$$= mgx + mg(h - x)$$

$$= mgh \qquad ...(2)$$

At position C

Potential energy = 0(as $h = 0$)

Using equation of motion

$$v_c^2 - u^2 = 2as$$

$$v_c^2 = u^2 + 2as$$

$$= 0 + 2gh$$

$$v_c^2 = 2gh$$

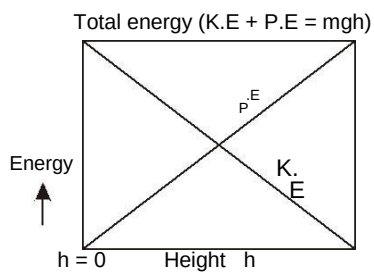
$$\text{K.E.} = \frac{1}{2}mv_c^2$$

So that $\text{K.E.} = \frac{1}{2}m(2gh)$

$$= mgh$$

Total Energy = K.E. + P.E. = $mgh + 0 = mgh$ ...(3)

From equation (1) and (2) and (3), it is clear that total mechanical energy of freely falling body remain conserved.



As body falls its PE decrease while K.E increase, however total mechanical energy is same.

Example 1. *A spring extended by 20 mm possesses a P.E. of 10 J. What will be P.E., if the extension of spring becomes 30 mm.*

$$h = 20 \text{ mm} = 20 \times 10^{-3}\text{m}$$

$$g = 9.8 \text{ ms}^{-2}, \text{ m} = ?$$

$$\text{P.E} = \text{mgh} = 10J \text{ i.e., } m \times 9.8 \times 20 \times 10^{-3} = 10 J$$

$$m = \frac{10 \;\; 10^3}{20 \;\; 9.8} \quad \frac{10^4}{20 \;\; 9.8} = 51.021 \text{ kg}$$

When extension is 30 mm *i.e.,* $= 30 \times 10^{-3}$ m, then

$$P.E = mgh = 51.021 \times 9.8 \times 10^{-3} = 15j$$

Example 2. *What will be the velocity of a body having mass 1 kg and kinetic energy 1J?*

Sol. $\text{K.E} = \frac{1}{2}mv^2 = 1J, m = 1 \text{ kg}$

i.e., $= \frac{1}{2}1\ v^2 \quad = 1$

$$\frac{V^2}{2} = 1$$

$$V^2 = 2$$

$$v = \sqrt{2} = 1.414\ ms^{-1}$$

3.6 POWER

Power is defined as the rate at which work is done by a force Or the workdone per unit time is also called power. (or Rate of doing work is known as Power). If a body does work W in time t, power is

$$P = \frac{W}{t}$$

Also $W = F.S$

$$P = \frac{F.S}{t} \quad F.v$$

where, $v = \frac{S}{t}$ is velocity

Thus power is do product of force and velocity

Units of Power: SI unit of power is watt (W)

Power is said to be 1 if 1 J work is done in 1 s.

$$W = \frac{1\,J}{1s}$$

Bigger units of power are:

Kilowatt (KW) = 10^3W and

Megawatt (MW) = 10^6 W 1 Horse power (h.p) = 746 W

$$\boxed{\text{Dimension of power} = M^1\ L^2\ T^{\ 3}}$$

Example. *A man weighting 65 kg lifts a mass of 45 kg to the top of a building 10 meters high in 12 second. Find:*

(i) Total work done by him.

(ii) The power developed by him.

Sol. Mass of the man, m_1 = 65 kg

Mass lifted m_2 = 45 kg

Height through which raised h = 10 m

Time taken t = 12 seconds. (*i*) Total work done by the man,

$W = mgh$

$$= 110 \times 9.81 \times 10 = 10791.0\text{J}$$

(*ii*) Power developed $P = \frac{w}{t} = \frac{10791J}{125} = 899.25$ W

VERY SHORT ANSWER TYPE QUESTIONS [2 Marks]

- Define the terms energy, potential energy and kinetic energy.
- Define potential energy, Derive expression for gravitational potential energy.
- Define work and write its unit.
- Define the term power and write its unit.
- State and prove principle of conservation of energy.
- Define power. Give it S.I unit.
- What is transformation of energy.

SHORT ANSWER TYPE QUESTIONS [4 Marks]

3. A person walking on a horizontal road with a load on his head does not work. Explain.

4. State kinetic energy. Find the expression for kinetic energy of a body of mass m moving at a speed u.

5. Explain kinetic and potential energy of body. Derive their expressions.

[Dec. 2012, HSBTE June 2013]

LONG ANSWER TYPE QUESTIONS [10 Marks]

2. Explain the law of conservation of energy for free falling body, show that mechanical energy remains same.

[HSBTE Dec. 2012, May, June, 2013, March 2013]

Chapter 4: Rotational Motion

4.1 ROTATIONAL MOTION

The rotation of a body about fixed axis is called Rotational motion. eg
(*i*) Motion of a wheel about its axis (*ii*) Rotation of earth about its axis.

4.2 TORQUE

It is measured by the product of magnitude of force and perpendicular distance of the time of action of force from the axis of rotation.

It is denoted by τ,

2. $= Fr$, F is force and r is perpendicular distance.

$$\boxed{= I \propto} \quad I = \text{Moment of Intertia}$$

3. = angular accelartion

Angular Momentum: Angular momentum of a rotating body about its axis of rotation is the algebric sum of the linear momentum of its particles about the axis. It is denoted by L.

L = Momentum × perpendicular distance

$p \times r$

4.mvr

$$\boxed{L = mvr}$$

Unit of Angular momentum

SI unit=kg m^2/sec

CGS unit=gm/sec.

Dimensional Formula=$[ML^2T^{-1}]$

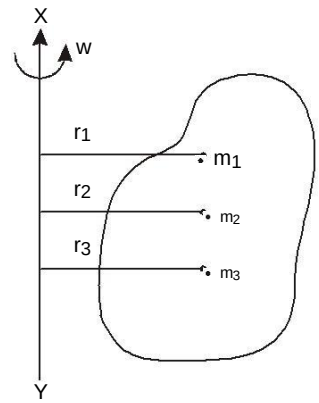
Derivation of Angular Momentum of Rigid Body: Consider a rigid body rotating about a given axis with a uniform angular velocity w.

Let m_1, m_2, ... m_n be masses of n particles.

Let r_1, r_2, ... r_n be their respective perpendicular distance from axis of rotation.

Let v_1, v_2, ... v_n be linear velocities then

$$v_1 = r_1 w$$
$$v_2 = r_2 w$$
.....
.....
$$v_n = r_n w$$



Where w is the angular velocity of all particles.

Linear momentum of particle of mass m_1 is

$$P_1 = m_1 v_1 = m(r_1 w)$$

Angular momentum of particle about given axis

$$= P_1 \times r_1$$
$$= (m_1 r_1 w) \times r_1$$
$$= m_1 r_1^2 w$$

Similarly for other particles

Angular momentum of body about given axis

$$X = m_1 r_1^2 w + m_2 r_2^2 w + ... + m_n r_n^2 w$$

$$X \quad (m_1 r_1^2 + m_2 r_2^2 + ... + m_n r_n^2)w$$

$$\boxed{L = Iw}$$

Angular momentum of a body a given axis is product is moment of Inertia and angular velocity of body about that axis.

4.3 LAW OF CONSERVATION OF ANGULAR MOMENTUM

It states that ‘‘When no external torque acts on a system of particles, then the total angular momentum of the system remains always a constant’’.

Proof: Let I be moment of inertia and a the angular acceleration then torque is given by

$$\tau = I\alpha$$

But $$\alpha = \frac{dw}{dt}$$

therefore $$\tau = I\frac{dw}{dt} \qquad ...(1)$$

The angular momentum is related to I as indicator by formula

$$L = Iw$$

Differentiating, we get

$$\frac{dL}{dt} = I\frac{dw}{dt} \qquad ...(2)$$

comparing (1) and (2), we get

$$\tau = \frac{dL}{dt}$$

If no external torque is present on the body *i.e.,*

$$\omega = 0 \text{ then } \frac{dL}{dt} = 0$$

which means L is constant (as derivative of constant quantity is zero)

Hence, if no external torque acts on system, the total angular momentum remains conserved.

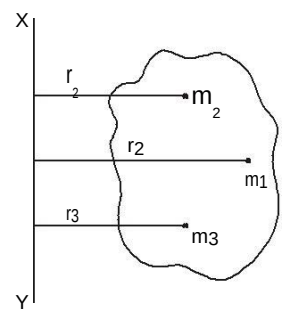
4.4 MOMENT OF INTERTIA

Moment of Intertia of a rotating body about an axis is defined as the sum of the product of the mass of various particles constituting the body and square of respectively perpendicular distance of different particles of the body from the axis of rotation.

Expression for the Moment of inertia: Let us consider a rigid body of mass M having n number of particles revolving about any axis XY. Let m_1, m_2, m_3 ..., m_n be the masses of particles at distance r_1, r_2, r_3... r_n from the axis of rotation (XY) respectively

$\therefore$ Moment of Inertia of whole body (I) = $m_1 r_1^2 + m_2 r_2^2 + ... m_n r_n^2$

$$I = \sum_{i=1}^{n} m_1 r_1^2$$



Radius of Gyration: Radius of gyration of a body, may be defined as the distance of a point from the axis of rotation of at which whole mass of the body is supposed to be concentrated, so that moment of inertia about the axis remains the same. It is denoted by K

If the mass of the body is M, the moment of inertia (I) of the body in terms of radius of gyration is given as,

$$I = MK^2 \quad ...(i)$$

Also $$I = m_1 r_1^2 + m_2 r_2^2 + ... + m_n r_n^2$$

If all the particles have same mass (m), then

$$n = mr_1^2 + mr_2^2 + ... + mr_n^2$$

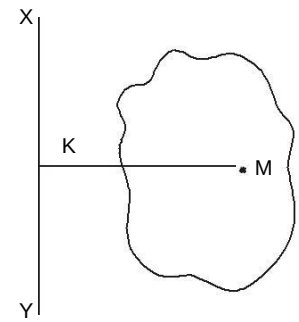
$$= m(r_1^2 + r_2^2 + \ldots \pm r_n^2)$$

$$= m \times n \left[\frac{r_1^2 + r_2^2 + \ldots + r_n^2}{n} \right]$$

$$I = M \left[\frac{r_1^2 + r_2^2 + \ldots + r_n^2}{n} \right] \quad \ldots(ii)$$

{where mn = M is the total mass of the body}

Comparing equation (1) and (2)



$$MK^2 = M \left[\frac{r_1^2 + r_2^2 + \ldots + r_n^2}{n} \right]$$

$$K^2 = \frac{r_1^2 + r_2^2 + \ldots + r_n^2}{n}$$

$$K = \sqrt{\frac{r_1^2 + r_2^2 + \ldots + r_n^2}{n}}$$

Thus, radius of gyration may also be defined as the root mean square (r.m.s.) distance of particles from the axis of rotation.

Unit: SI unit of radius of gyration is meter.

Example 1. What torque will produce an acceleration of 2 rad/s^2 in a body moment of inertia 500 kg m^2?

Sol. Here, I = 500 kg m^2,

and α = 2 rad/s^2

Now, torque τ = 1

τ = 500 kg m^2 × 2 rad/s^2 = 1000 kg m^2 s^{-2}

= 1000 Nm or joule **Ans.**

Example 2. *An engine is rotating at the rate of 1500 rev. Per minute. Find its angular velocity.* **Sol.** Here, R.P.M of engine N = 1500

$\therefore$ Angular velocity, $w = 2\pi \frac{N}{60} = 2 \times \frac{22}{7} \times \frac{1500}{60}$

= 157.1 rad/s **Ans.**

Example 3. *How large a torque is needed to accelerate a wheel, for which I = 2 kg m^2, from rest to 30 r.p.s in 20 seconds?*

Sol. Here, Moment of inertia, I = 2 kg m^2

R.P.S after 20 sec, n = 30

initial velocity, w = 0

Final velocity, $w_2 = 2\pi \times 30$ rad/s.

$\therefore$ Angular acceleration $= \frac{w_2 - w_1}{t} = \frac{2\pi \times 30 - 30}{20}$

$= 9.43$ rad/s^2.

Hence, torque required, $\tau = I \times \ = 2$ kg m$^2 \times 9.43$ rad/s^2

$= 18.86$ kg m^2 s^{-2}

Example 4. *It A point on the rim of wheel 4 m in diameter has a linear velocity of 16m s^{-1} find the angular velocity of wheel in rad/sec.*

Sol. Radius of wheel (R) = $\frac{\text{Diameter}}{2} = \frac{4}{2} = 2$ m.

From the relation $v = rw$.

$w = \frac{v}{r} = \frac{16}{2} = 8$ rad/s.

Angular velocity of wheel is 8 rad/s.

VERY SHORT ANSWER TYPE QUESTION [2 Marks]

1. Define torque. [HSBTE May, June 2013, Dec. 2012]

v What is moment of inertia?

3. What is Radius of gyration [May, June 2013]

SHORT ANSWER TYPE QUESTION [4 Marks]

N What is rotational inertia or moment of inertia? Give its SI unit.

2. What is radius of gyration and mention its SI units? [HSBTE May, June 2013]

vi What do you understand by kinetic energy of rotation with expression?

vii Derive an expression for torque in terms of moment of inertia.

viii Derive the relation between torque and angular momentum.

LONG ANSWER TYPE QUESTION [10 Marks]

1. Derive an expression for angular momentum in terms of moment of inertia.

2. State and prove law of conservation of angular momentum.

Unit-5

PROPERTIES OF MATTER

Elasticity: - It is the property of solid materials to return to their original shape and size after the forces deforming them have been removed.

Deforming Forces:-The forces which bring the change in configurations in the bodies are called deforming forces.

Restoring Force:- It is a force exerted on a body or a system that tends to move it towards an equilibrium state.

Elastic Body:- It is the body that returns to its original shape after a deformation.

Examples:-Golf Ball, Soccer Ball, Rubber Band etc.

Plastic Body:- It is the body that do not returns to its original shape after a deformation.

Examples:- Polyethylene (PE), Polypropylene (PP), Polystyrene (PS) and Polyvinyl Chloride (PVC).

Applications: automotive *body* parts, dashboards, wheel covers etc.

Stress:- *It* is *defined* as the restoring force per unit area of a material.

Type of Stress:-

1) Longitudinal Stress
2) Tangential Stress

STRAIN:

May be defined as the ratio of change in configuration to the original configuration, When a deforming force is applied to a body. The strain is of three types:

(i) Longitudinal strain:

If the deforming force produces a change in length only, the strain produced is called longitudinal strain or tensile strain. It is defined as the ratio of change in length to the original length.

$$\text{Longitudinal strain} = \frac{\text{Change in length}(\Delta l)}{\text{orignal length}(l)}$$

(ii) Volumetric strain: It is defined as the ratio of the change in volume to the original volume.

$$\text{Volumetric strain} = \frac{\text{Change in volume}(\Delta v)}{\text{original volume}(v)}$$

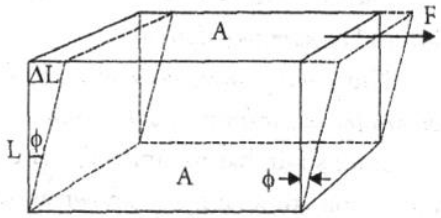
(iii) Shearing strain:

Is defined as the ratio of displacement of a surface under the tangential force to the perpendicular distance between surfaces

$$\text{Shearing strain} = \frac{\text{Lateral displacement}}{\text{Distance between surfaces}}$$

$$= \frac{\Delta L}{L}$$

$$= \tan\phi \cong \phi$$



The shearing strain is also defined as the angle in radian through which a plane perpendicular to the fixed surface of a rectangular block gets turned under the effect to tangential force.

UNITS OF STRAIN:

Strain is a ratio of two similar physical quantities, it has no units and dimensions.

Hooks law:-within elastic limits, the stress and strain are proportional to each other.

Thus, Stress $\propto$ Strain

Stress = E × Strain

Where E is the proportionality constant and is known as modulus of elasticity.

Modulus of Elasticity:-The ratio of stress and strain is called modulus of elasticity.

Young's Modulus(Y):-The ratio of tensile (or compressive) stress (σ) to the longitudinal strain (ε) is defined as Young's modulus and is denoted by the symbol Y.

$$Y = (F/A)/ (\Delta L/L) = (F \times L) / (A \times \Delta L)$$

Since strain is a dimensionless quantity,the unit of Young's modulus is the same as that of stress i.e., Nm^{-2} or Pascal (Pa)

Bulk Modulus (B):-The ratio of hydraulic stress to the corresponding hydraulic strain is called bulk modulus. It is denoted by symbol B.

$$B = -p/(\Delta V/V)$$

The negative sign indicates the fact that with an increase in pressure, a decrease in volume occurs.

SI unit of bulk modulus is the same as that of pressure i.e., Nm^{-2}or Pa

Shear Modulus (G) :-The ratio of shearing stress to the corresponding shearing strain is called the shear modulus of the material and is represented by G. It is also called the modulus of rigidity.

G = shearing stress /shearing strain

$G = (F/A)/(\Delta x/L) = (F \times L)/(A \times \Delta x)$

SI unit of shear modulus is Nm^{-2}or Pa.

Pressure:-*It* is *defined* as the force per unit area over the surface of a body

P= F/A

SI unit is Nm^{-2}or Pa

Pascal Law:-A change in the pressure applied to an enclosed incompressible fluid is transmitted undiminished to every portion of the fluid to the walls of its container.

Surface Tension:-*property of liquid to* acquire the minimum *surface* area. *Surface tension* allows insects (e.g. water striders), usually denser than water, to float and stride on a water *surface.*

T=F/l

SI unit is N/m

<u>Applications</u>

It plays an important role in many applications in our daily life.

- Washing clothes
- Cleaning
- Cosmetics
- Lubricants in machines
- Rain drops etc
- Spreading of ink, colours
- Wetting of a surface
- Action of surfactants
- Paints, insecticides
- Creating fuel-spray in automobile engines
- Passing of liquid in porous media

<u>Effect of Temperature on Surface Tension</u>

In general, *surface tension* decreases when *temperature* increases because cohesive forces decrease with an increase of molecular thermal activity. The influence of the surrounding environment is due to the adhesive action liquid molecules have at the interface.

Viscosity: - The extent to which a fluid resists a tendency to flow.

SI *unit* of *viscosity* is the Pascal-second (Pa.s) & CGS unit is Poise.

Effect of Temperature on Viscosity

With an increase in temperature, there is typically an increase in the molecular interchange as molecules move faster in higher temperatures.

The gas viscosity will increase with temperature. According to the kinetic theory of gases, viscosity should be proportional to the square root of the absolute temperature, in practice, it increases more rapidly.

In a liquid there will be molecular interchange similar to those developed in a gas, but there are additional substantial attractive, cohesive forces between the molecules of a liquid (which are much closer together than those of a gas). Both cohesion and molecular interchange contribute to liquid viscosity.

The impact of increasing the temperature of a liquid is to reduce the cohesive forces while simultaneously increasing the rate of molecular interchange.

The former effect causes a decrease in the shear stress while the latter causes it to increase. The result is that liquids show a reduction in viscosity with increasing temperature. With high temperatures, viscosity increases in gases and decreases in liquids, the drag force will do the same.

Streamline Flow:-*Flow* of a fluid in which its velocity at any point is constant or varies in a regular manner.

Turbulent flow:-It is type of fluid (gas or liquid) *flow* in which the fluid undergoes irregular fluctuations, or mixing, in contrast to laminar *flow*, in which the fluid moves in smooth paths or layers. In *turbulent flow* the speed of the fluid at a point is continuously undergoing changes in both magnitude and direction.

