COURSE MATERIAL
ON
ENGINEERING PHYSICS

For

First Year Diploma Engineering Students
According To SCTE&VT Syllabus

Prepared by

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PREFACE

Engineering and technology would not exist without physics. Any technology involving energy (heat, light, sound, electromagnetic, mechanical),involves physics! All manufactured items originate in physics-based technology.

In Engineering Physics you will learn about the physics concepts that form the foundation of any mechanical design. To be an engineer, you not only have to be able to come up with the ideas, but you must also understand the physics behind those ideas so that you can design and manufacture a successful product.

This study material is designed to provide students in Pure & Applied Science who wish to study engineering or physical sciences at university with an enhanced background in order to improve their chances of success in their chosen program. The material will be presented using the normal mix of lectures and problem-solving sessions. Some useful data and information are given in the appendices.

I hope that the study material will prove helpful and will meet the needs of the students at undergraduate level.

Suggestions and criticisms for further improvement of the study material are most welcome.

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A BRIEF INTRODUCTION OF ENGINEERING PHYSICS

Physics is the study of the mechanical universe. It is the basic science that underlies all the natural sciences. It is a search for the basic rules of the behaviour of matter and energy on every scale: from the interaction of subatomic particles, to the motion of everyday objects, to the evolution of galaxies. Physics consists of many sub-fields, including particle and nuclear physics, atomic and molecular spectroscopy, optics, solid state physics, biological and medical physics, computational physics, acoustics, astrophysics and cosmology.

Engineering physics is the study of the combined disciplines of physics, engineering and mathematics in order to develop an understanding of the interrelationships of these three disciplines. Fundamental physics is combined with problem solving and engineering skills, which then has broad applications. Career paths for Engineering physics is usually (broadly) "engineering, applied science or applied physics through research, teaching or entrepreneurial engineering". This interdisciplinary knowledge is designed for the continuous innovation occurring with technology.

Unlike traditional engineering disciplines, engineering science/physics is not necessarily confined to a particular branch of science or physics. Instead, engineering science/physics is meant to provide a more thorough grounding in applied physics for a selected specialty such as optics, quantum physics, materials science, applied mechanics, nanotechnology, micro fabrication, mechanical engineering, electrical engineering, biophysics, control theory, aerodynamics, energy, solid-state physics, etc. It is the discipline devoted to creating and optimizing engineering solutions through enhanced understanding and integrated application of mathematical, scientific, statistical, and engineering principles.

It is a bridge between pure and applied science, utilizing fundamental concepts in today's rapidly changing and highly technical engineering environment. An engineering physicist is motivated by the application of science for advancing technology and sustainability. The program emphasizes the solid foundations of modern scientific principles, mathematical rigour, technical know-how in designing, building and doing experiments, the knowledge essential for a successful professional career in science and technology. The program is recommended for students interested in newly developing areas of physics, modern technology, instrumentation, and experimentation. It also enriches a student with analytical skills of mathematics and scientific reasoning; technical skills of design, construction and operation of systems including nanotechnology, space instrumentation, particle accelerators and more; leadership skills as engineering physicists are called to manage projects involving electrical, mechanical or chemical components and tasks. They tend to be versatile and adaptable to the projects as they evolve.

Undergraduate program in engineering science focuses on the creation and use of more advanced experimental or computational techniques where standard approaches are inadequate (i.e., development of engineering solutions to contemporary problems in the physical and life sciences by applying fundamental principles).The study of Engineering Physics emphasizes the application of basic scientific principles to the design of equipment, which includes electronic and electro-mechanical systems, for use in measurements, communications, and data acquisition.

The program is recommended for students interested in newly developing areas of physics, high technology, instrumentation and communications. Our program is fully accredited by the Canadian Engineering Accreditation Board so graduates will be eligible to be certified as a professional engineer. Graduates are also qualified for entry into graduate schools in Physics or other disciplines.

Engineering Physics Educational Outcomes:

- an ability to apply knowledge of mathematics, science, and engineering.
- an ability to design and conduct experiments, as well as to analyze and interpret data.
- an ability to function on multi-disciplinary teams.
- an ability to identify, formulate, and solve engineering problems.
- an understanding of professional and ethical responsibility.
- an ability to communicate effectively.
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and social context.
- a recognition of the need for, and an ability to engage in life-long learning.
- a knowledge of contemporary issues.
- an ability to use techniques, skills, and modern engineering tools necessary for engineering practice.
- knowledge of fundamental physical principles and their applications.
- an ability to use the computer to solve engineering physics problems.
- knowledge and application of advanced mathematics.

Engineering Physics offers a wide range of exciting opportunities for students who are curious about the way things work and who want to use their talents to make the world a better place. Engineers are inventors and problem-solvers. They use science and technology to find faster, better, and cheaper ways of doing things. They take ideas and raw materials and design machinery and systems that increase efficiency and productivity. They develop new products to simplify household tasks. They find new energy sources and ways to protect the environment. Almost everything we use today has been designed and produced by engineers.

Discoveries by physicists, like quantum phenomena and the theory of the Big Bang, have literally transformed have literally transformed our view of the natural world. Inventions like the transistor and the laser have fuelled the modern technological revolution. We can look forward to even more exhilarating breakthroughs in the future - a future that holds exciting opportunities for the physics students of today.

UNIT-1

UNITS & DIMENSIONS

Physical World

- **<u>Science</u>** means organized knowledge.

It is human nature to observe things and happenings around in the nature and then to relate them. This knowledge is organized so that it become well connected and logical. Then it is known as Science. It is a systematic attempt to understand natural phenomenon and use this knowledge to predict, modify and control phenomena.

Scientific Method

Scientific methods are used to observe things and natural phenomena. It includes several steps:

- Observations
- Controlled experiments,
- Qualitative and quantitative reasoning,
- Mathematical modeling,
- Prediction and
- Verification or falsification of theories.

There is no 'final' theory in science and no unquestioned authority in science.

- Observations and experiments need theories to support them. Sometimes the existing theory is unable to explain the new observations, hence either new theories are formed or modification is done in the existing theories.
- For example to explain different phenomena in light, theories are changed. To explain bending of light a new Wave-theory was formed, and then to explain photoelectric effect help of quantum mechanics was taken.

Natural Sciences can be broadly divided in three branches namely Physics, Chemistry and biology

- **<u>Physics</u>** is a study of basic laws of nature and their manifestation in different phenomenas.

Principal thrusts in Physics

- There are two principal thrusts in Physics;
- 1.Unification 2. reduction

<u>Unification</u>

- <u>Efforts are made to explain different phenomena in nature on the basis of one or minimum laws. This is principle of Unification.</u>

Example: Phenomena of apple falling to ground, moon revolving around earth and weightlessness in the rocket, all these phenomena are explained with help of *one* Law that is, Newtons Law of Gravitation.

- ***The scope of Physics*** can be divided in to two domains; Macroscopic and Microscopic.
- Macroscopic domain includes phenomena at the level of Laboratory, terrestrial and astronomical scales.
- Microscopic domain I ncludes atomic, molecular and nuclear phenomena.
- Recently third domain in between is also thought of with name Mesoscopic Physics. This deals with group of Hundreds of atoms
  - Scope of physics is very wide and exciting because it deals with objects of size as large as Universe (10^{25}m) and as small as 10^{-14} m, the size of a nucleus.

The excitement of Physics is experienced in many fields like:

- Live transmissions through television.
- Computers with high speed and memory,
- Use of Robots,
- Lasers and their applications

Physics in relation to other branches of Science

Physics in relation to Chemistry.

- Chemical bonding, atomic number and complex structure can be explained by physics phenomena of Electrostatic forces,
- taking help of X-ray diffraction.

Physics in relation to other Science

- Physics in relation to Biological Sciences: Physics helps in study of Biology through its inventions. Optical microscope helps to study bio-samples, electron microscope helps to study biological cells. X-rays have many applications in biological sciences. Radio isotopes are used in cancer.

Physics in relation with Astronomy:

- Giant astronomical telescope developed in physics are used for observing planets. Radio telescopes have enabled astronomers to observe distant limits of universe.
- Physics related to other sciences: Laws of Physics are used to study different phenomenas in other sciences like Biophysics, oceanography, seismology etc.

Physical Quantity.

A quantity which can be measured and by which various physical happenings can be explained and expressed in form of laws is called a physical quantity. For example length, mass, time, force *etc*.

On the other hand various happenings in life *e.g.*, happiness, sorrow *etc*. are not physical quantities because these can not be measured.

Measurement is necessary to determine magnitude of a physical quantity, to compare two similar physical quantities and to prove physical laws or equations.