Fill in the Blanks

1) *Elastic Body* is the body that returns to its original shape after a ……. (restoration/deformation).
2) *Stress* is *defined* as the …….. per unit area of a material.(force/ velocity)
3) ……is the ratio of change in dimensions to the original dimensions.(Strain/Surface Tension)
4) For small deformations the stress and strain are proportional to each other, is called …… (Hooks Law/Pascal's Law)
5) *Pressure* is *defined* as the force per unit …….. over the surface of a body.(area/volume)
6) A change in the pressure applied to an enclosed incompressible fluid is transmitted undiminished to every portion of the fluid to the walls of its container, it is called…… (Hooks Law/Pascal's Law)
7) *Surface tension* is the elastic tendency of a fluid *surface* which makes it acquire the …… *surface* area possible. (least/most)
8) *Surface Tension* ……when *temperature* increases.(increase/decreases)
9) *Streamline flow* is the *flow* of a fluid in which its velocity at any point is …….(constant/fluctuate)
10) *Turbulent flow* the *flow* of a fluid in which its velocity at any point is …….(constant/fluctuate)

True or False

1) *Elasticity* is the property of solid materials to return to their original shape and size after the forces deforming them have been removed.
2) Deforming Forces are the forces which bring no change in configurations in the bodies are called deforming forces.
3) *Restoring force is the* force exerted on a body or a system that tends to move it towards an equilibrium state.
4) Stress $\propto$ Strain
5) *SI unit of Surface Tension is N.*
6) Viscosity the extent to which a fluid resists a tendency to flow
7) SI unit of shear modulus is Nm^{-2}
8) SI unit of bulk modulus is the same as that of pressure.
9) Bulk Modulus is denoted by symbol Y.
10) *Elastic body* is the body that never returns to its original shape after a deformation.

One Word Answer Type Question

1) Give example of Plastic Body.
2) Give example of Elastic Body.
3) What is the SI unit of Pressure?
4) What is the SI unit of Surface Tension?
5) What is the formula of Surface Tension?

Very Short Answer Type of Questions

1) Define Elasticity.
2) What is Viscosity?
3) What is Turbulent Flow?
4) Define Surface Tension.
5) What is Young's Modulus of Elasticity?

Short Answer Type Of Questions

1) State and explain Hooks Law.
2) State and explain Pascal's Law.
3) What is the effect of temperature on surface tension?
4) What is the effect of temperature on viscosity?
5) Give any five applications of Surface Tension.

Long Answer Type of Questions

1) Explain different kind of modulus of elasticity.
2) What is Surface Tension? Give formula, Units and Applications of Surface Tension.

Unit-6

HEAT AND TEMPERATURE

The hotter an object is, the faster the motion ***of the*** molecules inside it. Thus, the ***heat*** of an object is the total energy of all the molecular motion inside that object. ***Temperature***, on the other hand, is a measure ***of the*** average ***heat*** or ***thermal*** energy ***of the*** molecules ***in a*** substance.

Principle of Measurement of Temperature:-

Measurement of temperature depends on principle that properties (physical/electrical/chemical) of material changes with temperature. Temperature is a principle parameter that needs to be monitored and controlled in most engineering applications such as heating, cooling, drying and storage. Temperature can be measured via a diverse array of sensors. All of them infer temperature by sensing some change in a physical characteristic be it a thermal expansion, thermoelectricity, electrical resistance or thermal radiation. There are four basic types of temperature measuring devices, each working on a different principle: 1. Mechanical (liquid-in-glass thermometers, bimetallic strips, bulb & capillary, pressure type etc.) 2. Thermocouples 3. Thermo-resistive (RTDs and thermistors) 4. Radiative (infrared and optical pyrometers)

What is Heat?

Heat is the form of energy which produces the sensation of warmth or coldness.

HEAT ON THE BASIS OF KINETIC THEORY:

According to this concept

Heat of a body is total kinetic energy of all its molecules.

If a body have n number of molecule having mass m and velocities v_1, v_2, v_3, --------, v_n respectively.

Then total Heat Energy in the Body (H) = sum of Kinetic energy of all molecules

$$= K\left(\frac{1}{2}mV_1^2 + \frac{1}{2}mV_2^2 + \frac{1}{2}mV_3^2 + \ldots\ldots + \frac{1}{2}mV_n^2\right)$$

Where K is constant.

When the temperature is increased, the Kinetic energy of each molecule increases (due to velocity). This results in the increase of total kinetic energy of the body. This in turn represents heat of the body.

TEMPERATURE:

It is the degree of hotness of the body. It is measured as the average kinetic energy of its molecules.

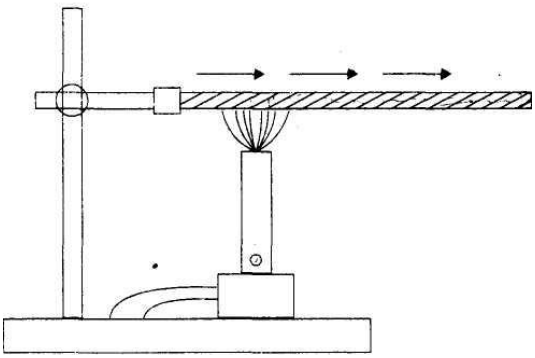
Unit: Kelvin (K), Celsius

Modes of Transfer of

(i) Thermal conduction:

It is defined as that mode of transfer of heat in which the heat travels from particle to particle in contact, along the direction of fall of temperature without any net displacement of the particles of solid.

e.g a rod of brass held in such a way that its one end is on an ignited burner. After some time other end of rod also become hot. This is due to the transfer of energy in form of vibration to nearby atoms.



ii) Convection:

The process of transmission of heat in which heat is transferred from one point to another by the physical movement of the heated panicles is called convection.

Liquids and gases transfer heat by convection. This is because the density of these substances varies with temperature. Speed of molecule increase and density decreases when liquid or gases are heated. The molecule having more kinetic energy rise upward and carry heat with them.

Thus a convectional cycle is set up. The molecules of fluid start moving in closed loops. They transfer heat energy from the hotter region to colder region. The convectional cycles are helped by gravity. That is why a liquid should be heated by using burner at the base of its container.

Eg. Heating of water, cooling of transformer, heating of rooms by heater etc.

Thermal radiation:

The process of heat transfer in which heat is transmitted from one place to another in straight line with the velocity of light, without heating the intervening medium.

Thermal radiation is the energy emitted in the form of radiation, by a body, on account of its temperature. All the bodies around us do emit this radiation. These radiations are the electromagnetic waves.

The energy contained in radiation is $E = h\,v$, Where v is frequency of heat wave.

e.g.

1. The sun transfer heat to earth by radiation.

2. an open fire place gives heat to room mainly by radiation.

Properties of Heat Radiation:

(i) Heat radiations are electromagnetic wave
(ii) They do not require a medium for their propagation.
(iii) Heat radiations travel in straight line.
(iv) Thermal radiations do not heat the intervening medium.
(v) Media are transparent or opaque depending upon the wavelength of incident wave.
(vi) They travel with a velocity $3x10^8$m/s in vacuum.
(vii) Their velocity obeys the relation,

$$C = v\,\lambda$$

Where v = frequency

λ = Wavelength

(viii) They undergo reflection, refraction, interference, diffraction and polarization.
(ix) They obey inverse square law.

<u>DIFFERENT SCALES OF TEMPERATURE</u>

FAHRENHEIT SCALE:

It was given by G. Fahrenheit. On this scale freezing point of water is taken as the lower fixed point (32°F) and boiling point of water is taken as upper fixed point (212°F). The interval between two points is divided into 180 equal parts. Each division is 1° F.

This scale is used for Clinical and meteorological purpose.

CELSIUS SCALE: was given by A. Celsius in 1742.

On this scale freezing point of water is taken as the lower fixed point (marked 0°C) and boiling point of water is taken as upper fixed point (marked 100°C). The interval between two points is divided into 100 equal parts. Each division is 1° C.

This scale is also called centigrade scale. This scale is used for common scientific, clinical, meteorological and technological work.

KELVIN SCALE OR ABSOLUTE TEMPERATURE SCALE:

On this scale freezing point of water is taken as the lower fixed point (marked 273°K) and boiling point of water is taken as upper fixed point (373°K). The interval between two points is divided into 100 equal parts. Each division is 1K.

$$1^oC = 1^o K$$

This scale is also called as absolute scale

Absolute zero: the temperature at which all molecular motion comes to a stand still. i.e. net kinetic energy becomes Zero. It is taken as zero Kelvin (or -273° C)

At this temperature the pressure (or volume) of the gas goes to zero. This mean if the temperature is less than -273.16°C, the volume becomes negative which is obviously not possible. Hence -273.16°C is the lowest temperature man can achieve. Therefore, 273.16°c is called the absolute zero of temperature

Triple point of water: The triple point is that point on a pressure versus temperature graph which corresponds to the equilibrium among three phases of water i.e. gas, liquid and solid.

It is taken equal to 273.16K.

RELATION AMONG THE SCALES OF TEMPERATURE

Temperature of a body can be converted from one scale to the other.

Let, L = lower reference point (freezing point)

H = upper reference point (boiling point)

T = temperature read on the given scale.

Now $\frac{T-L}{H-L}$ = Relative temperature w.r.t both reference point.

This relative temperature should not change if we are measuring the temperature of a body by using different thermometers.

Let us take a body whose temperature is determined by three different thermometers giving readings in ^oC, ^oF and K respectively.

Let $T_1 = C$ = Temperature in ^oC, $L_1 = 0°C$ $H_1 = 100°C$

$T_2 = F$ = Temperature in ^oF, $L_2 = 32°F$ $H_2 = 212°F$

$T_3 = K$ = Temperature Kelvin, $L_3 = 273$ K $H_3 = 373K$

We can write,

$$\left(\frac{T_1 - L_1}{H_1 - L_1}\right) = \left(\frac{T_2 - L_2}{H_2 - L_2}\right) = \left(\frac{T_3 - L_3}{H_3 - L_3}\right)$$

$$\Rightarrow \quad \left(\frac{C - 0}{100 - 0}\right) = \left(\frac{F - 32}{212 - 32}\right) = \left(\frac{K - 273}{373 - 273}\right)$$

$$\Rightarrow \quad \frac{C}{100} = \frac{F - 32}{180} = \frac{K - 273}{100}$$

$$\Rightarrow \quad \frac{C}{5} = \left(\frac{F - 32}{9}\right) = \left(\frac{K - 273}{5}\right)$$

Fill in the Blanks

1) *Heat* of an object is the ……. energy of all the molecular motion inside that object. (total/average)
2) *Temperature* is a measure ***of the*** ……. *heat* or *thermal* energy ***of the*** molecules. (Total/average)
3) …… is the transfer of heat across a medium or objects which are in physical contact.(conduction/convection)
4) …….. is the transfer of heat from a fluid to a solid surface or within a fluid. (conduction/convection).
5) Matter that is at finite temperature emits energy in space in the form of electromagnetic waves, this is known as ……..(radiation/conduction)

True or False

1) Heat radiation travels at the same speed as sound.
2) The Kelvin scale is an absolute scale.
3) Heat radiation cannot travel through a vacuum.
4) The Celsius temperature is defined to be exactly 273.15 less than the Kelvin temperature.
5) *Air conditioner is an example of radiation.*

One Word Answer Type Question

1) Give SI unit of Heat.
2) Give SI unit of Temperature.
3) Whether heat radiation travel in straight line or not?
4) What is absolute zero of temperature?
5) Whether heat radiation follow inverse square law?

Very Short Answer Type of Questions

1) What is heat?
2) What is Absolute scale of temperature?
3) What is temperature?
4) What is principle of measurement of temperature?
5) Give example of convection.

Short Answer Type Of Questions

1) Explain conduction.
2) Explain convection.
3) Give any five properties of Heat Radiation.
4) What is the difference between heat and temperature?
5) Write a short note on Absolute scale of Temperature.

Long Answer Type of Questions

1) Explain different modes of transfer of Heat.
2) Explain different scales of temperature.

Chapter 7: WAVE MOTION AND ITS APPLICATIONS

Introduction

Motion of an object is the change in its position with time. A motion is characterised by distance, displacement, velocity, acceleration, time and speed. There are four different types of motion. These are linear (translatory), rotary, oscillatory and reciprocating.

1. **Linear motion**
   A linear motion is anything that moves in a straight line. For example a vehicle moving on a straight path, man walking in a straight path.
2. **Rotary Motion**
   Anything which moves in a circle forms rotary motion. For example spinning wheel, spinning top etc.
3. **Reciprocating motion**
   It is the motion in which object moves backwards and forwards in a straight line. For example cutting wood with a saw, motion of a piston in cylinder etc.
4. **Oscillatory motion(Vibratory motion)**
   A motion in which the object moves to and fro about a fixed mean position is called oscillatory motion (vibration). All oscillatory motion needs to be periodic.
   The motion in which the object repeats its path aftera fixed regular interval of time is called periodic motion. For example motion of hands of clock, motion of spring mass system, simple pendulum, cantilever, rim of cycle wheel etc.

Whenever there are vibrations, there is transfer of energy which makes a wave. An understanding of vibrations and waves is required to understandour physical world. We see around us because of light waves and we hear the world around us because of sound waves. If we can understand waves, then we will be able to understand the world of sight and sound. In this chapter, we will discuss about waves and its applications.

What Causes Objects to Vibrate?

When an object is positioned at its equilibrium position, it is in a state of equilibrium. According to Newton’s Law, an object which is in a state of equilibrium is experiencing a balance of forces. All the individual forces are balanced or add up to an overall net force of 0N. An object remains in the equilibrium position until disturbed from its equilibrium.

The Restoring Force

A vibrating object often does the back and forth a number of times. The vibrations repeat themselves over and over. As such, the objectwill move back to (and past) the equilibrium position every time it returns from its maximum displacement to its mean position. If the forces acting upon the object are balanced when at the equilibrium position, then why doesn't the object stop the first time it returns to the equilibrium position? The answer lies in Newton's first law of motion. According to Newton's first law of inertia, an object which is moving will continue its motion if the forces are balanced. So every time the object is at its equilibrium position, the momentary balance of forces will not stop the motion.

The object keeps moving. As the object is displaced past its equilibrium position, then a restoring force acts to bring it back to equilibrium position.

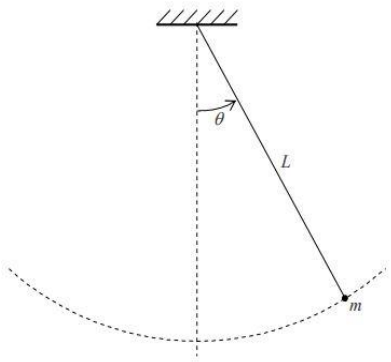


Figure 7.1

A pendulum is a classic example of an object that is considered to vibrate. A simple pendulum consists of a relatively massive object hung by a string from a fixed support as shown in figure 7.1. It typically hangs vertically in its equilibrium position. When the mass is displaced from equilibrium, it begins it's back and forth vibration about its fixed equilibrium position. The motion is regular and repeating.

Another classic example of an object that undergoes vibrational motion is a mass on a spring. The mass hangs at a resting position as shown in figure 7.2. If the mass is pulled down, the spring is stretched. Once the mass is released, it begins to vibrate. It does the back and forth, vibrating about a fixed position. If the spring is rotated horizontally and the mass is placed upon a supporting surface, the same back and forth motion can be observed. Pulling the mass to the right of its resting position stretches the spring. When released, the mass is pulled back to the left, heading towards its resting position. The cycle continues as the mass vibrates back and forth about a fixed position. The springs inside of a bed mattress, bathroom scales and the suspension systems of some cars- all are operated as a mass on a spring system.

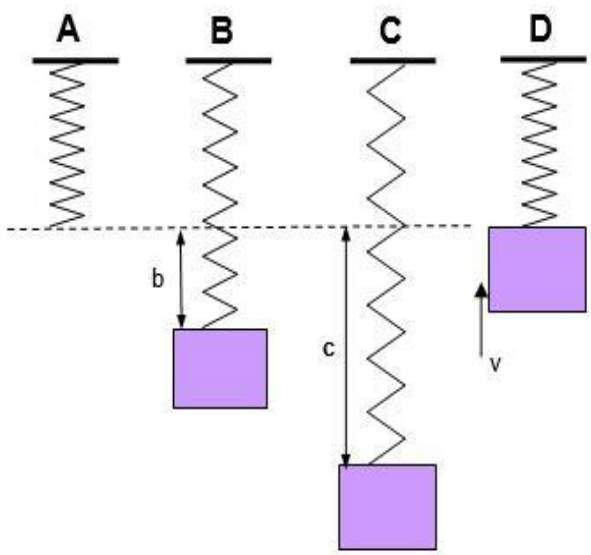


Figure 7.2

7.1 Types of Vibrations: There are three types of vibrations:

1) **Free Vibrations:** A force can set a resting object into motion. But when the force is a short-lived or momentary, it only begins the motion. The object moves back and forth, repeating the motion over and over. If force is applied to an object to set it into vibrations and then vibrations are maintained by internal elastic forces of the object then such vibrations are called free vibrations. The frequency of free vibrations is called natural frequency of the object. For example vibrations of simple pendulum, cantilever, loaded beam etc.

   Free vibrations can also be divided in two classes as damped vibrations and undamped vibrations.

a) **Damped Vibrations**: In case of free vibrations, the extent of displacement from the equilibrium position reduces with time. This is because the force that started the motion is a momentary force and the vibrations ultimately cease. The object is said to experience damping. Thus when the amplitude of vibrations goes on decreasing with time and finally the vibrations stop after some time then such vibrations are called damped vibrations as shown in figure 7.3. For example vibrations of cantilever, loaded beam, spring mass system etc. Damping is the tendency of a vibrating object to lose or to dissipate its energy over time. The mechanical energy of the object is lost to other objects. Without a sustained forced vibration, the back and forth motion of the object eventually ceases as energy is dissipated to other objects.

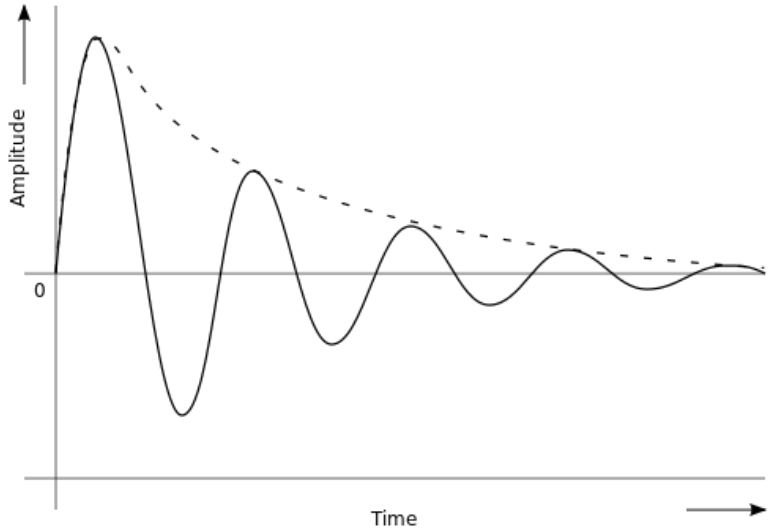


Figure 7.3

b) **Un Damped Vibrations**: If the amplitude of vibration remains constant and the vibrations continue to infinite time then such vibrations are called undamped vibrations as shown in figure 7.4. For example vibrations of simple pendulum in a closed glass box.

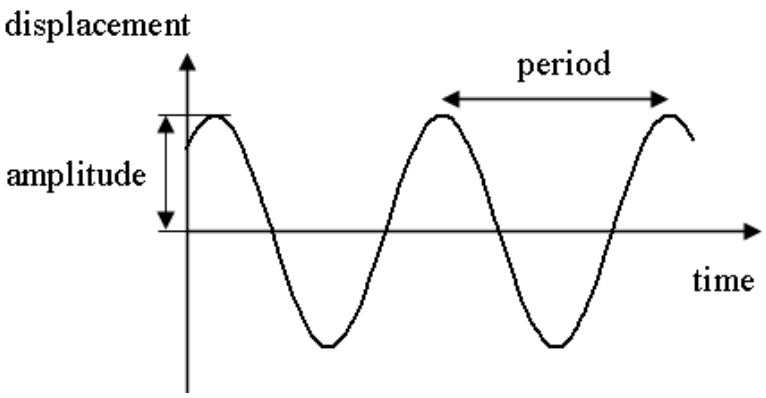


Figure 7.4

2) **Forced Vibrations**: A vibrating object naturally loses energy with time. It must continuously be put back into the vibrations through a forced vibration in order to sustain the vibration. A sustained input of energy would be required to keep the back and forth motion going. Thus when a periodic force is used to maintain the vibrations of object then such vibrations are called forced vibrations. For example swing of a child.
3) **Resonant Vibrations**: It is a special type of forced vibration in which the frequency of applied force matches with natural frequency of object. In this situation resonance occurs and the amplitude of vibrations increases largely. For example tuning of radio set, swing of a child
   (a) Tuning of a radio set: There are many stations sending radio waves of various frequencies causing forced oscillations in the circuit of receiver. When the frequency of tuner equals that of waves from particular broadcasting station, the resonance takes place and hence we can hear only that station, whose amplitude of frequency has increased.
   (b) Another example is swing of a child, which acts as a pendulum. The force with a frequency that matches with the natural frequency of the swing (its resonant frequency) makes the swing go higher and higher (maximum amplitude), while attempts to push the swing at a faster or slower rate produce smaller amplitude. This is due to the fact that swing absorbs maximum energy when the force matches withnatural frequency of swing.

   Resonance occurs widely in nature. Some sounds we hear, like when hard objects of metal, glass, or wood are struck, are caused by brief resonant vibrations in the object. Electromagnetic waves are produced by resonance on an atomic scale, as electrons in atoms.

   Other examples are the balance wheel in a mechanical watch, Tidal resonance, acoustic resonances of musical instruments, production of coherent light by optical resonance in a laser etc.

7.2 Simple Harmonic Motion (SHM):-

It is a special type of **periodic motion in which the acceleration is directly proportional to displacement and is always directed towards mean position.** It can be represented in terms of harmonic functions i.e. sinθ and cosθ.

Characteristics of SHM are:

• The motion should be periodic
• Force causing the motion is directed toward the equilibrium point (minus sign).
• Force is directly proportional to the displacement from equilibrium.

Acceleration = - ω^2 x Displacement

$$a = -\omega^2 y$$

Where ω is angular velocity defined as rate of change of angular displacement θ .

$$\omega = \frac{\theta}{t} = \frac{2\pi}{T} = 2\pi n$$

7.3 Cantilever

A metallic beam fixed at one end and free to vibrate at other end is called cantilever. The normal configuration of a cantilever is shown in figure 7.5.

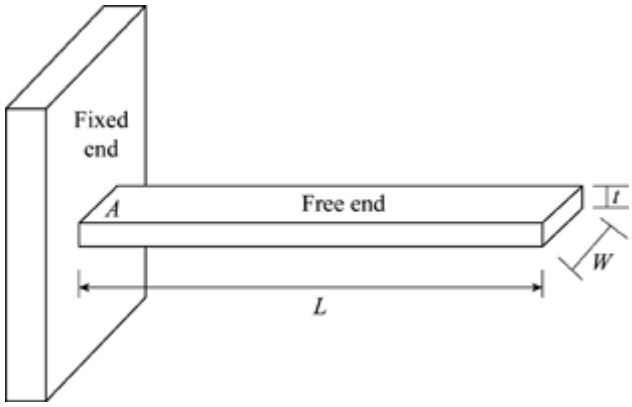


Figure 7.5

When it is loaded at free end it vibrates and its edge performs simple harmonic motion. The time taken to complete one vibration is called time period.

The time period is given by

$$T = 2\pi\sqrt{\frac{p}{g}}$$

Where p is the depression of beam (displacement of beam from its unloaded position) and g is acceleration due to gravity.

7.4 Waves

A wave is the disturbance in which energy is transferred from one point to other due to repeated periodic motion of particles of the medium. There are two types of waves are

1. Electromagnetic waves
2. Mechanical or elastic wave.

Electromagnetic wave (Light)

The wave which travels in form of varying electric and magnetic fields mutually perpendicular to each other and also perpendicular to direction of propagation of wave. They do not need material medium for their propagation. For example-light waves are electromagnetic waves. The energy of electromagnetic waves is given by relation:

$$E = \frac{hc}{\lambda}$$

Where h is Planck's constant and is equal to 6.6 $x10^{-34}m^2kg/s$

c (velocity of light)=$3x10^8$m/s

and λ is wavelength of light

Mechanical wave (Sound)

Those waves which are produced due to repeated periodic motion of medium particles are called mechanical or elastic waves. They need a material medium for their generation and propagation. For example sound waves, water waves are mechanical in nature.

Wave Motion

The propagation of disturbance through a medium due to repeated periodic motion of medium particles is called wave motion. The characteristics of wave motion are:

1. The wave travels forward but the particles vibrate only about their mean position.
2. The velocity of propagation is the rate at which the disturbance travels through the medium.
3. The velocity of the wave depends on the type of wave (light, sound, or radio) and type of medium (air, water, or metal).
4. The velocity of waves is different from the velocity of particles.
5. There is regular phase difference between particles of wave.

The wave motion is characterised by following terms:

1. **Displacement-** It is the minimum distance of the position of the particle from its mean position. It is denoted by y and is measured in metres.
2. **Amplitude-** It is the maximum displacement between mean and extreme position of a vibrating particle. It is denoted by r and is measured in metres.
3. **Time Period-** Total time taken by a wave to complete one cycle or vibration. It is denoted by T and measured in sec.
4. **Frequency-** Number of cycles/vibrations completed by the wave in one second. It is reciprocal of time period, denoted by n and is measured in hertz (Hz) or sec^{-1}.
5. **Wave Length-** The linear distance travelled by wave in one complete cycle. It is denoted by λ and measured in metres.
6. **Wave velocity-** It is defined as distance travelled by wave per unit time. Its unit is m/s.
7. **Phase-** Phase of a vibrating particle tells the position of a particle at that instant. It is measured by the fraction of angle or time elapsed by wave at any instant since the particle has crossed its mean position in positive direction. It is denoted by θ. Its unit is radian.
8. **Phase difference**: The difference in angle or time elapsed between two particles at any instant. It is calculated by the formula

$$\text{Phase difference} = \frac{2\pi}{\lambda} * \text{ path difference}$$

9. **Relation between velocity, wavelength and frequency**

Wave velocity is distance travelled by the wave in one time period.

$$v = \frac{\lambda}{T}$$

And frequency is reciprocal of time period i.e.

$$n = \frac{1}{T}$$

Thus $$v = n\lambda$$

There are two types of wave motion:

a) Transverse wave motion
b) Longitudinal wave motion

a) Transverse wave motion

When the particles of the medium vibrate perpendicular to the direction of propagation of wave then such wave motion is called transverse wave motion. A transverse wave motion is shown in figure 7.6. A transverse wave consists of one crest and one trough that makes one cycle. The distance between two consecutive crests or two consecutive troughs is called wave length. The farthest point in positive direction is called crest and that in negative direction is called trough.

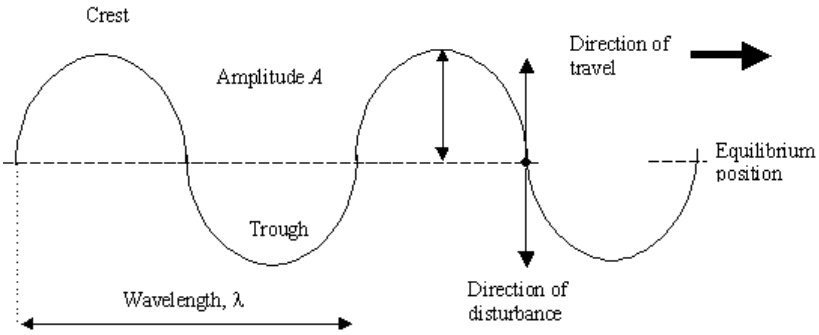


Figure 7.6

Longitudinal Waves

When the particles of medium vibrate parallel to the direction of propagation of wave then such wave motion is called longitudinal wave motion. A longitudinal wave travels in the form of compressions and rarefactions as shown in figure 7.7. The part of medium where distance between medium particles is less than their normal distance is called compression and the portion where distance is more than their normal distance is called rarefaction. One cycle consist of one complete compression and one complete rarefaction. The distance between two consecutive compressions and rarefaction is called wave length.

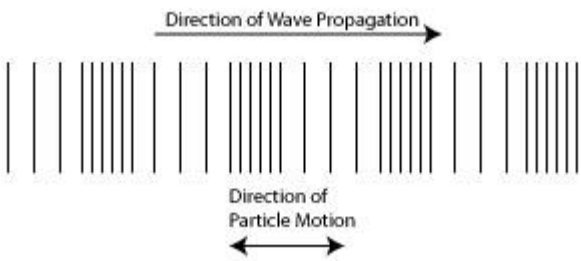


Figure 7.7

The main points of difference between transverse and longitudinal waves are listed below:

S.No.	Transverse waves	Longitudinal waves
1.	The particles of the medium vibrate perpendicular to the direction of propagation of wave	The particles of medium vibrate parallel to the direction of propagation of wave
2.	The wave travels in form of crests and troughs	The wave travels in form of compressions and rarefactions.
3.	There is no change in density of the medium.	These waves produce change in density of the medium.
4.	These waves can be polarised.	These waves cannot be polarised.
5.	Electromagnetic waves, wave travelling on stretched string , light waves are its examples.	Sound waves, pressure waves are its examples.

7.5 Sound Waves:

They are also called pressure waves and can be transmitted through solid liquid or gas.There are three frequency ranges in which sound is categorised:

a) **Audible**-The sound waves between frequency 20 Hz to 20 kilo Hz is audible to human ears and is called audible range.
b) **Infrasonic**-Sound waves below frequency 20 Hz are called infrasonic and are inaudible to human ears. A number of animals produce and use sounds in the infrasonic range. For example elephant, whales, rhinos etc.
c) **Ultrasonic**- The sound waves with frequency above 20 kilo Hz are called ultrasonic. Bats communicate through ultrasonic waves. They are also inaudible to human ears.

Characteristics of sound waves are:-

1. Sound waves are longitudinal mechanical waves.
2. They need material medium for their generation and propagation.
3. They cannot traverse through vacuum so their velocity in vacuum is zero.
4. Their velocity in air at NTP is 332 m/s and it increases by a factor of .61 m/s with every one degree centigrade rise in temperature.
5. Sound waves travel faster in solids than in liquids than in gasses.
6. They show the phenomena of reflection , transmission, diffraction etc.

Acoustics: The branch of Physics that deals with study of audible sound including their generation, propagation and properties is called acoustics.

Acoustics of buildings: The branch of Physics that deals with construction of Public halls, auditoriums, cinema halls etc for best sound effects is called acoustics of buildings.

Generation of Audible Sound: Any object that can produce longitudinal mechanical waves of frequency between 20 Hz to 20 KHz generates audible sound. For example musical instruments, vibrating fork, human throat (vocal chord) etc.

Propagation of Audible sound: Audible sound propagates in material medium only. Its velocity is lowest in air and increases with increase in density of the medium. It travels fastest in metals.

While travelling in one medium if it meets another medium it gets divided in three parts. Reflected part, absorbed part and transmitted part.

Absorption coefficient:

The ratio of sound energy absorbed by a surface to total sound incident on surface is called absorption coefficient. It is denoted by 'a' and its SI unit is OWU (Open window unit). Its value is maximum ie one for an open window.

a = sound energy absorbed by a surface/ total sound energy incident on the surface.

Types of Audible sound: Two types of audible sound are musical sound and noise.

Musical sound:

The sound that produces pleasant effect on our ears is called musical sound. It is a single sound or multiple sounds having same frequency, wavelength meeting in same phase.

Noise:

The sound that produces unpleasant effect on our ears are called noise. It has irregular amplitude with time. It is generally a combination of multiple sounds of different frequency, wavelength meeting in different phases.

Reverberation: It is the persistence of sound after the source has stopped emitting sound due to reflection from multiple surfaces.

Reverberation Time: The time upto which a sound persists in a hall or room after the source has stopped emitting it is called reverberation time.

Standard reverberation time (Sabine's formula): Reverberation time is the time taken by the sound intensity to drop by 60 dB or reduce to its one millionth parts. An American scientist named W. C. Sabine developed an equation for calculating the reverberation time as:

$$T = \frac{0.16V}{\sum as}$$

Where V is the volume of the hall in m^3, a is the average absorption coefficient of room surfaces and S is total surface area of room in m^2.

Where $\sum as = a_1 s_1 + a_2 s_2 + a_3 s_3 .....$

Where a_1, a2, a3etc. are absorption coefficients of different objects in hall and s_1, s2, s3etc. are their surface areas.

Echo:-

The repetition of original sound by reflection from a surface is called echo. The echo is produces if the reflected sound reaches our ears after 1/10 of a second. It is different from reverberation as echo is identified as repeated sound due to a time gap of at least 1/10 of a second.

The distance ‘s’ of reflector/obstacles causing echo is given by

$$s = vt/2.$$

Where ‘v’ is velocity of sound and ‘t’ is time taken by reflected sound to reach our ears.

The minimum distance of obstacle to produce echo thus is given as

$$s = (332X (1/10))/2 = 16.6 \text{ m/s}$$

The obstacle must be placed at minimum 16.6m from the source to produce echo.

Methods to control Reverberation time:-To control reverberation time the simplest way is to increase absorption in the hall. The methods to control reverberation are:

1. Provide few open windows in hall-Open windows are good absorbers of sound and the reverberation time can be controlled by adjusting the number of open windows in the hall.
2. Cover the floor with carpets- The carpets are also good absorbers of sound which help in reducing the reverberation time in the hall.
3. Curtains- the use of heavy folded curtains on doors and windows allows to control the reverberation time.
4. Cover the walls-Covering the walls with absorbing materials like fibre or asbestos sheetsetc. help in reducing reverberation time.
5. Provide false ceiling- False ceiling is made of sound absorbing material which reduces the reverberation in a hall.
6. Using upholstered cushioned seats in hall- The seats in the empty hall would also absorb the sound if they are made of good absorbing cushioned material and turn up when no one is sitting on them.
7. A good number of audience increases the absorption of hall.

7.6 Ultrasonic: The sound waves having frequency more than 20 kilo hertz are called ultrasonic. Their characteristics are :-

1. They are high frequency and high energy waves.
2. Their energy is proportional to square of frequency, thus follow inverse square law.
3. If they are passed through a liquid it is shaken violently.
4. They work as catalyst for chemical reactions.
5. They can be sent in form of narrow beams to long distances without loss of energy.
6. Travelling in one medium if they meet another, they return back in same medium at 180 degree.)
7. Just like ordinary sound waves, ultrasonic waves get reflected, refracted and absorbed.
8. They produce intense heating effect when passed through a substance.

Production of Ultrasonic:- The natural producer of ultrasonic is 'BAT'. Another simple method to produce low frequency ultrasonics is 'Galton's whistle'. Two types of oscillators are used to produce ultrasonic sounds:

1. Magnetostriction oscillator
2. Piezo electric oscillator.

Applications of Ultrasonic: Ultrasonic waves are used in various fields like medical for ultrasound, navigation for various purposes, engineering etc. Some important applications of ultrasonic are described below:

1) **Drilling:** Ultrasonic is high frequency and high energy wave, so they can be used in applications involving high amount of energy. They can be used tomake a drill even in hardest material of world i.e. Diamond. For this a tool bit is attached at lower end of magnetostriction oscillator. The sheet to be drilled is kept below the tool bit. It is driven by a Piezoelectric oscillator that creates the vibrations. When oscillator is switched on the tool bit moves up and down that produces enough strain to make a drill in the sheet. The setup of drilling is shown infigure 7.8.

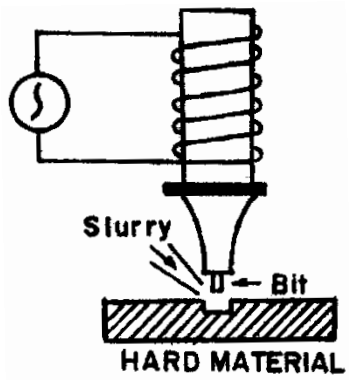


Figure 7.8

2) **Ultrasonic welding (cold welding):**The setup is shown in figure 7.9. Cold welding means welding without involvement of heat which is possible only with ultrasonic. A hammer is attached at lower end of magnetostriction oscillator. The sheets to be welded are kept below hammer. When oscillator is switched on hammer strikes the sheets frequently. In case of resonance the molecules of both sheets enter in each other due to high amplitude and welding is performed without involvement of heat. The interface of the two parts is specially designed to concentrate the energy for maximum weld strength.

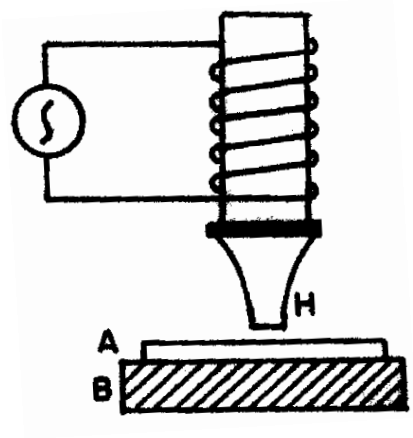


Figure 7.9

3) **SONAR**: SONAR is a technique which stands for Sound Navigation and Ranging. It uses ultrasonic for the detection and identification of underwater objects. A powerful beam of ultrasonic is sent in the suspected direction in water. By noting the time interval between the emission and receipt of beam after reflection, the distance of the object can be easily calculated.Measuring the time interval (t) between the transmitted pulses and the received pulse, the distance between the transmitter and the remote object is determined using the formula

$$d = \frac{vt}{2}$$

Where v is the velocity of sound in sea water. The same principle is used to find the depth of the sea as shown in figure 7.10.

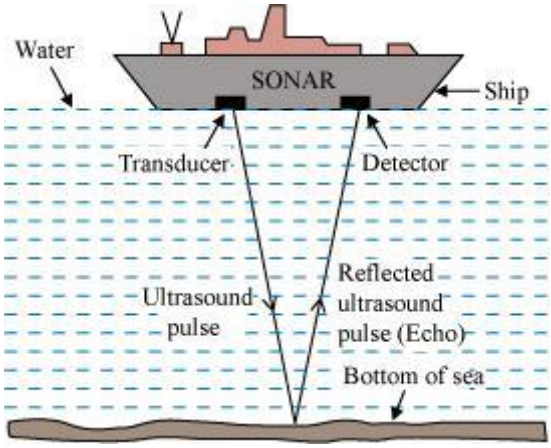


Figure 7.10

Summary:

- ***Every motion that repeats itself in equal intervals of time is called periodic motion***
- ***To and fro motion of a body about a mean position is called oscillatory or vibratory motion.***
- ***If oscillatory motion is periodic, it is called harmonic motion***
- ***SHM stands for simple harmonic motion where acceleration is proportional to the displacement from the fixed point and is always directed towards it.***

- ***Time period and frequency are inversely proportional.***
- ***Cantilever is a beam fixed at one end and other end is kept free to vibrate.***
- ***The time period of vibration in a cantilever is*** $T = 2\pi\sqrt{\frac{p}{g}}$
- ***When a force is applied to an object to set it into vibrations and then allowed to vibrate freely, such vibrations are called free vibrations.***
- ***When an externalperiodic force is applied to an object, it produces forced vibrations.***
- ***Resonant vibrations are produced when the frequency of external periodic force matches with natural frequency of body.***
- ***The sound waves between frequencies 20 Hz to 20 kilo Hz is constitute the audible range.***
- ***Sound waves below frequency 20 Hz are called infrasonic and are inaudible to human ears.***
- ***Ultrasonic- The sound waves with frequency above 20 kilo Hz are called ultrasonic.***
- ***The sound that produces unpleasant effect on our ears is called noise.***
- ***The ratio of sound energy absorbed to the total sound energy incident on a surface is called absorption coefficient.***
- ***Reverberation is the persistence of sound after the source has stopped emitting sound due to reflection from multiple surfaces.***
- ***Reverberation Time is the time upto which a sound persists in a hall or room after the source has stopped emitting it is called reverberation time.***

Solved numerical problems

NP 1) A sound wave traveling at 450 m/s and has a frequency of 500 Hz. What is its wavelength?