A physical quantity is represented completely by its magnitude and unit. For example, 10 *metre* means a length which is ten times the unit of length 1 *kg*. Here 10 represents the numerical value of the given quantity and *metre* represents the unit of quantity under consideration. Thus in expressing a physical quantity we choose a unit and then find that how many times that unit is contained in the given physical quantity, *i.e*

$$\text{Physical quantity } (Q) = \text{Magnitude} \times \text{Unit} = n \times u$$

Where, n represents the numerical value and u represents the unit. Thus while expressing definite amount of physical quantity, it is clear that as the unit(u) changes, the magnitude(n) will also change but product 'nu' will remain same.

i.e. $\quad n\,u = \text{constant}, \quad$ or $\quad n_1 u_1 = n_2 u_2 = \text{constant}\ ; \quad \therefore \quad n \propto \dfrac{1}{u}$

i.e. magnitude of a physical quantity and units are inversely proportional to each other .Larger the unit, smaller will be the magnitude.

Types of Physical Quantity.

(1) **Ratio (numerical value only) :** When a physical quantity is a ratio of two similar quantities, it has no unit.

e.g. Relative density = Density of object/Density of water at 4°*C*

Refractive index = Velocity of light in air/Velocity of light in medium

Strain = Change in dimension/Original dimension

Note : ❑ Angle is exceptional physical quantity, which though is a ratio of two similar physical quantities (angle = arc / radius) but still requires a unit (degrees or radians) to specify it along with its numerical value.

(2) **Scalar (Magnitude only) :** These quantities do not have any direction *e.g.* Length, time, work, energy *etc*.

Magnitude of a physical quantity can be negative. In that case negative sign indicates that the numerical value of the quantity under consideration is negative. It does not specify the direction.

Scalar quantities can be added or subtracted with the help of following ordinary laws of addition or subtraction.

(3) **Vector (magnitude and direction) :** *e.g.* displacement, velocity, acceleration, force *etc*.

Vector physical quantities can be added or subtracted according to vector laws of addition. These laws are different from laws of ordinary addition.

Fundamental and Derived Quantities.

(1) **Fundamental quantities :** Out of large number of physical quantities which exist in nature, there are only few quantities which are independent of all other quantities and do not require the help of any other physical quantity for their definition, therefore these are called absolute quantities. These quantities are also called fundamental or base quantities, as all other quantities are based upon and can be expressed in terms of these quantities.

(2) **Derived quantities :** All other physical quantities can be derived by suitable multiplication or division of different powers of fundamental quantities. These are therefore called derived quantities.

If length is defined as a fundamental quantity then area and volume are derived from length and are expressed in term of length with power 2 and 3 over the term of length.

Fundamental and Derived Units.

Normally each physical quantity requires a unit or standard for its specification so it appears that there must be as many units as there are physical quantities. However, it is not so. It has been found that if in *mechanics* we choose arbitrarily units of any *three* physical quantities we can express the units of all other physical quantities in mechanics in terms of these. Arbitrarily the physical quantities *mass*, *length* and *time* are choosen for this purpose. *So any unit of mass, length and time in mechanics is called a* **fundamental, absolute or base unit.** *Other units which can be expressed in terms of fundamental units, are called derived units.* For example light year or *km* is a fundamental units as it is a unit of length while s^{-1}, m^2 or kg/m are derived units as these are derived from units of time, mass and length respectively.

System of units : A complete set of units, both fundamental and derived for all kinds of physical quantities is called system of units. The common systems are given below –

(1) **CGS system :** The system is also called Gaussian system of units. In it length, mass and time have been chosen as the fundamental quantities and corresponding fundamental units are centimetre (*cm*), gram (*g*) and second (*s*) respectively.

(2) **MKS system :** The system is also called Giorgi system. In this system also length, mass and time have been taken as fundamental quantities, and the corresponding fundamental units are *metre*, kilogram and second.

(3) **FPS system :** In this system foot, pound and second are used respectively for measurements of length, mass and time. In this system force is a derived quantity with unit poundal.

(4) **S. I. system :** It is known as International system of units, and is infact extended system of units applied to whole physics. There are seven fundamental quantities in this system. These quantities and their units are given in the following table

Quantity	**Name of Unit**	**Symbol**
Length	metre	*m*
Mass	kilogram	*kg*
Time	second	*s*
Electric Current	ampere	*A*
Temperature	Kelvin	*K*
Amount of Substance	mole	*mol*
Luminous Intensity	candela	*cd*

Besides the above seven fundamental units two supplementary units are also defined –

Radian (*rad*) for plane angle and Steradian (*sr*) for solid angle.