Solution:

The wavelength is related to the frequency and the speed by the following relation:

$$\lambda = vT = \frac{v}{n} = \frac{450}{500} = 0.9m$$

NP 2) An ultrasonic scanner travelling with a speed of 1.5km/s in a tissue operating under a frequency of 4.1 MHz. What is the wavelength of sound in the tissue?

Solution:

Given, v=1.5km/s= 1.5x1000=1500m/s

n=4.1MHz=4.1x10^6Hz

$$\lambda = \frac{v}{n} = \frac{1500}{4.1x10^6} = 3.65x10^{-4}m$$

NP 3) A man hears his sound again after reflection from a cliff after 1 seconds. If the velocity of sound is 330m/s, find the distance of cliff from the man.

Solution:

The velocity of sound is V=330m/s

Time after which sound is heard, t=1s

Let d be the distance of cliff from man.

Total distance travelled by man in going and coming back from cliff=2d

Thus 2d=Vxd=330x1=330m

$$d=\frac{330}{2}=165m$$

NP 4) What is the frequency of dribbling if you bounce a ball 27 times in 20 seconds.

Solution:

$$\text{Frequency =number of vibrations per second}=\frac{27bounces}{20seconds}=1.35Hz$$

Multiple choice questions:

1. In _____ waves, matter in the medium moves forward and backward in the same direction the wave travels.
   A) Transverse
   B) Compressional
   C) Radio
   D) ocean
2. The bending of a light wave as it moves from one medium into another is called _____.
   A) Reflection
   B) interference
   C) diffraction grating
   D) refraction
3. Wave motion is a form of
   A) Energy
   B) work
   C) disturbance
   D) all of them
4. IN SHM acceleration is directly proportional to
   A) Velocity
   B) displacement
   C) timeperiod
   D)none

5. As per hook's law, the deformation is proportional to
   A) Deforming force
   B) Displacement
   C) acceleration
   D) all of them
6. The vibrations in which amplitude of vibrations remains constant is called
   A) Damped vibration
   B) Undamped vibration
   C) Forced vibration
   D) Resonant vibration
7. When the vibration of body are maintained by its own elastic forces then such vibrations are called
   A) Free vibration
   B) Forced vibration
   C) Resonant vibration
   D) None of them
8. Sound wave cannot get
   A) Reflected
   B) Refracted
   C) Diffracted
   D) Polarised
9. Echo is caused due to
   A) Interference
   B) Diffraction
   C) Reflection
   D) None
10. Perfect absorber has absorption coefficient of
   A) 0
   B) 1
   C) Maximum
   D) Infinity
11. Waves that use matter to transfer energy are called _____ waves.
   A) Electromagnetic
   B)Medium
   C)Mass
   D)mechanical
12. Standard reverberation time is given by
   A) Sabine's formula
   B) Newton's formula
   C) Kepler's formula
   D) None of these.

13. Sound waves cannot travel in outer space because _____.
    A) The gas molecules in outer space air are too far apart
    B)They are electromagnetic waves
    C)They cannot travel through a medium
    D)They are mechanical waves
14. Reflection occurs when a wave _____.
    A)Compresses air particles as it travels
    B)Bends and changes speeds as it travels
    C)Causes ripples in a pool of water
    D)Strikes an object and bounces off of it
15. What type of waves does not require matter to carry energy?
    A) Compressional
    B) Transverse
    C) Mechanical
    D) Electromagnetic
16. What is the region of a compressional wave where particles are far apart called?
    A) Rarefaction
    B) Crest
    C) Trough
    D) Rest position
17. _____ is a measure of the energy in a wave.
    A) Wave velocity
    B) Wavelength
    C) Amplitude
    D) Frequency
18. In _____ waves, matter in the medium moves back and forth at right angles to the direction the wave travels.
    A) Transverse
    B) Light
    C) Compressional
    D) Sound
19. A _____ is a repeating disturbance that transfers energy through matter or open space.
    A) Medium
    B) Conductor
    C) Frequency
    D) Wave

20. _____ is the distance from the top of one crest of a transverse wave to the top of the next crest in that wave.

A)Wavelength

B)Amplitude

C)Frequency

D)Wave velocity

21. The velocity of sound waves in vacuum is

A) 230m/s

B) 332 m/s

C) 0

D) 360 m/s

22. The _____ is an imaginary line perpendicular to the surface of a medium where a wave strikes it.

A) Incidence

B) Normal

C) Diffraction grating

D) Interference

23. Which of the following is not the application of ultrasonic?

A) Drilling

B) Welding

C) Sonar

D) Radar

24. Sound waves cannot travel through

A) Steel

B) Air

C) Vacuum

D) Water

25. The minimum distance of an obstacle for echo to be heard is

A) 14 m

B) 20 m

C) 16.5 m

D) None of these

Answer to multiple choice questions:

1. B	6. B	11. B	16. A	21. B
2. D	7. A	12. A	17. D	22. B
3. C	8. D	13.D	18. A	23. D
4. B	9. C	14. D	19.D	24. C
5. A	10. B	15. D	20.A	25 C

Very short answer type questions:

Q1) Define periodic motion

Ans) A motion is said to be periodic motion which repeats itself after a regular interval of time.

Q2) Define Wave motion

Ans) Wave motion is the propagation of disturbance by repeated periodic motion of the particles of medium.

Q3) What is a wave ?

Ans) Wave is a disturbance in which energy is transferred from one place to another.

Q4) What are types of waves

Ans) There are two types of wave:

1. Mechanical waves
2. Electromagnetic waves

Q5) What are mechanical waves?

Ans) Those waves which require a material medium for propagation are called mechanical waves. For example sound waves are mechanical waves.

What are electromagnetic waves?

Ans) Those waves which do not require a material medium for propagation are called non-mechanical or electromagnetic waves. For example-light waves.

Q6) What are types of wave motion

Ans) There are two types of wave motion

1. Transverse wave motion
2. Longitudinal wave motion

Q7) What is transverse wave motion?

Ans) The wave motion in which particles of the medium vibrate perpendicular to the direction of wave propagation is called transverse wave motion. Light waves are transverse in nature.

Q8) What is longitudinal wave motion?

Ans) The wave motion in which particles of the medium vibrate parallel to the direction of wave propagation is called longitudinal wave motion. For example- sound waves are longitudinal in nature.

Q9) Define SHM

Ans) SHM stands for simple harmonic motion. A particle is said to be in SHM if its acceleration is proportional to displacement from mean position and it is expressed in terms of harmonic functions like sine or cosine of angles.

Q10) Define amplitude

Ans) The amplitude of a wave is the maximum displacement between mean and extreme positions of a wave.

Q11) Define wavelength

Ans) The wavelength is the distance travelled by a wave in one complete vibration.

Q12) Define time period

Ans) It is the time taken by a wave to complete one vibration.

Q13) Define frequency

Ans) frequency is defined as number of vibrations made by a wave in one second.

Q14) Define Acoustics

Ans) It is the branch of physics which deals with generation, properties and propagation of sound waves.

Q15) Define acoustics of buildings

Ans) It is the branch of acoustics which deals with the construction of public halls, theatres etc. to have best sound effects.

Q16) What is Sabine's formula?

Ans) It gives the value of standard reverberation time as

$$T = \frac{0.16V}{\sum as}$$

Where V is the volume of the hall, a is the absorption coefficient and s is the surface area of the absorbing surface.

Q17) What is audible range?

Ans) The audible range is the frequency which can be heard by humans i.e. frequency range of 20Hz to 20000Hz.

Q18) Define Ultrasonic waves

Ans: It is the compressional waves (sound waves) having frequency greater than 20kHz.

Q19) What is the relation between velocity, frequency and wavelength?

Ans) wave velocity= distance travelled by wave/ time period

$$v = \frac{\lambda}{T}$$

$$v = n\lambda$$

where n is the frequency of the wave which is inverse of time period T.

Q20) Give full form of SONAR

Ans) Sound navigation and ranging

Q21) Define Noise

Ans) It is unwanted sound which produces unpleasant effect on the listener. It has irregular amplitude.

Q22) What are vibrations?

Ans) To and fro motion of the particles about their mean positions is called vibrations.

Q23) Name different types of vibrations.

Ans) There are three types of vibrations:

1. Free vibrations
2. Forced vibrations
3. Resonant vibrations

Q24) What is a cantilever

Ans) Cantilever is a beam which is fixed at one end and other end is kept free to vibrate.

Q25) What are free vibrations

Ans) When a body is set into vibrations and is left to itself, then it vibrates with its own natural frequency. For example- vibrations in simple pendulum are free vibrations.

Q26) What are forced vibrations?

Ans) When a body is forced to vibrate with the help of an external periodic force, it is said to execute forced vibrations. For example-swing of a child.

Q27) What are resonant vibrations?

Ans) When the natural frequency of the body matches with the frequency of external periodic force, then resonance occurs and the amplitude of vibration increases.

Q28) What are damped and undamped vibrations?

Ans) The free vibrations which die out after some time, as their amplitude continuously decreases with time are called damped vibrations.

The vibrations which do not die and their amplitude remains constant with time are called undamped vibrations.

Q29) Why do army platoon march pasting on a bridge are asked to break steps?

Ans) Army platoon are asked to break steps because the legs of army person march pasting on bridge work as periodic force and bridge behaves as loaded beam. If frequency of their step matches with natural frequency of bridge , resonance may take place and the large amplitude of vibration may cause damage to bridge.

Practice short answer questions:

Q1 Differentiate between transverse and longitudinal wave motion.

Q2Derive the relationship between wave velocity, frequency and wave length .

Q3 Write a note on Simple Harmonic Motion.

Q4 What is a cantilever? Write the formula for its time period.

Q5 What is acoustics and acoustics of buildings?

Q6 Explain the terms: reverberation, reverberation time and echo.

Q7What is coefficient of absorption of sound. Give its units.

Q8 Give methods to control reverberation time.

Q9 Explain any two applications of ultrasonics.

Practice long answer questions

Q1What is wave motion? Explain transverse and longitudinal wave motion with examples.

Q2Explain free, forced and resonant vibrations with examples

Q3What is ultrasonic? Explain their engineering applications.

Chapter 8: OPTICS

Introduction

Optics is the branch of physics which deals with the study of properties and behavior of light. Light is an electromagnetic wave. Although light has dual nature of particle as well as wave, classical approach considers only wave nature. Its wave nature is simplified in geometric optics, where light is treated as a ray which travels in straight lines. Physical optics model includes wave effects like diffraction, interference etc. Quantum optics deals with application of light modelled as particles (called photons) to the optical systems. The phenomena of photoelectric effect and X-rays are explained in the quantum optics (particle nature of light).

Ray optics (Geometric optics)

Geometrical optics describes the propagation of light in terms of rays. The assumptions of geometrical optics are:

- Light travels in straight-line paths.
- It bends, or split in two, at the interface between two different media.
- It follows curved paths in a medium where refractive index changes.
- It may be absorbed or transmitted or reflected.

8.1 a) Reflection of light

Reflection is the bouncing back of light at an interface between two different media. Glossy surfaces such as mirrors exhibit specular reflection. This allows for production of reflected images that can be associated with real or virtual location in space.

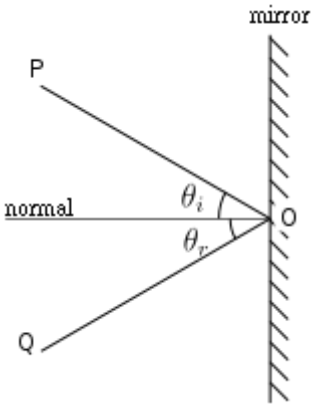


Figure 8.1

The **laws of reflection** are:

1) The incident and reflected ray and the normal, all lie in same plane, and

2 The angle between the reflected ray and the surface normal is the same as that between the incident ray and the normal i.e. $\theta_i = \theta_r$

b) Refraction of light

When a light ray passes from one transparent medium to another, it gets deviated from its original path while crossing the interface of two media. The phenomena of bending of light rays from their original path while passing from one medium to another is called refraction.

- When light travels from a rarer medium to denser medium it bends towards the normal.
- When light travels from a denser medium to rarer medium, it bends away from the normal.

It occurs when light travels through space that has a changing index of refraction. This phenomena occurs due to change in speed of light as it enters a different media.

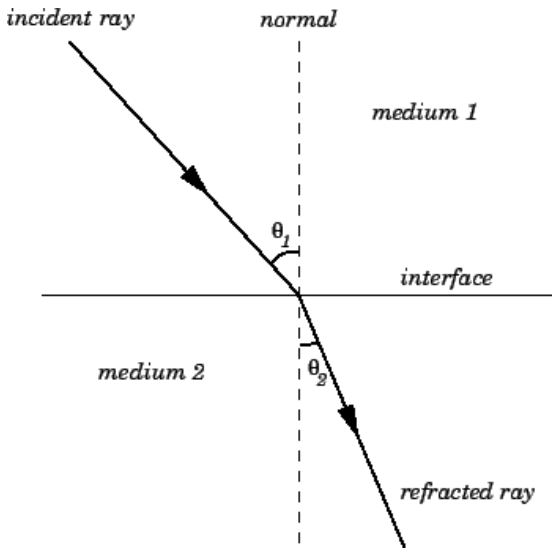


Figure 8.2

The Laws of refraction are:

1) The incident ray, the refracted ray and the normal ray, all lie in the same plane.

2) The ratio of sine of incidence angle θ_1 to the refracted angle θ_2 is a constant for that pair of media and is equal to the **refractive index** of that media. This is also known as **snell's law**

$$^{1}\mu_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{\sin i}{\sin r}$$

Where iis the angle of incidence and r is the angle of refraction and $^{1}\mu_2$ is the refractive index of medium 2 w.r.t. medium 1.If medium 1 is vacuum then,

$$\mu = \frac{\sin\theta_1}{\sin\theta_2}$$

When light travels from air/vacuum to a medium then refractive index of the medium can be written as

$$\mu = \frac{c}{v}$$

Where c is the speed of light in vacuum and v is the velocity of light in the medium. For example, the refractive index of water is 1.333, meaning that light travels 1.333 times faster in vacuum than in the water. Thus, the refractive index of a material is a dimensionless number that describes how light propagates through that medium. It can also be defined as the ratio of velocity of light in air/vacuum to the velocity of light in that medium.

The Snell's law is used to find the deflection of light rays when they pass through different media. It is used to produce dispersion spectra through a prism since light ray having different frequencies have slightly different refractive index in most materials.

The refractive index of some material varies with position and time, light travels through that medium in curves rather than straight lines. This is responsible for mirage effect observed on hot day due to different refractive index of air that causes light to bend, creating specular reflections in distance(as if water on the surface of a pool). The material having varying refractive index is useful in modern photocopy and scanning technologies.

Lens is an optical device that is based on refraction. A lens is a transparent medium bounded by two refracting surfaces. It can produce two types of rays- converging and diverging rays. Convex lens is converging while concave lens is diverging.

Terms related to study of lenses:

1. Centre of curvature: The center of curvature of a lens is the centre of sphere which forms a part of the spherical surface of the lens.
2. Radius of curvature: The radius of the sphere of the spherical surface of lens is called radius of curvature. It is the distance of the vertex of the lens from the center of curvature.
3. Principal axis: The principal axis of a lens is an imaginary line that is perpendicular to the vertical axis of the lens. Principal focus of the lens lies on this axis. All rays parallel to the principal axis that are incident on the lens, would either converge (if lens is converging) to, or diverge (if the lens is diverging) from, the principal focus.
4. Optical centre: Optical centre is the centre of the lens lying on the principal axis. If a light ray passes through optical centre, it goes undeviated.
5. Principal focus: When the parallel rays are incident on a lens, they either converge at a point or appear to diverge from a point on the principal axis, that point is called principal focus.
6. Focal length: The distance of principal focus from the optical centre is called focal length. In other words, focal length is equal to the image distance when the object is at infinity.
7. Image: If two or more rays passing from a point gets refracted through a lens and converges or appears to diverge to a point then that point is called the image of first point. The image can be real or virtual. In real image, rays actually meet at the second point, while in virtual image, the rays appear to diverge from the second point.

c) Lens formula

The focal length f of a lens is related to object distance u and image distance v as

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

d) Power of lens

Power of a lens is defined as the reciprocal of the focal length measured in metres. The unit of power of lens is dioptre indicated by symbol 'D'. One diopter is the power of a lens of one metre focal length.

$$P = \frac{1}{f}$$

The power of a convex lens is positive and that of concave lens is negative. If two lenses are combined (placed in contact), the focal length of the combination is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

Thus the power of combination becomes sum of power of individual lenses.i.e.

$$P = P_1 + P_2$$

8.2 a) TIR- Total Internal Reflection

When light is reflected into a denser medium from an interface of the denser and a rarer medium, the phenomena is known as total internal reflection.

There are two essential conditions for TIR:

1. The light should travel from a denser medium to a rarer medium.
2. The angle of incidence in the denser medium should be greater than the critical angle.

The largest possible angle of incidence which results in a refracted ray is called the critical angle. At the critical angle of incidence, the refracted ray travels along the boundary between the two media i.e. the angle of refraction becomes 90^0.

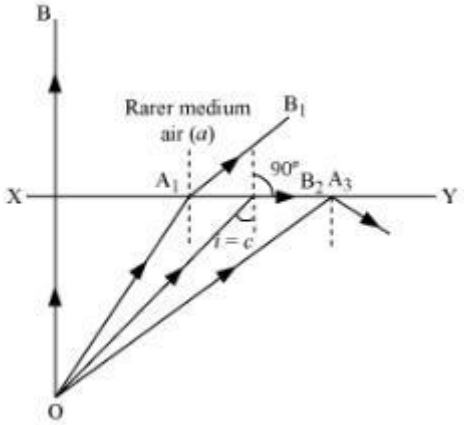


Figure 8.3

The critical angle for a material depends upon the refractive index. The higher the refractive index, the lower the critical angle. It can be calculated using the following formula:

$$\sin c = 1/n$$

Where c is the critical angle and n is the refractive index.

b) Applications of TIR

1. TIR is the basic principle of optical fibers which are used in telecommunications signals and endoscopes.
2. Automotive rain sensors work on the principle of TIR, which control automatic windscreen wipers.
3. Prisms in binoculars also form erect images based on total internal reflection.
4. Some multi-touch screens also use TIR to pick up multiple targets.
5. Optical fingerprinting devices used to record an image of a person's fingerprint without the use of ink are also based on TIR.
6. TIR is the operating principle of LED Light Panels.
7. The bright shining of diamonds is also a result of total internal reflection.

7.3 Optical Instruments

An optical instrument is a device which is used to look the objects. The eye is basic and essential optical system. In addition to it, other instruments are devised to increase the range a human's viewing ability. The optical instruments are an aid to the eye. They consist of an arrangement of lenses, prisms or mirrors which enables to see better than what we can see with the naked eye.They canbe of two types:

1. When the real image is formed on screen as in case of photographic camera, overhead projector etc.
2. When a virtual image is formed and can be seen directly with eye as in telescopes, microscopes, binocular prisms etc.

We will study about microscopes and telescopes in this chapter

a) Microscope: A microscope is an optical instrument which enables us to see magnified image of objects that are too small to be seen by the naked eye. A microscopic object is invisible to the eye unless aided by a microscope.