Note : ❑ Apart from fundamental and derived units we also use very frequently practical units. These may be fundamental or derived units

e.g., light year is a practical unit (fundamental) of distance while horse power is a practical unit (derived) of power.

❑ Practical units may or may not belong to a system but can be expressed in any system of units, e.g., 1 mile = 1.6 *km* = 1.6×10^3 *m*.

S.I. Prefixes.

In physics we have to deal from very small (*micro*) to very large (*macro*) magnitudes as one side we talk about the atom while on the other side of universe, *e.g.*, the mass of an electron is 9.1×10^{-31} *kg* while that of the sun is 2×10^{30} *kg*. To express such large or small magnitudes simultaneously we use the following prefixes :

Power of 10	**Prefix**	**Symbol**
10^{18}	exa	*E*
10^{15}	peta	*P*
10^{12}	tera	*T*
10^{9}	giga	*G*
10^{6}	mega	*M*
10^{3}	kilo	*k*
10^{2}	hecto	*h*
10^{1}	deca	*da*

10^{-1}	deci	d
10^{-1}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Standards of Length, Mass and Time.

(1) **Length :** Standard metre is defined in terms of wavelength of light and is called atomic standard of length.

The metre is the distance containing 1650763.73 wavelength in vacuum of the radiation corresponding to orange red light emitted by an atom of krypton-86.

Now a days metre is defined as length of the path travelled by light in vacuum in 1/299,7792, 458 part of a second.

(2) **Mass :** The mass of a cylinder made of platinum-iridium alloy kept at International Bureau of Weights and Measures is defined as 1 *kg*.

On atomic scale, 1 *kilogram* is equivalent to the mass of 5.0188×10^{25} atoms of ${}_6C^{12}$ (an isotope of carbon).

(3) **Time :** 1 *second* is defined as the time interval of 9192631770 vibrations of radiation in *Cs*-133 atom. This radiation corresponds to the transition between two hyperfine level of the ground state of *Cs*-133.

Practical Units.

(1) **Length :**

(i) 1 fermi = 1 $fm = 10^{-15}\ m$

(ii) 1 *X*-ray unit = $1XU = 10^{-13}\ m$

(iii) 1 angstrom = $1\text{Å} = 10^{-10}\ m = 10^{-8}\ cm = 10^{-7}\ mm = 0.1\ \mu mm$

(iv) 1 micron = $\mu m = 10^{-6}\ m$

(v) 1 astronomical unit = 1 $A.U. = 1.49 \times 10^{11}\ m \approx 1.5 \times 10^{11}\ m \approx 10^8\ km$

(vi) 1 Light year = 1 $ly = 9.46 \times 10^{15}\ m$

(vii) 1 *Parsec* = 1*pc* = 3.26 light year

(2) **Mass :**

(i) Chandra Shekhar unit : 1 *CSU* = 1.4 times the mass of sun = $2.8 \times 10^{30}\ kg$

(ii) Metric tonne : 1 Metric tonne = 1000 *kg*

(iii) Quintal : 1 Quintal = 100 kg

(iv) Atomic mass unit (amu) : $amu = 1.67 \times 10^{-27}\ kg$ mass of proton or neutron is of the order of 1 amu

(3) **Time :**

(i) Year : It is the time taken by earth to complete 1 revolution around the sun in its orbit.

(ii) Lunar month : It is the time taken by moon to complete 1 revolution around the earth in its orbit.

$$1\ L.M. = 27.3 \text{ days}$$

(iii) Solar day : It is the time taken by earth to complete one rotation about its axis with respect to sun. Since this time varies from day to day, average solar day is calculated by taking average of the duration of all the days in a year and this is called Average Solar day.

$$1 \text{ Solar year} = 365.25 \text{ average solar day}$$

or $$\text{average solar day} = \frac{1}{365.25} \text{ the part of solar year}$$

(iv) Sedrial day : It is the time taken by earth to complete one rotation about its axis with respect to a distant star.

$$1 \text{ Solar year} = 366.25 \text{ Sedrial day} = 365.25 \text{ average solar day}$$

Thus 1 Sedrial day is less than 1 solar day.

(v) Shake : It is an obsolete and practical unit of time.

$$1 \text{ Shake} = 10^{-8}\ sec$$

Dimensions of a Physical Quantity.