There are two types of microscope:

1. **Simple microscope**. It is also known as magnifying glass. It is made of only one convex lens and the object is so adjusted before the focal point that the image is formed at least distance of distinct vision.
2. **Compound microscope**. The magnification produced by a simple microscope is small and is only governed by the focal length of lens. To produce large magnification, a compound microscope is used in which magnification is obtained in two stages by the use of two convex lenses.

b) **Telescope** is an optical instrument which is used to see distant objects clearly. There are three types of telescopes:

1. Astronomical (to see astronomical objects)- It is used to see heavenly objects like stars and planets. The image formed in an astronomical telescope is inverted.
2. Terrestrial (To see objects on earth)- astronomical telescope forms an inverted image which is not suitable to see the terrestrial objects like buildings, trees etc. For seeing the distant objects lying on earth, the final image should be erect. A terrestrial telescope forms an erect image and makes use of three convex lenses.
3. Galilean (modification of terrestrial telescope)- It is a modified version of terrestrial telescope which also forms erect image but with the use of only two lenses.

8.4 a) Uses of microscope

Microscope is used in various fields for examining the details of very small parts:

1. Biological scientists use microscope to see microorganisms and their behavior.
2. Doctors use microscope to see and examine blood corpuscles.
3. Forensic science experts use microscope to analyze the evidences.
4. Jewelers and watch makers use it to see the details of parts they are working with.
5. Environmentalist uses it to test the soil and water samples for presence of pollutants.
6. Geologist uses it to test the composition of different types of rocks.
7. They are used in various experiments in schools and colleges.

8.5 **Uses of Telescope**

There are many uses of telescope in industries, science laboratories and by astronomers. The most common uses are listed below:

1. Astronomical objects are seen by using telescope by astronomers.
2. They found use in terrestrial applications also. They are used in laboratories to perform different experiments and finding values of different quantities.
3. Spectrometry uses telescope to find wavelength of light and bandwidth etc.
4. It is used in spy glasses and long focus camera lenses.

Summary

- *Reflection is the bouncing back of light at an interface between two different media.*
- *Refraction is the phenomena of bending of light rays from their original path while passing from one medium to another.*
- *Power of a lens is defined as inverse of focal length.*
- *TIR is the bouncing back of light at the interface of two media when light is going from denser medium to rarer medium incident at an angle greater than critical angle.*
- *Microscope is an optical instrument which enables us to see objects that are too small to be seen by the naked eye.*
- *A microscope is used by scientist, laboratories and investigating officers.*
- *Telescope is an optical instrument which is used to see distant objects clearly.*
- *Telescope has terrestrial and industrial uses.*

Solved Numerical problems

NP1) If the power of a lens is +4D, what is its focal length?

Solution:

Given P=4D

We know that P= $\frac{1}{f}$

Thus 4= $\frac{1}{f}$ or f= $\frac{1}{4} = \frac{100}{400} = 25X10^{-2}m = 25cm$

Thus focal length of lens is 25cm

NP2) An object is kept at 0.3m distance from a convex lens of focal length 0.2 m. Find the position of image.

Solution: Given u=-0.3m, f=0.2m

The lens formula is

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{0.2} + \frac{1}{(-0.3)} = 5 - 3.33 = 1.67$$

$$v = \frac{1}{1.67} = 0.598 = 0.6m$$

NP3) A light wave has wavelength 600 nm in vacuum. What is the wavelength of the light as it travels through water (index of refraction = 1.33)?

Solution:

Given $\lambda = 600nm = 600X10^{-9}m$

The wavelength of light that travels through a medium of refractive index n changes by expression

$$\lambda_n = \frac{\lambda}{n} = \frac{600X10^{-9}}{1.33} = 451X10^{-9}m = 451nm$$

Multiple choice questions:

1. The speed of light in vacuum is:
   A)3X108m/s
   B)3X1010m/s
   C)3X108cm/s
   D)3X1010mm/s
2. Spectrum is formed due to ---------- of light.
   A) reflection
   B)refraction
   C)diffraction
   D)dispersion
3. A …… lens is thick at centre and thin at ends:
   A)concave
   B)convex
   C)can't say
   D)none of them
4. A transparent medium bound by two curved surfaces is called:
   A)mirror
   B)prism
   C)lens
   D)binocular
5. Light travels in
   A) Straight line
   B) Circular path
   C) Harmonic path
   D) None of them
6. Concave mirrors are used in:
   A) Search lights
   B) Solar cookers
   C) Reflection in cinema projectors
   D) All of them
7. Changing path of light while entering second medium is called:
   A) Diffraction
   B) Reflection
   C) Refraction
   D) polarization
8. power of a lens is measured in:
   A) metre
   B) Watt
   C) Diopter
   D) volt
9. power of a lens is always:
   A) inverse of focal length
   B) Equal to focal length

C) Double the focal length
D) Not related to focal legth

10. Simple microscope uses:
    A) One concave lens
    B) One convex lens
    C) Two concave lens
    D) Two convex lens
11. Simple microscope is also known as:
    A) Lens
    B) Mirror
    C) Magnifying glass
    D) None of the above
12. Telescope that uses three lenses is called
    A) Astronomical telescope
    B) Galilean telescope
    C) Terrestrial telescope
    D) None of the above
13. An instrument that forms image on screen is called
    A) Camera
    B) Telescope
    C) Projector
    D) microscope
14. Refractive index of a medium is
    A)constant
    B)changing
    C)zero
    D)none
15. Two lenses are used in
    A)Astronomical telescope
    B) Galileo telescope
    C) Compound microscope
    D) All of them

Answers to multiple choice questions:

1. A	6. D	11. C
2. D	7. C	12. B
3. B	8. C	13. C
4. C	9. A	14. A
5. A	10. B	15. D

Very short answer type questions:

Q 1) What are laws of reflection?

Ans) There are two laws of reflection:

1. The incident ray, the reflected ray and the normal all lie in the same plane.

2. The angle of incidence is equal to the angle of reflection.

Q 2) What are laws of refraction?

Ans) There are two laws of refraction:

1. The incident ray, the refracted ray and the normal, all lie in the same plane.
2. The ratio of angle of incidence to the angle of refraction for two media is a constant and is equal to the refractive index of the medium. It is also called snell's law.

Q 3) What is TIR?

Ans) TIR stand for total internal reflection. It is the process of bouncing back of light at the interface of two media when light is incident at an angle greater than critical angle and is travelling from denser medium to rarer medium.

Q 4) What is critical angle?

Ans) Critical angle is that angle at which if the ray is incident in the denser medium, its angle of refraction will become 90 degree in the rarer medium.

Q 5) What is power of a lens?

Ans) Power of a lens is the inverse of focal length measured in metres. Its unit is diopter.

Q 6) What is principal focus?

Ans) It is a point on principal axis at which parallel rays converge of appear to converge.

Q 7) What is lens formula?

Ans) The lens formula is given as

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

Where f is focal length of lens, v is image distance and u is object distance.

Q 8) What is a microscope?

Ans) A microscope is an optical instrument which is used to see magnified image of nearby objects.

Q 9) What is a telescope?

Ans) A telescope is an optical instrument used to see the distant objects clearly.

Practice short answer questions:

1 Explain laws of Reflection.
2 Explain laws of refraction
3 What is refractive index? Explain with examples.
4 Write a note on TIR.
5 What is critical angle? Explain conditions necessary for TIR.
6 State any four applications of TIR.
7 What is a microscope? State its uses.
8 What is a telescope? State the uses of telescope.

Chapter 9: ELECTROSTATICS

A branch of Science which deals with the *study of charge at rest* is called electrostatics.

9.1 **Electric Charge** There are two types of charges.

(1) **Positive**: eg. Proton, Alpha particle

(2) **Negative**: Electron

Same charges repel each other and opposite charges attract each other. i.e.

+ ve	+ve	Repel
-ve	-ve	Repel
+ve	-ve	Attract
-ve	+ve	Attract

Charge on electron = - 1.6 x 10^{-19} C

Charge on Proton = + 1.6 x 10^{-19} C

Charge on electron is smallest unit of charge.

unit of charge coulomb

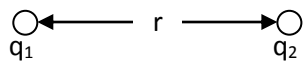
9.2 Coulomb Law of Electrostatics:

States that force of interaction between two point charges is

(i) Directly proportional to magnitude of charges and

(ii) Inversely proportional to the square of the distance between them.

Let F is force between them. Then



$$F \alpha q_1 q_2$$

$$F \alpha \frac{1}{r^2}$$

$$\Rightarrow F \alpha \frac{q_1 q_2}{r^2} \qquad \text{.....(1)}$$

$$F = K \frac{q_1 q_2}{r^2} \qquad \text{.....(2)}$$

Where K is constant of proportionality. Its value is given as

$$K = \frac{1}{4\pi \in_o} = 9 \text{ X } 10^9 \text{ Nm}^2/\text{C}^2$$

Now from equation (2)

$$F = \frac{q_1 q_2}{4\pi \in_0 r^2} \qquad \text{.....(3)}$$

Here $\in_0$ is electrical permittivity of Vacuum.

Unit of Charge: S I unit is Coulomb (C)

Let $q_1 = q_2 = q$

$r = 1$ m

then from equation (3) F = 9 X 10^9 N

Thus *one Coulomb is that much charge which produces a force of 9 X 10^9 N at a unit charge placed at a distance of 1 m.*

Smaller units of charge milli Coulomb (mC) = 10^{-3} C.

micro Coulomb (μC) = 10^{-6} C.

9.3 ELECTRIC FIELD:-

The area around the charge in which force of attraction or repulsion can be experienced by another charge

Electric field intensity at point is defined as the force acting on a unit positive charge at that point.

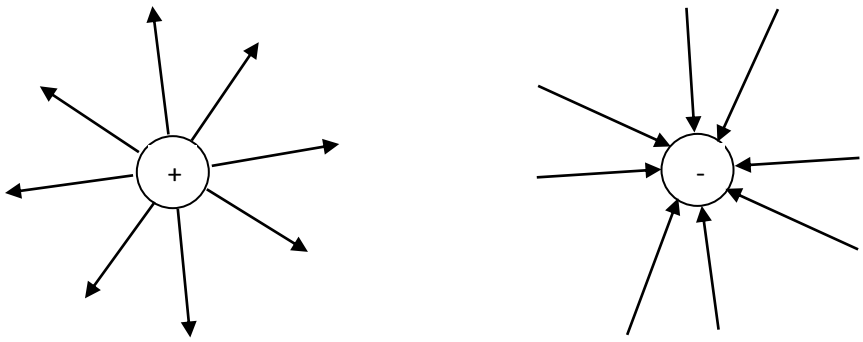
Unit Positive charge is also called as test charge

$$\vec{E} = \frac{\vec{F}}{q_0}$$

The value of q_0 should be very small. Its SI unit is N /C (Newton per Coulomb)

Electric Lines of Force:-

It is the path traversed by an electric charge in the electric field, when is free to do so. These are imaginary lines. *These lines are outward from +ve charge and inward from –ve charge as shown:-*



Properties of electric lines of force

- *Lines of force originate from a positive charge and terminate to a negative charge*
- *The tangent to the line of force indicates the direction of the electric field and electric force.*
- *Electric lines of force are always normal to the surface of charged body.*
- *Electric lines of force contract longitudinally and expand laterally.*
- *Two electric lines of force cannot intersect each other.*
- *Two electric lines of force proceeding in the same direction repel each other.*
- *Two electric lines of force proceeding in the opposite direction attract each other. There are no lines of force inside the conductor*

9.4 Electric flux:

Total number of electric lines of force passing a unit area normal to the surface is called electric flux. It is denoted by ψ (psi).

Consider small elementary area ds on a closed surface S. Electric field E exit in the space. If θ is the angle between $\vec{E}$ and area vector $\vec{ds}$ as then

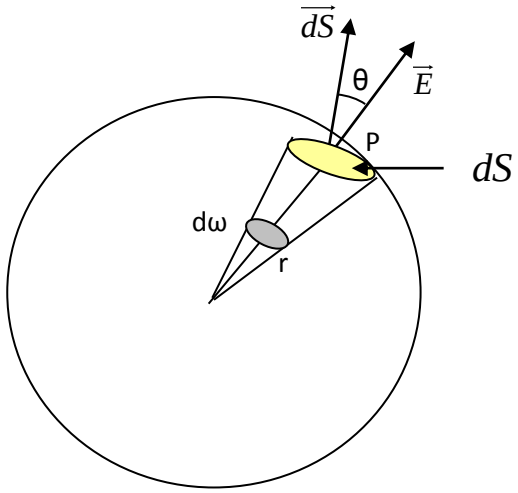
$$\psi = \oint EdS\cos\theta \quad \textit{is called electric flux.}$$

GAUSS'S LAW:

State that total electric flux over a closed surface is equal to the net charge enclosed by the surface divided by $\in_0$ i.e.

$$\psi = \oint_s EdS\cos\theta = \frac{q}{\in_0}$$

Proof: *Consider a closed surface S having a charge q placed at a point O inside a closed surface. Take a point P on the surface and consider a small area dS around P.*



Then Electric fie O P is

$$E = \frac{q}{4\pi \in_0 r^2} \qquad \ldots\ldots\ldots\ldots(1)$$

Now electric flux

$$\psi = \oint_s EdS\cos\theta$$

Putting value of E we get

$$\psi = \oint_s \frac{q}{4\pi \in_0 r^2} dS\cos\theta$$

$$\psi = \frac{q}{4\pi \in_0} \oint_s \frac{dS\cos\theta}{r^2}$$

$$\psi = \frac{q}{4\pi \in_0} \oint_s d\omega \qquad \because \frac{dS\cos\theta}{r^2} = d\omega$$

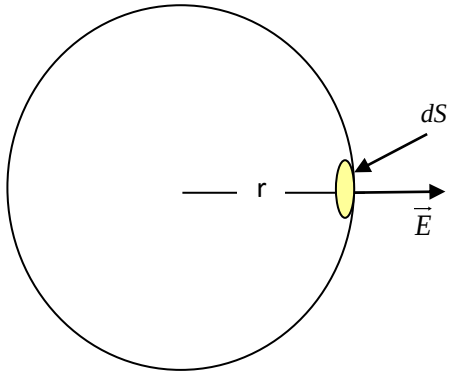
$$\psi = \frac{q}{4\pi \in_0} \cdot 4\pi \qquad \because Total \quad Solid \quad angle = 4\pi$$

$$\psi = \frac{q}{\in_0}$$

Hence $\boxed{\psi = \oint_s EdS\cos\theta = \frac{q}{\in_0}}$

Applications of Gauss's Law:
Electric field due to a point charge:

Consider a point charge q. We want to find electric field at point P at a distance of r from it. Construct a spherical surface of radius r. This is called as Gaussian surface. Consider small area dS on the surface. Let θ is angle between $\vec{E}$ and Area vector



Now flux

$$\psi = \oint_s EdS\cos\theta = \frac{q}{\epsilon_0} \qquad (\because\ \theta = 0)$$

$$\Rightarrow E\oint_s dS = \frac{q}{\epsilon_0}$$

$$\Rightarrow E.4\pi r^2 = \frac{q}{\epsilon_0} \qquad (\because \text{ Area of Sphere} = 4\pi r^2)$$

$$\Rightarrow \boxed{E = \frac{q}{4\pi\epsilon_0 r^2}}$$

Thus the electric intensity decreases with increase in distance.

CAPACITOR

It is a device used to store the charge .

Capacitance

The capacity of a capacitor to store charge

As potential is proportional to Charge

$$V \propto q$$

Or $$q \propto V$$

$$q = CV$$

$$C = \frac{q}{V}$$

Unit: Farad (F), microfarad

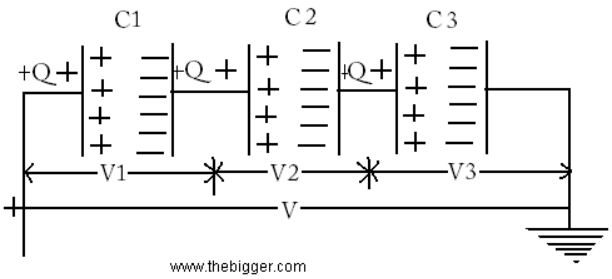
Grouping of Capacitors

<u>Series Grouping :</u>

A number of capacitors are said be connected in series if -ve plate of one capacitor is connected to the +ve plate of other capacitor and so on.

In this grouping charge is same on each capacitor.

Consider 3 capacitors of Capacitances C_1, C_2, C_3 in series. Let V is total applied voltage.
V_1, V_2, V_3 → voltage drops across C_1, C_2, C_3.



Then $V = V_1+V_2+V_3$ ---------- (1)

Now $C = \frac{q}{V} \rightarrow V = \frac{q}{C}$

So, $V_1 = \frac{q}{C_1}$, $V_2 = \frac{q}{C_2}$, $V_3 = \frac{q}{C_3}$

Putting in Equation (1)

$$\frac{q}{C} = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$$

$$\frac{q}{C} = q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

So the total capacitance decreases in series grouping.

Parallel Grouping:

A number of capacitors are said to be connected in parallel if +ve plate of each capacitor is connected to the +ve terminal of battery and –ve plate of each capacitor is connected to the –ve terminal of battery.

In this grouping voltage across each capacitor in same.

Consider 3 capacitors of capacitances C, C_2, C_3 connected in parallel let V is applied voltage.

q_1, q_2, q_3 → charges on capacitors C_1, C_2, C_3

So

$q = q_1 + q_2 + q_3$ ---------- (1)

Now $C = \frac{q}{V}$, $q = CV$

$\therefore$ $q_1 = C_1 V$, $q_2 = C_2V$, $q_3 = C_3V$

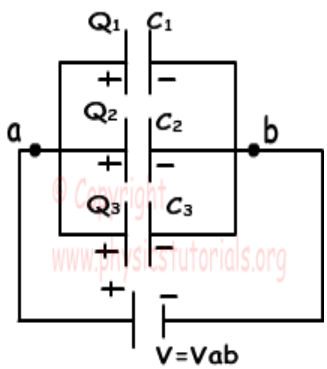
Put in equation (1)

$CV = C_1V + C_2V + C_3V$

$CV = (C_1 + C_2 + C_3) V$

$C = C_1 + C_2 + C_3$

So the total capacitance increases in parallel grouping.



Numerical Problems :-

1. Calculate the coulomb force between two protons separated by a distance of 1.6×10^{-15} m.

Solution:-

q1 = q2 = 1.6×10^{-19}C

r = 1.6×10^{-15}m

Also $\frac{1}{4\pi Eo} = 9x10^9 \ Nm^2/C^2$

Now $F = \frac{1}{4\pi Eo}\frac{q_1 q_2}{r^2}$

$$F = \frac{9x10^9 x1.6\times10^{-19} x1.6x10^{-19}}{\left(1.6x10^{-15}\right)^2}$$

F = 90 Newton

2. Calculate the force between on alpha particle and a proton separated by $5.12x\ 10^{-15}$m.

Solution :

q_1 = Charge on alpha particle

= $2 \times 1.6 \times 10^{-19}$ C

q_2 = Charge on proton

=1.6×10^{-19} C

r = 5.12×10^{-15} m

$\frac{1}{4\pi Eo} = 9x10^9 \ Nm^2/C^2$

Now

$$F = \frac{1}{4\pi Eo}\frac{q_1 q_2}{r^2}$$

$$F = \frac{9x10^9 x3.2\times10^{-19} x1.6x10^{-19}}{\left(5.12x10^{-15}\right)^2}$$

F = 17.58 Newton

3. Three Capacitors of capacitances 3μF, 2μF and 4μF are connected with each other calculate total capacitance (a) In Series grouping (b) Parallel grouping.

Solution:

C_1 = 3μF, C_2 = 2μF and C_3 = 9μF

In Series grouping

$$\frac{1}{C_{tot}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\frac{1}{C_{tot}} = \frac{1}{3} + \frac{1}{2} + \frac{1}{9}$$

$$= \frac{17}{18}\mu F$$

$$\therefore C_{tot} = \frac{18}{17} = 1.06\mu F$$

In Parallel grouping

$$\therefore C_{tot} = C_1 + C_2 + C_3$$

$$C_{tot} = 3 + 2 + 9$$

$$C_{tot} = 14\ \mu F$$

4. Three capacitors 1F, 2F, and 3F are joined in series first and then in parallel calculate. The ratio of equivalent capacitance in two cases.

Solution:

$C_1 = 1$ F, $C_2 = 2$F, $C_3 = 3$F

In series grouping

$$\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\frac{1}{C_S} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3}$$

$$\frac{1}{C_S} = \frac{11}{6}$$

$$\therefore Cs = \frac{6}{11}F$$

In Parallel grouping

$$Cp = C_1 + C_2 + C_3$$

$$Cp = 1 + 2 + 3$$

$$Cp = 6F$$

$\therefore$ Ratio $\frac{Cp}{C_S} = \frac{6}{\frac{6}{11}}$

$$\therefore \frac{Cp}{C_S} = 11$$

Conservation of Change

Charge conservation is the principle that total electric charge in an isolated system never changes. It always remains constant. This also means that no net charge can be created or destroyed. When an atom is ionized, equal amounts of positive and negative charges are produced. Hence the algebric sum of charges before and after remains the same.

EXERCISE:

1. SI unit of charge is _____ (Columb/ Volt)
2. Formula for capacitance is _____.
3. The law governing force between electric charge is _____ (Gauss Law/ Coulomb's law)
4. Path traced by a test charge in an electric field is called_____.
5. Farad is the unit of _____ (capacitance/ electric potential)
6. Three capacitors of 2μF are joined in parallel, their resultant capacitance is _____ (6μF/ 10rF)
7. Unit of electric intensity is _____ (N/ Coulamb Joule)
8. Electric Intensity is a _____ quantity (scalar or vector)
9. Two capacitors of 2 farad area joined in series their resultant is _____ (one farad/ four farad).
10. Air and paper are _____ (insulators/ Dielectric)

Very Short Answer Questions

Define the Following terms

1. Electric Field
2. Electric Line of force
3. Capacitance
4. Electric flux
5. Capacitor
6. Electric Potential
7. Electric Intensity

Short Answer Question

1. State and Explain Coulomb's Law
2. Derive expression for electric intensity at a point due to point charge.
3. Explain properties of electric lines of force.
4. Calculate total capacitance in series combination.
5. Calculate total capacitance in parallel combination
6. Explain Gauss's law
7. Write Note on Electric Charge and Conservation of Charge.

Long Answer Type Question

1. Calculate total capacitance when capacitors are connected in series and parallel grouping.
2. State and prove Guass's Law.

Chapter 10: CURRENT AND ELECTRICITY

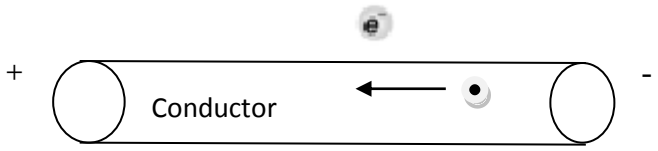
10.1 ELECTRICITY

We know in a conductor there are many free electrons. These electrons are always in motion but there is no net motion along the conductor. But if the two ends of a conductor are at different potentials, the charge will start flowing from one end of conductor to the other end. Therefore, the free electrons (charge) which were moving randomly will now move towards positive terminal of the battery and constitute a current. Hence a potential difference is always needed to make charge move from one end of the conductor to the other end of the conductor.

10.2 ELECTRIC CURRENT AND ITS UNITS

In a conductor the motion of the free electrons give rise to the electric current.

DEFINITION



Electric current passing through a conductor is the rate of flow of charge passing through any of its cross sections.

If a charge of q units passes through any cross section of the conductor in t seconds. The current flowing through the wire(I) is given by the formula

$$I = \frac{q}{t} = \frac{charge}{time}$$

Where I = the electric current
q = charge
t = time taken

UNIT OF CURRENT = Ampere In the relation

$$I = \frac{q}{t}$$

If the charge is mesasured In coulumbs and time is measured in seconds then the unit of current will be ampere

Where 1 ampere (A) $= \frac{1\ coulomb}{1\ sec}$

The direction of current is the direction of flow of positive charge i.e. opposite to the direction of flow of electron.

DEFINITION OF ONE AMPERE

The current flowing through the conductor is said to be of One Ampere if one coulomb of charge flows through the conductor in one second.

10.3 POTENTIAL DIFFERENCE (V)

It is the difference in electric potential between two points in an electric field, the work that has to be done in transferring unit positive charge from one point to other measured in volts

UNIT of Potential Difference is Volts (V)

10.4 RESISTANCE (R)

The opposition to the flow of electric current in a conductor is called resistance. Therefore, It is the measure of the difficulty to pass an electric current through the conductor.

Symbol

Formula RESISTANCE $R = \frac{V}{I} = \frac{Ptential\ difference}{Electric\ current}$

Units of Resistance = ohms (Ω)

In the relation $R = \frac{V}{I}$

If V is measured in volts and I is measured in amperes then the resistance R is measured in ohms.

DEFINITION OF One Ohm

$$1 \text{ ohm} = \frac{1\ Volt}{1\ Ampere}$$

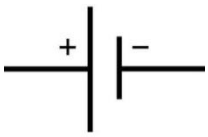
Therefore, one ohm is the resistance of conductor in which a current of one ampere flows through it when the potential difference of one volt is maintained between its two ends.

10.5 DIRECT CURRENT

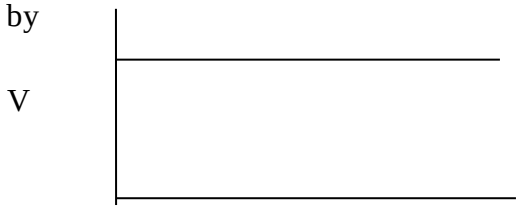
Direct current in an electric wire is that which flow in only one direction. It is the unidirectional flow of current. The electric current flowing through a semi conductor diode is an example of direct current. Direct current (DC) is produced by sources such as batteries, fuel cells and solar cells and cannot travel over long distances since it has more loss of energy.

The frequency of DC is zero and it has a single polarity. In direct current the electron flow from negative end of the battery to the positive end of the battery.

Symbol of DC voltage source



It can be shown by



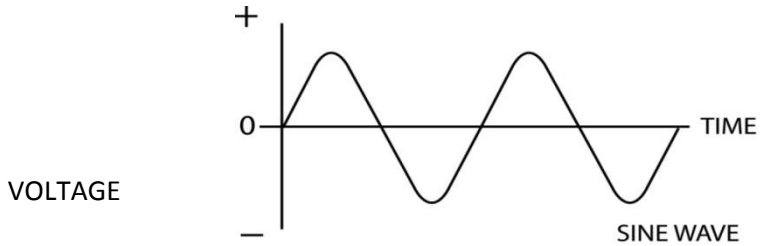
DC form is used in low voltage apparatus like charging batteries, cell phones, automotive apparatus, aircraft apparatus and other low voltage low current apparatus.

10.6 AC (Alternating current)

AC is current that reverses the direction periodically and also has a magnitude that varies continuously with time.

AC is used in our homes. Power stations generate ac because it is easy to lower and raise the voltage with the help of transformers.

In North America the frequency of AC is 60 Hz and in India it is 50 Hz. The AC in our home is sinusoidal in nature.



The radio frequency current in antennas and transmission lines are the examples of AC.

SYMBOL of AC

It is produced by an alternator and has more power and can be easily transferred from one place to another.

10.7 SPECIFIC RESISTANCE (DEFINITION AND UNITS)

LAWS of RESISTANCE

The resistance of a conductor depends on following factors

1. Length (l)

   Resistance of a uniform conductor depends on the length of the conductor. As the length of the conductor increases the resistance also increases.

   Resistance (R) of the conductor is directly proportional to its length(l)

   $$R \ \alpha \ l \qquad \text{---------- 1}$$

2. Area of Cross Section (a)

   Resistance of a condunctor depends on its area of cross section(a). As the area of cross section of the conductor increases the resistance decreases. Resistance (R) of a conductor is inversely proportional to its area of cross section(a).

   $$R \ \alpha \ \frac{1}{a} \qquad \text{----------2}$$

3. Nature of material

   The resistance of a conductor depends on the nature of the material.

   Combining equation 1 and 2 above we get

   $$R \ \alpha \ \frac{l}{a}$$

   $$R = \rho \frac{l}{a}$$

Where ρ is the constant of proportionality and depends upon the nature of the material of the conductor

ρ is called specific resistance or resistivity

$$\rho = R \frac{a}{l}$$

If we put A = 1 and l = 1 then we get

P = R

Therefore, specif resistance of material is equal to the resistance of the material of unit length having a unit area of crossection.

UNIT of ρ = ohm - meter

10.8 CONDUCTANCE (G)

It is the reciprocal of the resistance and it is a measure of ease with which the current flows through a substance.

$$G = \frac{1}{R}$$

Where G = Conductance

R = Resistance

UNIT of G = mho

10.9 OHM`S LAW

According to ohm's law "The **current flowing through a conductor is always directly proportional to the potential difference between the two ends if the physical condition (temperature etc) of the conductor remains the same**".

If I is the current passing through a conductor and and V is the potential difference between the ends of the conductor then

$$V \ \alpha \ I$$

$$V = I R$$

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

Therefore, $R = \frac{V}{I} = \frac{Potential\ Differnce}{Electric\ Current}$

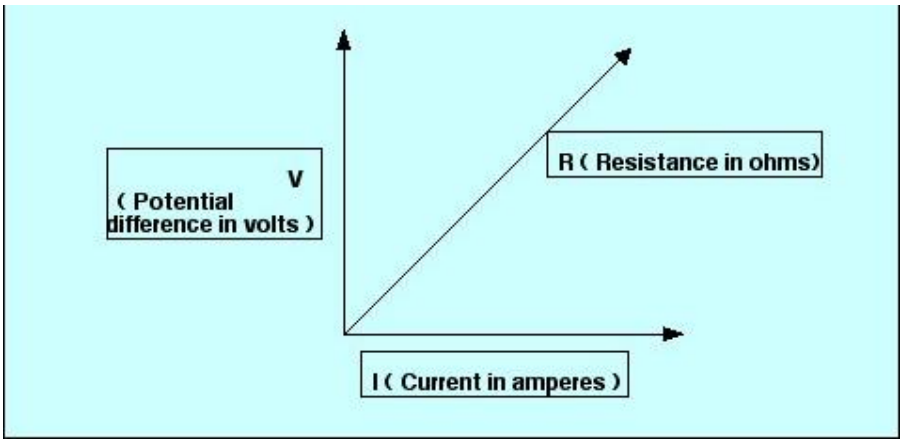
Where R is a constant and is called electric resistance.

The value of R depends upon nature, dimension and temperature of the conductor.

$$V = I R$$

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

If a graph is drawn between current (I) and the potential difference (V) it will be a straight line for a conductor.

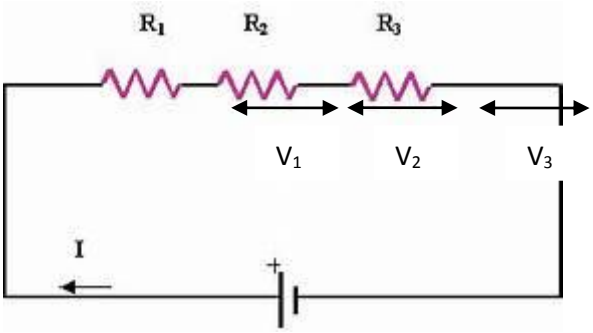


10.10 COMBINATION of RESISTANCE

1. Series combination

The resistance are said to be connected in series if the same current passes through all the resistances and the potential difference is different across each resistance.

Let three resistances R_1, R_2, R_3 be connected in series as shown in the figure below



Let

V = Voltage applied across the series combination

I = Current passing through the circuit

Clearly current I is same throughout the circuit

Let V_1, V_2, V_3 be the potential difference across R_1, R_2, R_3 respectively

The according to ohms law

or $V = I R$

Where R is the total resistance in series

Now

$V = V_1 + V_2 + V_3$ ----------(1)

Then by ohms law

$V_1 = I R_1$

$V_2 = I R_2$

$V_3 = I R_3$

Putting the values of V1, V2 and V3 in equation (1) we get

$I R = I R_1 + I R_2 + I R_3$

$I R = I (R_1 + R_2 + R_3)$

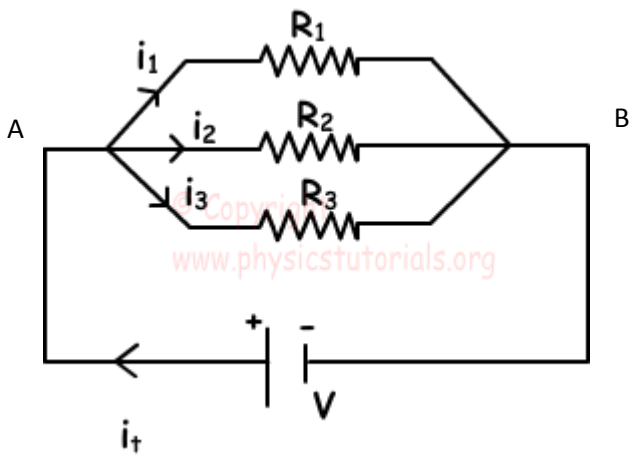
$R = (R_1 + R_2 + R_3)$

Thus the combined resistances when they are connected in series is the sum total of the individual resistances.

PARALLEL COMBINATION

The resistances are said to be connected in parallel if the potential difference across each resistance is the same but the current passing through each resistance is different.

Let there be three resistances R_1, R_2, R_3 connected in parallel as shown in figure below



One end of each resistance is connected to point A and the other end of each resistance is connected to the point B.

Let

V = Potential Difference applied across A and B

Clearly, potential difference V is same across each resistances.

Let I = total current flowing in the circuit.

R = total resistance of the circuit

Let I_1, I_2, I_3 be the current passing through the resistances R_1, R_2, R_3 respectively

From ohms law applied to the whole circuit

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

By ohms law

$$I_1 = \frac{V}{R_1}$$

$$I_2 = \frac{V}{R_2}$$

$$I_3 = \frac{V}{R_3}$$

Now we have,

$$I = I_1 + I_2 + I_3 \quad \text{----------} (1)$$

Putting the values of I, I_1, I_2, I_3 in the equation (1)

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$V\left(\frac{1}{R}\right) = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Thus we can say that if the resistances are connected in parallel, then the reciprocal of the total resistance is equal to the sum of reciprocals of individual resistances in the circuit.

10.11 HEATING EFFECT OF ELECTRIC CURRENT

When an electric current is passed through a conductor, the conductor becomes hot after some time and produce heat. This happens due to the conversion of some electric energy

passing through the conductor into heat energy. This effect of electric current is called heating effect of current.

The heating effect of current was studied experimentally by Joule in 1941. After doing his experiments Joule came to the conclusion that the heat produced in a conductor is directly proportional to the product of square of current (I^2), resistance of the conductor (R) and the time (t) for which current is passed . Thus,

$$H \ \alpha \ I^2RT$$

DERIVATION OF FORMULA

To calculate the heat produced in a conductor, consider current I is flowing through a conductor AB of resistance R for time t. Also consider that the potential diffence applied across its two ends is V.

Now, total amount of work done in moving a charge q from point A to point B is given by:

$$W = q \times V \quad \text{---------- (1)}$$

Now, we know that charge = current x time

Or $q = I \times t$

And $V = I \times R$ (ohm's law)

Putting the values of q and V in equation (1), we get

$$W = (I \times t) \times (I \times R)$$

Or $W = I^2RT$

Now, assuming that all the work done is converted into heat energy we can replace symbol of 'work done' with that of 'heat produced'. So,

$$H = I^2 RT$$

APPLICATIONS OF HEATING EFFECT OF CURRENT

The heating effect of current is used in various electrical heating appliances such as electric bulb, electric iron, room heaters, geysers, electric fuse etc.

10.12 ELECTRIC POWER

Electric power is the rate per unit time at which electric energy is transferred by an electric circuit.

Let P = Electric power

$P = W/t$

$P = V I$

Where

V = voltage

I = current

SI unit of power = Volt

Now

$P = V I$

If

P = 1 Watt

V = 1 Volt = 1 V

I = 1 Ampere = 1 A

Then 1 watt is said to be power of the circuit if a potential difference of 1 volt causes 1 ampere of current to flow through the circuit.

Bigger units of electric power are

Kilo Watt (KW) and Mega Watt (MW)

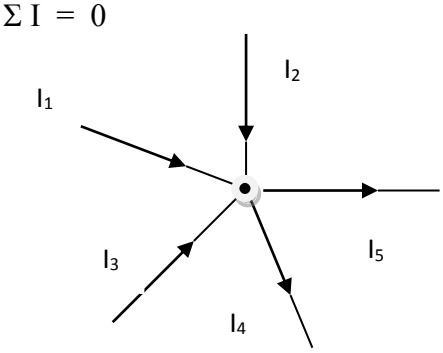
10.13 KIRCHHOFF LAWs

These two rules are commonly known as : Kirchhoffs circuit laws with one of Kirchhoffs laws dealing with the current flowing around a closed circuit, Kirchhoffs Current law (KCL) while the other law deals with the voltage sources present in a closed circuit, Kirchhoffs Voltage law, (KVL).

KIRCHHOFFS FIRST LAW (KIRCHHOFFS CURRENT LAW) KCL

The law states that " The algebraic sum of all the currents meeting at any junction point in an electric circuit is zero"

$$\Sigma I = 0$$



Let us suppose the currents I_1, I_2, I_3 entering the junction are all positives in value and the two currents I_4, I_5 are leaving the junction are negative in values, then according to KCL

$$I_1 + I_2 + I_3 - I_4 - I_5 = 0$$

$$I_1 + I_2 + I_3 = I_4 + I_5$$

Sum of incoming currents = sum of outgoing currents

KIRCHHOFFS SECOND LAW (KIRCHHOFFS VOLTAGE LAW) KVL

The law states that "In any closed loop of a circuit, the algebraic sum of products of the resistances and currents plus the algebraic sum of all the emf in that circuit is zero."

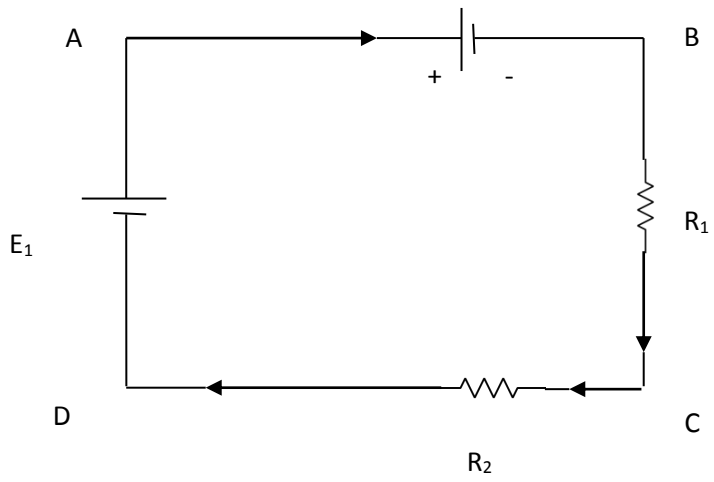
In any closed circuit

$$\Sigma E + \Sigma I R = 0$$

Here we use two sign conventions.

1. If we go from negative terminal of the battey to the positive terminal then there is rise in potential and it is considered positive. And if we go from postitive terminal to negative terminal, there is fall of potential and it is considered as negative.
2. If we go with the current voltage drop is negative and if we go against the current the voltage drop is positive.

E_2



In the closed loop ABCD using KVL we get

$$- E_2 - IR_1 - IR_2 + E_1 = 0$$

<u>Numericals on ohms law</u>

Based on $V = I R$

Q1. An emf source of 6V is connected to a resistive lamp and a current of 2 amperes flows. What is the resistance of lamp?

Sol. $V = I R$ $R = V/I$

$V = 6v$

$I = 2A$

$R = 6/2$ **= 3ohms**

Q2. An electric fan has a resistance of 100ohms. And is plugged into potential difference of 220 V. How much current passes through the fan.