When a derived quantity is expressed in terms of fundamental quantities, it is written as a product of different powers of the fundamental quantities. The powers to which fundamental quantities must be raised in order to express the given physical quantity are called its dimensions.

To make it more clear, consider the physical quantity force: Force = mass × acceleration $= \frac{\text{mass} \times \text{velocity}}{\text{time}} = \frac{\text{mass} \times \text{length/time}}{\text{time}}$ = mass × length × (time)$^{-2}$ .... (i)

Thus, the dimensions of force are 1 in mass, 1 in length and – 2 in time.

Here the physical quantity that is expressed in terms of the base quantities is enclosed in square brackets to indicate that the equation is among the dimensions and not among the magnitudes.

Thus equation (i) can be written as [force] = $[MLT^{-2}]$.

Such an expression for a physical quantity in terms of the fundamental quantities is called the dimensional equation. If we consider only the R.H.S. of the equation, the expression is termed as dimensional formula.

Thus, dimensional formula for force is, $[MLT^{-2}]$.

Important Dimensions of Complete Physics

MECHANICS

S. N.	Quantity	Unit	Dimension
(1)	Velocity or speed (v)	m/s	$[M^0L^1T^{-1}]$
(2)	Acceleration (a)	m/s^2	$[M^0LT^{-2}]$
(3)	Momentum (P)	kg-m/s	$[M^1L^1T^{-1}]$
(4)	Impulse (I)	*Newton-sec* or kg-m/s	$[M^1L^1T^{-1}]$
(5)	Force (F)	*Newton*	$[M^1L^1T^{-2}]$
(6)	Pressure (P)	*Pascal*	$[M^1L^{-1}T^{-2}]$
(7)	Kinetic energy (E_K)	*Joule*	$[M^1L^2T^{-2}]$
(8)	Power (P)	*Watt* or *Joule/s*	$[M^1L^2T^{-3}]$
(9)	Density (d)	kg/m^3	$[M^1L^{-3}T^0]$
(10)	Angular displacement (θ)	*Radian* (*rad.*)	$[M^0L^0T^0]$
(11)	Angular velocity (ω)	*Radian/sec*	$[M^0L^0T^{-1}]$
(12)	Angular acceleration (α)	$Radian/sec^2$	$[M^0L^0T^{-2}]$
(13)	Moment of inertia (I)	kg-m^2	$[M^1L^2T^0]$
(14)	Torque (τ)	*Newton-meter*	$[M^1L^2T^{-2}]$
(15)	Angular momentum (L)	*Joule-sec*	$[M^1L^2T^{-1}]$
(16)	Force constant or spring constant (k)	*Newton/m*	$[M^1L^0T^{-2}]$
(17)	Gravitational constant (G)	N-m^2/kg^2	$[M^{-1}L^3T^{-2}]$
(18)	Intensity of gravitational field (E_g)	N/kg	$[M^0L^1T^{-2}]$
(19)	Gravitational potential (V_g)	*Joule/kg*	$[M^0L^2T^{-2}]$
(20)	Surface tension (T)	N/m or $Joule/m^2$	$[M^1L^0T^{-2}]$
(21)	Velocity gradient (V_g)	$Second^{-1}$	$[M^0L^0T^{-1}]$
(22)	Coefficient of viscosity (η)	kg/m-s	$[M^1L^{-1}T^{-1}]$
(23)	Stress	N/m^2	$[M^1L^{-1}T^{-2}]$
(24)	Strain	No unit	$[M^0L^0T^0]$
(25)	Modulus of elasticity (E)	N/m^2	$[M^1L^{-1}T^{-2}]$
(26)	Poisson Ratio (σ)	No unit	$[M^0L^0T^0]$
(27)	Time period (T)	*Second*	$[M^0L^0T^1]$
(28)	Frequency (n)	Hz	$[M^0L^0T^{-1}]$