Sol. $I = V/R$

$R = 100$ ohms

$V = 220$ V

Therefore $I =$ **2.2 ampere**

<u>Numerials on</u> Series combination $R = R_1 + R_2 + R_3$

Parallel combination $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Q1. Calculate the total resistance if three resistances of 1 ohm, 2 ohm and 3 ohm are connected in series.

Sol. In series $\mathbf{R = R_1 + R_2 + R_3}$

$\mathbf{R_1 = 1ohm}$

$\mathbf{R_2 = 2\ ohm}$

$\mathbf{R_3 = 3\ ohm}$

therefore $\mathbf{R = 1} + 2 + 3 = 6$ ohm

Q2. Calculate the total resistance if three resistances of 4 ohm, 1 ohm and 6 ohm are connected in parallel.

Sol. $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

R_1 = 4ohm

R_2 = 1 ohm

R_3 = 6 ohm

$\frac{1}{R} = \frac{1}{4} + \frac{1}{1} + \frac{1}{6} = \frac{3 + 12 + 2}{12} = \frac{17}{12}$

Therefore $R = \frac{12}{17}$

Exercise

1. SI unit of electric potential is _____ (Ampere / Volt)
2. SI unit of electric current is _____ (Ampere / Watt)
3. The formula for ohms law is _____.
4. SI unit of resistance is _____
5. Conductance is reciprocal of _____(Resistance / current)
6. Two resistances R_1 and R_2 are connected in series. There equivalent resistance is _____.
7. Two resistances of two ohms each are connected in parallel. The resultant is _____.
8. $\Sigma E + \Sigma IR = 0$ is the formula for _____
9. SI unit of specific resistance is _____
10. Opposition to the flow of current is called _____(Current / Resistance)

Very short answer question

Define the terms and give the unit of following

a. Electric current
b. Resistance
c. Specific resistance
d. Conductance
e. Electric power

Short answer question

a. Explain Alternating current and Direct current
b. Calculate the total resistance when resistances are connected in series
c. Calculate the total resistance when resistances are connected in parallel
d. Explain ohms law
e. Explain heating effect of current
f. Write short note on electric power
g. Explain Kirchhoff laws

Long Answer type questions

1. Calculate the total resistance when resistances are connected in series and parallel.

NUMERICALS

a. If the resistance of a circuit is 12ohm and the current of 4 A passes through it calculate the potential difference. [Ans 48 v]
b. Electric fan takes a current of 0.5 amp when operated on a 200 V supply. Find the resistance. [Ans 440 ohms]
c. Calculate the total resistance when three resistances of 4 ohm, 8 ohm and 12 ohm are connected in series. [Ans 24 ohm]
d. Calculate the total resistance when resistances of 2 ohm and 2 ohm are connected in parallel. [Ans 1 ohm]
e. Calculate the power generated in a current of 2 A passes through a conductor having a potential difference of 220 V. [Ans 440 W]

Chapter 11: ELECTROMAGNETISM

Electromagnetism is the production of a magnetic field when current is passed through a conductor.

Magnetization (I):

Property of material to magnetize in magnetic field. It is given by Magnetic moment per unit volume of material.

Unit: Ampere/meter

Magnetic Intensity (H):

Capability of magnetic field to magnetize magnetic material

Magnetic Permeability:

It is property of material and defined as the degree to which magnetic lines of force can penetrate the medium.

Magnetic susceptibility (χ):

Property of material to get magnetize in magnetic field. It is given by ration of Magnetization and Magnetic Intensity.

$$X=I/H$$

TYPES OF MAGNETIC MATERIALS:

On the basis of behaviour of magnetic material in Magnetic field, the material is divided in to three category:

Diamagnetic materials:

The materials when placed in magnetic field, acquire magnetism opposite to the direction of magnetic field. The magnetic dipoles in these substances tend to align in opposition to the applied field tends to repel the external field around it.

- Diamagnetic substances have tendency to move from stronger to the weaker magnetic field.

- When rod of diamagnetic material id placed in magnetic field, it aligns perpendicular to the magnetic field.
- Permeability of diamagnetic material is < 1.

Ex: Gold, water, mercury, N_2, graphite, lead,

Paramagnetic materials:

Paramagnetic substances are those which get weakly magnetized when placed in an external magnetic field. These material shows week attraction in magnetic field. The magnetic dipoles in the Magnetic Materials tend to align along the applied magnetic field. Such materials show week feeble magnetization and the magnetization disappears as soon as the external field is removed.

- Permeability of diamagnetic material is > 1.
- The magnetization (**M**) of such materials dependent on the external magnetic field (**B**) and temperature T as:

$$M = C\frac{B}{T}$$

Where C= Curie Constant

Ex: Liquid oxygen, sodium, platinum, salts of iron and nickel.

Ferromagnetic materials:

Ferromagnetic substances are those which gets strongly magnetized when placed in an external magnetic field. They exhibit the strongest attraction in magnetic field. Magnetic dipoles in these materials are arranged into domains. These domains are usually randomly oriented and net magnetism is zero in the absence of magnetic field. When an external field is applied, the domains reorient themselves to reinforce the external field and produce a strong internal magnetic field that is along the external field.

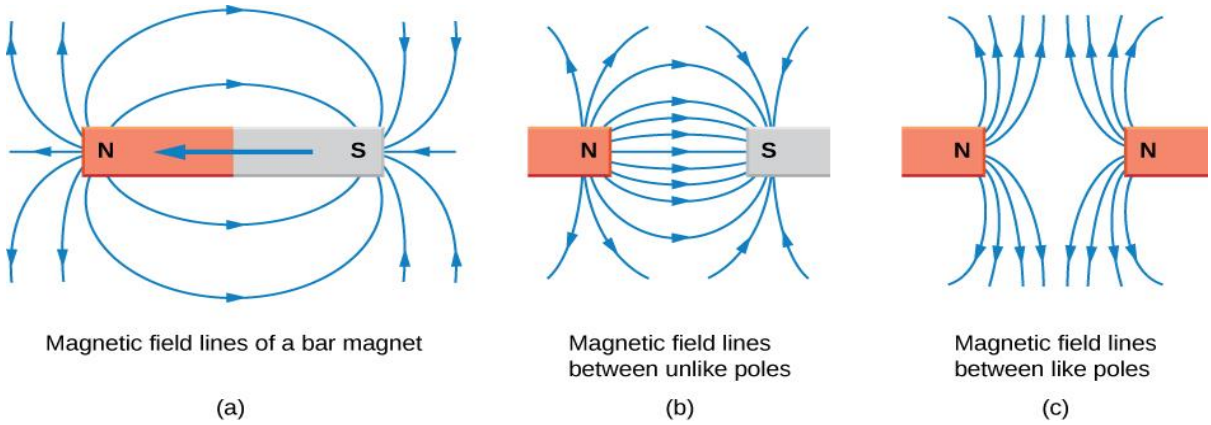
These material shows magnetism on removal of magnetic field.

Example: Iron, cobalt, nickel, neodymium and their alloys are usually highly ferromagnetic and are used to make permanent magnets.

Magnetic field:

The space around a magnetic material or a moving electric charge within which the force of magnetism can be experienced.

Unit: Tesla (Wb/m^2)



The magnetic lines of force:

Curved **lines** used to represent a **magnetic** field, drawn such that the number of **lines** relates to the **magnetic** field's strength at a given point

Properties of magnetic lines of force

(i) The magnetic field lines of a magnet form continuous closed loops.
(ii) The tangent to the field line at a given point represents the direction of the net magnetic field B at that point.
(iii) Larger the number of field lines crossing per unit area, the stronger is the magnitude of the magnetic field B.
(iv) Their density decreases with increasing distance from the poles.
(v) The magnetic field lines do not intersect with each other.
(vi) They flow from the South Pole to the North Pole within a material and North Pole to South Pole in air.

Magnetic flux:

The total number of magnetic field lines crossing through given surface area held perpendicular to direction of magnetic field.

$$\phi = BSCos\theta$$

Unit: The SI unit of magnetic flux is the weber (Wb)

Magnetic intensity
(B): the amount of magnetic flux in a unit area perpendicular to thedirection of magnetic flow

Electromagnetic induction

The **induction** of an electromotive force by the motion of a conductor across a magnetic field or by a change in magnetic flux in a magnetic field. Is called **electromagnetic induction**.

It is used in electrical motor, generator etc.

Question

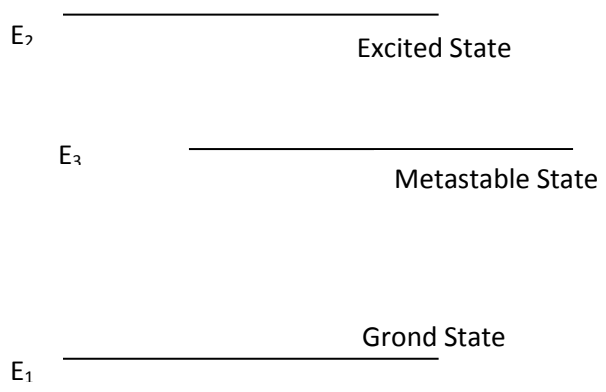
(i) Define magnetic flux and write its unit.
(ii) Define electromagnetic induction with example
(iii) Define magnetic field.
(iv) What is unit of magnetic field?
(v) What is magnetic susceptibility?
(vi) Write applications of EMI.
(vii) Define magnetic field intensity.
(viii) What are magnetic lines of force? Write their properties.
(ix) Explain type of magnetic materials with examples.

Chapter 12: SEMICONDUCTOR PHYSICS

Energy Level: - The electrons cannot revolve in any direction, and they are confined to well defined energy states, these states are called as energy level.

There are three type of energy level:

1. **Ground level:** This refers to the lowest energy state in the system (E_1). Thus the completely de-excited atoms would occupy this level.

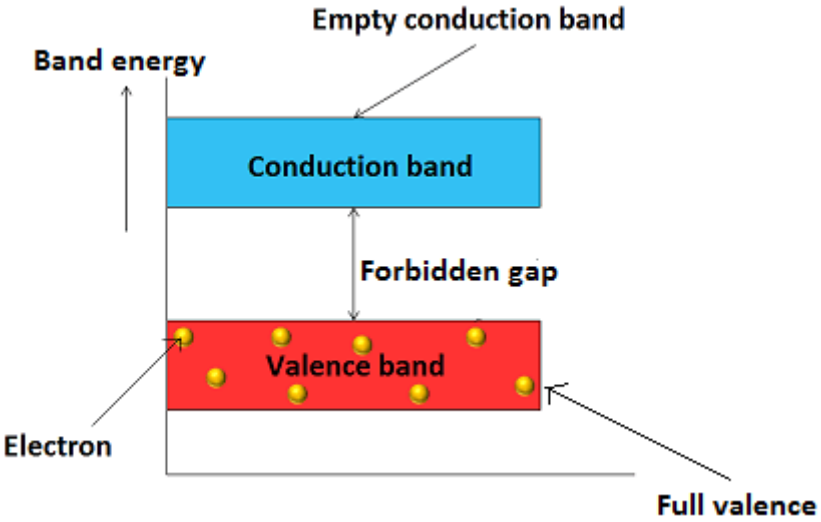


2. **Excited level:** any level above the ground state is excited state (E_2). The atom can stay in excited state only for 10^{-8} s. After this time the atom will lose its energy in the form of radiation and come back to ground state.

3. **Metastable level:** This level lies in between the excited and ground levels (E_3). Its lifetime is 100 times more than excited state.

Energy Band:

Now when two atoms are brought closer to form a solid, the energy levels get modified due to mutual interaction. Each energy level split into two level, one having energy higher than the original level another having lower energy.



Now when a large number atoms (n) comes closer to each other, each energy level splits into a large number (n) of levels. As a result a large number of discrete but closely spaced energy levels are formed. These are called Energy Bands. The inner shells however remain unaffected by neighbouring atoms. Because they are shielded by the outer electrons of their own atoms.

The highest energy band occupied by the valence electrons is called **the valence band**. Above this band there lays an empty band called the **conduction band.**

These bands are separated by an energy gap known as **Forbidden Gap (E_G).**

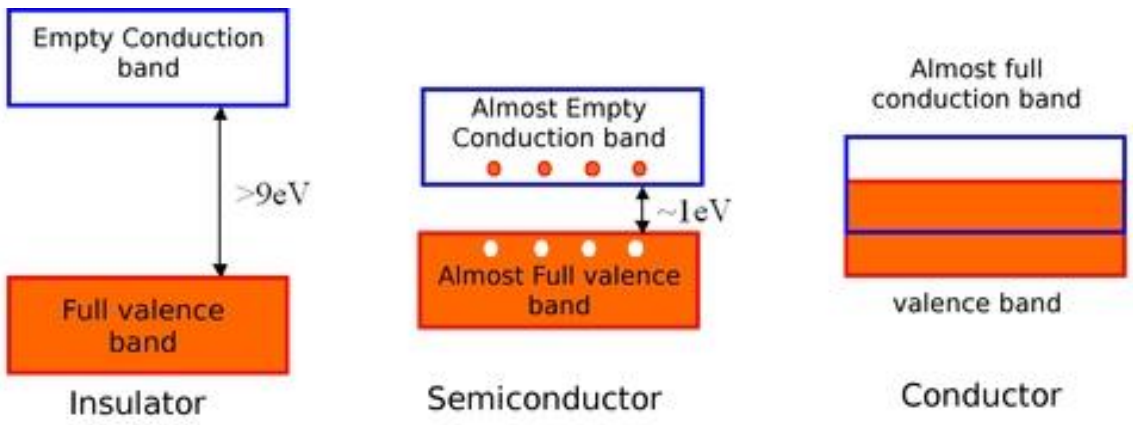
On the basis of the forbidden gap (E_G), the material can be divided into following categories.

Conductors:

Metals or good conductors are those substances which can conduct -heat and electricity through them easily as there are many free electrons.

In case of conductors $\mathbf{E_G = 0}$ i.e. valence band and the conduction band overlap each other.

e.g. Copper, Aluminum etc



Insulators: These are poor conductors of electricity. Forbidden gap is E_G = 5 - 6 eV.

The energy gap between valence band and conduction band is very large. Hence valence electrons will not be freed and no current will flow.

E.g. Paper, Wood, Plastic

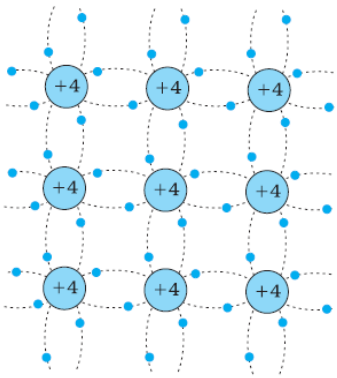
Semiconductors: The conductivity of a semiconductor lies between that of conductors and insulators. E_G = 1 -2 eV

At absolute zero of temperature, the conduction band is totally empty and there is no flow of current. But at the higher temperature, some valence electrons acquire sufficient energy to go in the conduction band. Hence, even a small electric field can cause a flow of current.

E.g. Silicon (Si) and Germenium (Ge).

INTRINSIC AND EXTRINSIC SEMI CONDUCTORS

Intrinsic Semi Conductors: A semiconductor, which is quite pure and completely free from any impurity, is called an intrinsic semiconductor. E.g. Silicon (Si) and Germenium (Ge).



They have four valence electrons. Each of the four-electrons form *covalent bond* with neighboring four atoms. By forming such covalent bonds, there is no free electron at absolute zero temperature. At room temperature some electrons break away from the covalent bond and enter into the conduction band. Each electron leave behind a vacancy known as hole.

Hence in pure semiconductors both electrons and holes constitute current and the numbers of these two types of charge carriers are equal i.e. $n_e = n_h$

Extrinsic Semi Conductors

A doped semiconductor is called an extrinsic semiconductor.

The addition of a desirable impurity to a **semiconductor is called doping and the impurity** atoms added are called dopants.

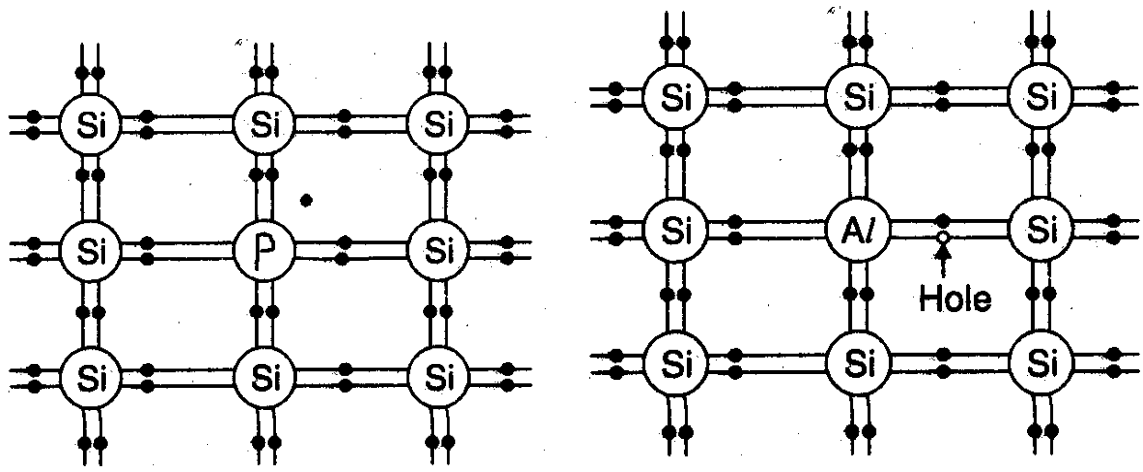
n-Type Semiconductor:

When a small amount of pentavalent impurity (e.g. phosphorous, Arsenic etc.) is added to an intrinsic semiconductor (Si or Ge), it provides a large numbers of free electrons. The semiconductor is then, called n-type semi conductor.

Because impurity atom has five valence electrons, four of these will form covalent bonds, but one excess electron will be left free. Hence the current carriers are electrons. Therefore majority carriers are negatively charge electrons while the holes are minority carriers.

In an n-type semiconductor, number of electrons is much larger than the number of holes.

Thus $n_e >> n_h$



n-type **p-type**

p-Type Semiconductor

When a small amount of trivalent impurity (e.g. Boron, Aluminum etc.) is added to intrinsic semiconductor, it creates a large number of holes in valence band. The semiconductor is called a p-type semiconductor.

When a trivalent impurity is added to semiconductor, its three valence electrons form covalent bonds with three neighbouring atoms, while the fourth bond has a deficiency of electron. Thus there is a vacancy, which acts as a hole that tends to accept electrons.

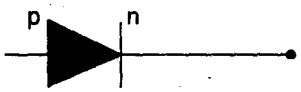
The number of holes is greater than the number of electrons

$$i.e.\ \ n_h >> n_e$$

Hence, in p-type semiconductors, holes are the majority *carriers* and electrons arc the minority carriers.

p-n JUNCTION DIODE

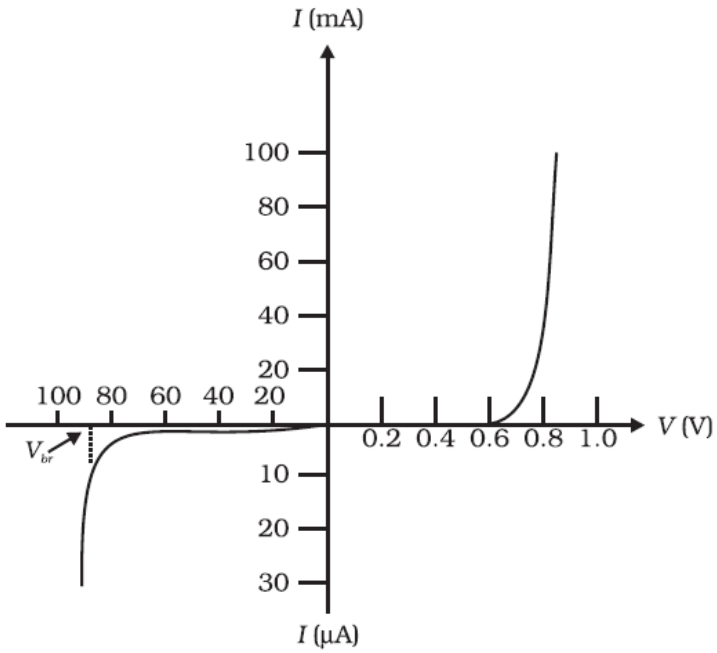
A single crystal of silicon or Germenium that has been doped in such a way that half of it is a p-type and the other half an n-type semi-conductor is known as a p-n junction diode. The junction is called p-n junction.



CHARACTERISTICS OF A p-n JUNCTION DIODE

The graph showing the variation of the current flowing through the junction, when the voltage is applied across the junction diode in forward biased and reverse biased, is known as characteristic curve of a p-n junction diode.

Forward bias characteristic: The p-n junction diode is said to be forward biased if the positive terminal of battery is connected to the p-type and the negative terminal to the n-type of semiconductor.



Let V is the voltage applied. This pushes the majority carriers, the holes in the p-type and electrons in the n-type towards the p-n junction.

If V > V_B, then the majority carriers from both sides are able to diffuse across the junction and a current is set up in the circuit. This process decreases the thickness of the depletion layers. The diode offers a low resistance to the flow of current.

A minimum amount of voltage required so that a current start flowing is known as the knee voltage. The current starts following at point A (knee voltage).

Reverse bias characteristic:

The p-n junction diode is said to be reverse biased if the negative terminal of the external source is connected to the p-type and the positive terminal to the n-type of semiconductor.

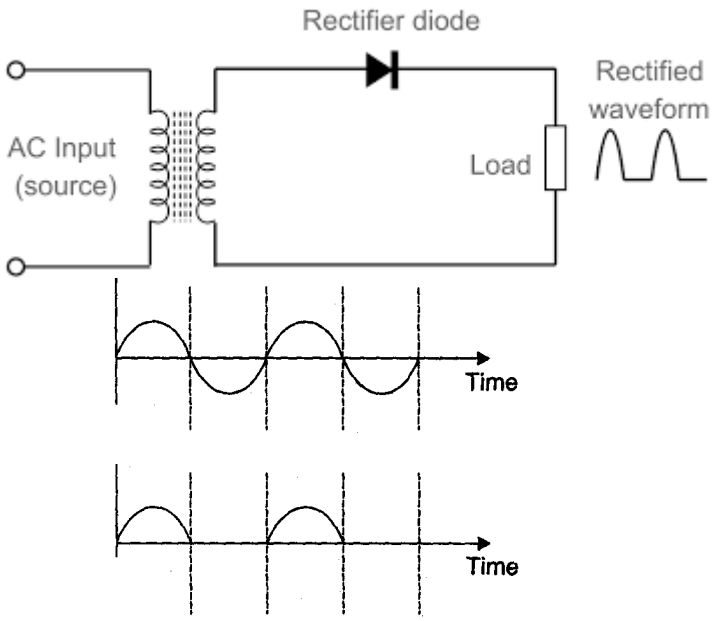
The external voltage pulls the majority carriers holes in the p-type crystal and the electrons in the n-type crystal away from the junction. This increases the width of depletion layer. The diode offers very high resistance and no current is set up across the Junction due to majority carriers. However a small current may be there across the junction due to minority carriers. It is called leakage *current.*

DIODE AS A RECTIFIER

The rectifier is an electronic device used to convert alternating current (AC) into direct current (DC).

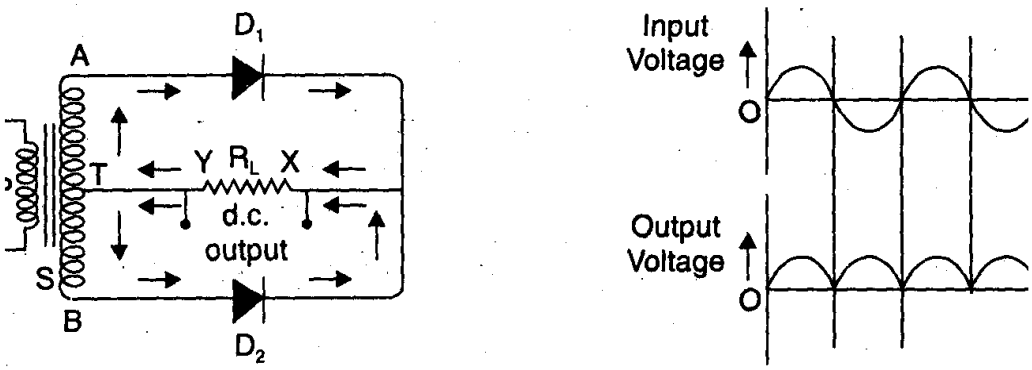
Half wave rectifier:

Half wave rectifier convert AC in to DC for only half of the input cycle. The circuit diagram for half wave rectifier using the p-n diode is as shown. During the first half cycle of AC the diode operates under a forward bias and current flows through the load R_L. During the other half, the diode becomes reverse bias and no current flows through the load R_L. Thus we get a rectified, unidirectional current across R_L and only half of the AC signal wave is rectified. The half wave rectifier gives output only for half cycle, hence power loss is high.



Full wave rectifier:

Full wave rectifier converts AC in to DC for complete cycle of input wave. The circuit diagram for full wave rectifier is shown. The Center tap transformer is used. Two diodes are connected across the secondary of the transformer, the middle point of which is tapped at T. During the first half of the AC cycle, one end of the secondary say A becomes positive and B becomes negative. Diode D_1 is forward biased and diode D_2 is reverse bias. Thus a current flows through the diode D_1.

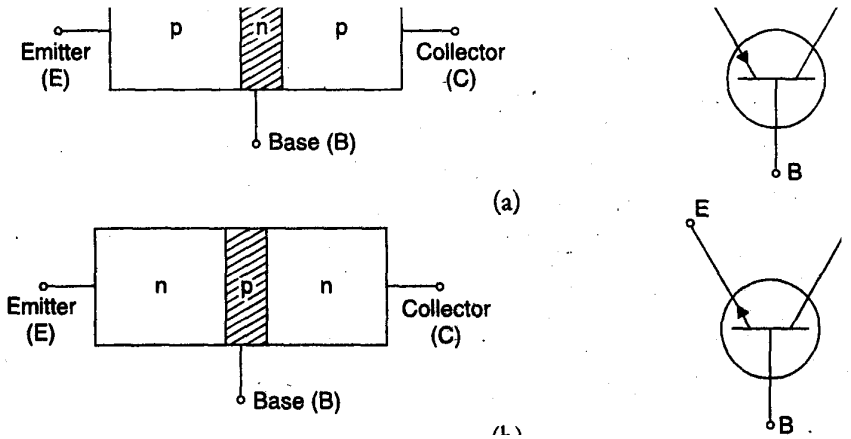


During the other half of AC cycle, end B becomes positive and the end A negative and the current flows through the diode D_2. Thus during both halves, the current through the load R_L is in the same direction and full wave rectification of AC is achieved.

Junction Transistor

The transistor is composed of three semiconductor elements. The three elements are combined in such a way that if n-type semiconductor is sandwiched between two p-type semiconductors. This is known as p-n-p transistor.

If p-type semiconductor is sandwiched between two n-type semiconductors then this is known as n-p-n transistor. In the circuit symbols of a transistor, only emitter has an arrow to indicate that it is the supplier electrode.



- The three elements of the transistor are the emitter (E), the collector (C) and the base (B).
- The emitter supplies the majority carriers for transistor current flow. The collector collects current and the base controls the passage of electrons from the emitter to collector.
- The doping level in the emitter is more than in the collector.
- The base is thin and lightly doped.
- In normal operation of a transistor, the emitter-base junction is always forward-biased whereas the collector-base junction is reverse-biased.

Effect of temperature on semiconductors:

The resistivity of semiconductors decreases with increase in temperature. It has negative coefficient of resistivity.

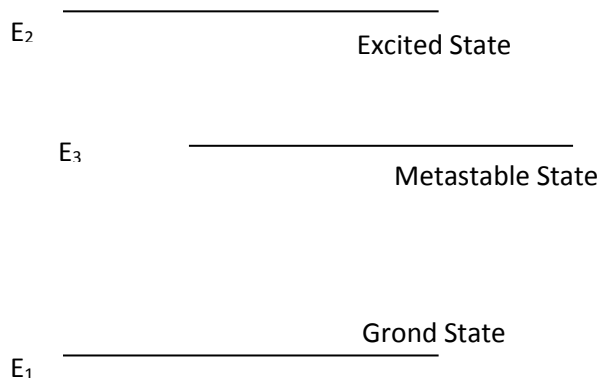
Chapter 13: Modern Physics

Laser means **Light Amplification by Stimulated Emission of Radiation**. The laser beam is coherent, monochromatic, highly directional and very intense.

Energy Level: - The electrons cannot revolve in any direction, and they are confined to well defined energy states, these states are called as energy level.

There are three type of energy level:

2. **Ground level:** This refers to the lowest energy state in the system (E_1). Thus the completely de-excited atoms would occupy this level.



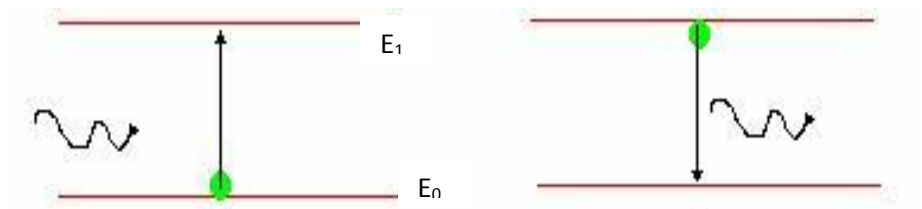
2. **Excited level:** any level above the ground state is excited state (E_2). The atom can stay in excited state only for 10^{-8} s. After this time the atom will lose its energy in the form of radiation and come back to ground state.

3. **Metastable level:** This level lies in between the excited and ground levels (E_3). Its lifetime is 100 times more than excited state.

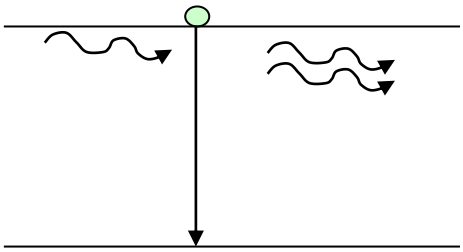
EMISSION

When a material is energized by some radiations, the atoms of the material get to the higher state from ground state. These exited atoms may loose energy and come back to ground state. The energy loss may be in the form of heat, radiation, light etc. This process may takes place in two ways.

Spontaneous Emission: when the atoms in excited state (E_1) comes back to ground state (E_0) after 10^{-8} seconds, without any external radiation. The emission of light in this process is called spontaneous emission. The atoms in excited state, release radiation of energy $h\nu = E_1 - E_0$ in the form of photons. These photons are emitted in a random direction



Stimulated Emission:



If before the spontaneous emission takes place, the excited atom is irradiated with a photon is energy hv = E_1 - E_0. Then the excited atom will loose the energy in the form of a photon. This process takes play in such a way that the incident photon and the emitted photon are found to be moving with same momentum and phase. This kind of emission is called stimulated emission.

POPULATION INVERSION:

When the number of atoms in excited state (N_2) becomes more than the number of atoms in ground state (N_1), this condition is known as Population Inversion. This condition is must for stimulated emission.

CHARACTERISTIC OF LASER

Laser light has four unique characteristics that differentiate it from ordinary light:

Coherence

The photons emitted from ordinary light sources have different phases and hence non-coherent. While in Laser all the photons have same phase or constant phase difference. Thus the Laser light is highly coherent in nature. Because of this coherence, a large amount of power can be concentrated in a narrow space.

Monochromatic

In laser, all the photons emitted have the same frequency, or wavelength. Hence, the laser light has single wavelength or color. Therefore, laser light covers a very narrow range of frequencies or wavelengths. Hence the Laser light is monochromatic.

Directionality

In ordinary light sources (lamp, torchlight), photons will travel in random direction. Therefore, these light sources emit light in all directions.

But, in laser, all photons will travel in same direction. Therefore, laser emits light only in one direction. This is called directionality of laser light. Hence, a laser beam can travel to long distances without spreading.

If an ordinary light travels a distance of 2 km, it spreads to about 2 km in diameter. On the other hand, if a laser light travels a distance of 2 km, it spreads to a diameter less than 2 cm.

High Intensity

In laser, the light spreads in small region of space and in a small wavelength range. Hence, laser light has greater intensity when compared to the ordinary light.

Thus, even a 1 Watt laser would appear many thousand times more intense than 100 Watt ordinary lamp.

Application:

1. **Laser welding:** laser welding can be used for **Spot welding, Seam welding, Inert gm laser welding and Welding of Non-metal matels**
2. **Laser cutting:** Metals can be cut with output power of at least 100 W to 500 W. Wide range of materials can be cut e-g. paper, cloth, plywood, glass, ceremics, sheet metal like steel, titanium, aluminium etc.
3. Laser is used for fine drilling
4. Lasers are used for accurate measurement of the order of 0.1 m to the extent of distant object.
5. Laser is used to produce thermonuclear fusion.
6. To study the chemical process, nature of chemical bonds, structure of molecule and scattering.
7. Long distance communication by using optical fibre and laser is very efficient.
8. Used to study many biological samples, treatment of lever and to remove tumer.
9. Laser is used for printing. Laser printers are very fast and efficient. The quality is very high.
10. In computer we use laser disc. In CD writer a tinny laser beam burns spot on the compact disc.

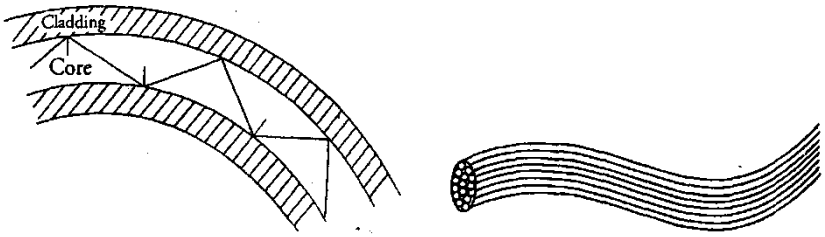
OPTICAL FIBRE

An optical fibre consists of a very thin core made of glass or silica having a radius of the order of a micrometer (10^{-6} m). This is covered by a thin layer cladding material of lower refractive index. Such optical fibres can transmit a light beam from one end to the other without any energy loss.

The branch of physics dealing with the propagation of light through an optical fibre is known as **fibre optics.**

Principle: it is based upon total internal reflections at the glass or silica boundary, even if the fibre is bend or twisted.

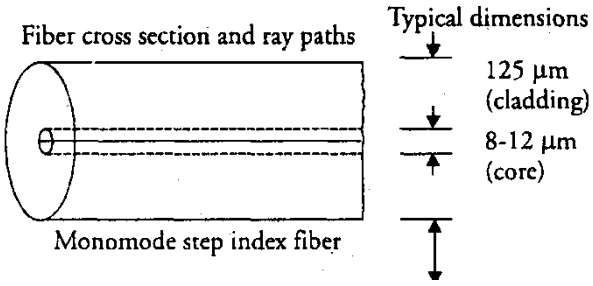
If ray of light travelling from a denser medium into an rarer medium, and the angle of incidence is greater than the critical angle, the ray is totally reflected back into the same media. This phenomenon is called as **total internal reflection.**



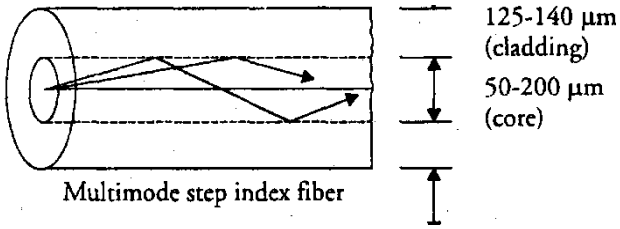
FIBRE TYPES

On the basis of mode of propagation the fibre can be divided as

Monomode fibre: has a very narrow core of diameter about 8-12 µm or less and the cladding is relatively big 125 µm. As the name implies, monomode fibre sustains only one mode of propagation that is why it is also known as single mode fibre.



Multimode fibre: has a core of relatively large diameter such as 50-200 µm. As the name suggests the multimode fibre contain many hundred of modes of propagation simultaneously. The signals do not intermix with each other. This is most commonly used optical fibre.



APPLICATIONS OF OPTICAL FIBRE

With the help of light pipe it is possible to examine the inaccessible parts of equipment or of the human body. For example, a patient's stomach can be viewed by inserting one end of a light pipe into the stomach through mouth.

Optical fibres are also used for transmitting and receiving electrical signals that are converted to light by transducers.

They are used to transmit communication signals. For example, about 2000 telephone signals, approximately mixed with light waves, may be simultaneously transmitted through a typical optical fibre.

The clarity of the signals transmitted with optical fibres is much better than other conventional methods.

Optical fibres are also being extensively used for local area networks (LAN).

NANOTECHNOLOGY

The branch of technology that deals with dimensions and tolerances of less than 100 nanometres, especially the manipulation of individual atoms and molecules.

NANOMATERIALIS:

The material with any dimension in the nanoscale (1 nm to 100 nm). They exhibit unique physical, chemical and biological properties due to high surface-to-volume ratio.

Example: carbon nanotube, nanoparticle, metal rubber, nano shell, quantum dots, nanopores, nanorod, nanotube, nanopowder, fullerene, etc.

Applications of Nanotechnology

Nanomaterials are of interest because of their unique optical, magnetic, electrical, and other properties. These emergent properties have the potential for great impacts in electronics, medicine, and other fields

- **Medicine**: Nanotechnology is being used to treat disease and prevent health issues, as customized nanoparticles that can deliver drugs directly to diseased cells in your body. For example, nanoparticles that deliver chemotherapy drugs directly to cancer cells are under development.
- **Electronics:** electronics devices with nano-technique help in reducing weight and power consumption. This also improves display screens on electronics devices and increasing the

density of memory chips. Nanotechnology can also reduce the size of transistors used in integrated circuits.

- **Food**: developing nanomaterials that will make a difference not only in the taste of food, but also in food safety, and the health benefits that food delivers.
- **Fuel Cells:** Nanotechnology is being used to reduce the cost of catalysts used in fuel cells to produce hydrogen ions from fuel such as methanol and to improve the efficiency of membranes used in fuel cells
- **Solar Cells:** nanotech solar cells that can be manufactured at significantly lower cost than conventional solar cells.
- **Space:** Advancements in nanomaterials make lightweight spacecraft and a cable for the space elevator.
- **Fuels:** Nanotechnology can be used for making the production of fuels from low grade raw materials which is economical and increasing the mileage of engines.
- **Catalyst:** made from nanoparticles have a greater surface area to interact with the reacting chemicals than catalysts made from larger particles. The larger surface area allows more chemicals to interact with the catalyst simultaneously, which makes the catalyst more effective.
- **Chemical Sensors:** Nanotechnology can enable sensors to detect very small amounts of chemical vapors. Various types of detecting elements, such as carbon nanotubes, zinc oxide nanowires can be used in nanotechnology-based sensors.
- **Fabric:** Making composite fabric with nano-sized particles or fibers allows improvement of fabric properties without a significant increase in weight, thickness, or stiffness
- **Environment:** Nanotechnology is being used in cleaning up existing pollution, improving manufacturing methods to reduce the generation of new pollution, and making alternative energy sources more cost effective.

Question

1. Define nanomaterials and give example.
2. Write four applications of nanomaterials.
3. What is size of namomaterial?
4. Give full form of LASER.
5. What is spontaneous and stimulated emission?
6. What is principle of Laser?
7. Define population inversion in Laser emission.
8. What is the principle of optical fibre.
9. Write four applications of Laser.
10. Write four applications of optical fibre.
11. What are the characteristic of Laser?