Heat

S. N.	Quantity	Unit	Dimension
(1)	Temperature (T)	*Kelvin*	$[M^0L^0T^0\theta^1]$
(2)	Heat (Q)	*Joule*	$[ML^2T^{-2}]$
(3)	Specific Heat (c)	*Joule/kg-K*	$[M^0L^2T^{-2}\theta^{-1}]$
(4)	Thermal capacity	*Joule/K*	$[M^1L^2T^{-2}\theta^{-1}]$
(5)	Latent heat (L)	*Joule/kg*	$[M^0L^2T^{-2}]$
(6)	Gas constant (R)	*Joule/mol-K*	$[M^1L^2T^{-2}\theta^{-1}]$
(7)	Boltzmann constant (k)	*Joule/K*	$[M^1L^2T^{-2}\theta^{-1}]$
(8)	Coefficient of thermal conductivity (K)	*Joule/m-s-K*	$[M^1L^1T^{-3}\theta^{-1}]$
(9)	Stefan's constant (σ)	*Watt/m²-K⁴*	$[M^1L^0T^{-3}\theta^{-4}]$
(10)	Wien's constant (b)	*Meter-K*	$[M^0L^1T^0\theta^1]$
(11)	Planck's constant (h)	*Joule-s*	$[M^1L^2T^{-1}]$
(12)	Coefficient of Linear Expansion (□)	*Kelvin*$^{-1}$	$[M^0L^0T^0\theta^{-1}]$
(13)	Mechanical eq. of Heat (J)	*Joule/Calorie*	$[M^0L^0T^0]$
(14)	Vander wall's constant (a)	*Newton-m*^{4}	$[ML^5T^{-2}]$
(15)	Vander wall's constant (b)	m^3	$[M^0L^3T^0]$

Electricity

S. N.	Quantity	Unit	Dimension
(1)	Electric charge (q)	*Coulomb*	$[M^0L^0T^1A^1]$
(2)	Electric current (I)	*Ampere*	$[M^0L^0T^0A^1]$
(3)	Capacitance (C)	*Coulomb/volt* or *Farad*	$[M^{-1}L^{-2}T^4A^2]$
(4)	Electric potential (V)	*Joule/coulomb*	$M^1L^2T^{-3}A^{-1}$
(5)	Permittivity of free space (ε_0)	$\frac{Coulomb^2}{Newton-meter^2}$	$[M^{-1}L^{-3}T^4A^2]$
(6)	Dielectric constant (K)	Unitless	$[M^0L^0T^0]$
(7)	Resistance (R)	*Volt/Ampere* or *ohm*	$[M^1L^2T^{-3}A^{-2}]$
(8)	Resistivity or Specific resistance (ρ)	*Ohm-meter*	$[M^1L^3T^{-3}A^{-2}]$
(9)	Coefficient of Self-induction (L)	$\frac{volt-second}{ampere}$ or *henery* or *ohm-second*	$[M^1L^2T^{-2}A^{-2}]$
(10)	Magnetic flux (ϕ)	*Volt-second* or *weber*	$[M^1L^2T^{-2}A^{-1}]$

S. N.	Quantity	Unit	Dimension
(11)	Magnetic induction (B)	$\frac{newton}{ampere - meter}$ $\frac{Joule}{ampere - meter^2}$ $\frac{volt - second}{meter^2}$ or *Tesla*	$[M^1L^0T^{-2}A^{-1}]$
(12)	Magnetic Intensity (H)	*Ampere/meter*	$[M^0L^{-1}T^0A^1]$
(13)	Magnetic Dipole Moment (M)	*Ampere-meter*^{2}	$[M^0L^2T^0A^1]$
(14)	Permeability of Free Space (μ_0)	$\frac{Newton}{ampere^2}$ or $\frac{Joule}{ampere^2 - meter}$ or $\frac{Volt - second}{ampere - meter}$ or $\frac{Ohm - second}{meter}$ or $\frac{henery}{meter}$	$[M^1L^1T^{-2}A^{-2}]$
(15)	Surface charge density (σ)	$Coulomb\ metre^{-2}$	$[M^0L^{-2}T^1A^1]$
(16)	Electric dipole moment (p)	$Coulomb - meter$	$[M^0L^1T^1A^1]$
(17)	Conductance (G) ($1/R$)	ohm^{-1}	$[M^{-1}L^{-2}T^3A^2]$
(18)	Conductivity (σ) ($1/\rho$)	$ohm^{-1}meter^{-1}$	$[M^{-1}L^{-3}T^3A^2]$
(19)	Current density (J)	*Ampere/m*^{2}	$M^0L^{-2}T^0A^1$
(20)	Intensity of electric field (E)	*Volt/meter*, *Newton/coulomb*	$M^1L^1T^{-3}A^{-1}$
(21)	Rydberg constant (R)	m^{-1}	$M^0L^{-1}T^0$

Quantities Having Same Dimensions.

S. N.	Dimension	Quantity
(1)	$[M^0L^0T^{-1}]$	Frequency, angular frequency, angular velocity, velocity gradient and decay constant
(2)	$[M^1L^2T^{-2}]$	Work, internal energy, potential energy, kinetic energy, torque, moment of force
(3)	$[M^1L^{-1}T^{-2}]$	Pressure, stress, Young's modulus, bulk modulus, modulus of rigidity, energy density
(4)	$[M^1L^1T^{-1}]$	Momentum, impulse
(5)	$[M^0L^1T^{-2}]$	Acceleration due to gravity, gravitational field intensity
(6)	$[M^1L^1T^{-2}]$	Thrust, force, weight, energy gradient
(7)	$[M^1L^2T^{-1}]$	Angular momentum and Planck's constant

(8)	$[M^1L^0T^{-2}]$	Surface tension, Surface energy (energy per unit area)
(9)	$[M^0L^0T^0]$	Strain, refractive index, relative density, angle, solid angle, distance gradient, relative permittivity (dielectric constant), relative permeability etc.
(10)	$[M^0L^2T^{-2}]$	Latent heat and gravitational potential
(11)	$[M^0L^2T^{-2}\theta^{-1}]$	Thermal capacity, gas constant, Boltzmann constant and entropy
(12)	$[M^0L^0T^1]$	$\sqrt{l/g}, \sqrt{m/k}, \sqrt{R/g}$, where l = length g = acceleration due to gravity, m = mass, k = spring constant
(13)	$[M^0L^0T^1]$	L/R, $\sqrt{LC}$, RC where L = inductance, R = resistance, C = capacitance
(14)	$[ML^2T^{-2}]$	$I^2Rt, \frac{V^2}{R}t,\ VIt,\ qV,\ LI^2,\ \frac{q^2}{C}, CV^2$ where I = current, t = time, q = charge, L = inductance, C = capacitance, R = resistance

Application of Dimensional Analysis.

(1) **To find the unit of a physical quantity in a given system of units** : Writing the definition or formula for the physical quantity we find its dimensions. Now in the dimensional formula replacing M, L and T by the fundamental units of the required system we get the unit of physical quantity. However, sometimes to this unit we further assign a specific name, *e.g.*, Work = Force $\times$ Displacement

So $[W] = [MLT^{-2}] \times [L] = [ML^2T^{-2}]$

So its units in C.G.S. system will be $g\ cm^2/s^2$ which is called *erg* while in M.K.S. system will be $kg\ m^2/s^2$ which is called *joule*.

(2) **To find dimensions of physical constant or coefficients** : As dimensions of a physical quantity are unique, we write any formula or equation incorporating the given constant and then by substituting the dimensional formulae of all other quantities, we can find the dimensions of the required constant or coefficient.

(i) Gravitational constant: According to Newton's law of gravitation $F = G\frac{m_1m_2}{r^2}$ or $G = \frac{Fr^2}{m_1m_2}$

Substituting the dimensions of all physical quantities $[G] = \frac{[MLT^{-2}][L^2]}{[M][M]} = [M^{-1}L^3T^{-2}]$

(3) **To convert a physical quantity from one system to the other** : The measure of a physical quantity is nu = constant

If a physical quantity X has dimensional formula $[M^aL^bT^c]$ and if (derived) units of that physical quantity in two systems are $[M_1^aL_1^bT_1^c]$ and $[M_2^aL_2^bT_2^c]$ respectively and n_1 and n_2 be the numerical values in the two systems respectively, then $n_1[u_1] = n_2[u_2]$

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

$$\Rightarrow n_2 = n_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c$$

where M_1, L_1 and T_1 are fundamental units of mass, length and time in the first (known) system and M_2, L_2 and T_2 are fundamental units of mass, length and time in the second (unknown) system. Thus knowing the values of fundamental units in two systems and numerical value in one system, the numerical value in other system may be evaluated.

Example : (1) conversion of *Newton* into *Dyne*.

The Newton is the S.I. unit of force and has dimensional formula $[MLT^{-2}]$.

So 1 N = 1 $kg\text{-}m/sec^2$

By using

$$n_2 = n_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c = 1\left[\frac{kg}{gm}\right]^1\left[\frac{m}{cm}\right]^1\left[\frac{sec}{sec}\right]^{-2} = 1\left[\frac{10^3\,gm}{gm}\right]^1\left[\frac{10^2\,cm}{cm}\right]^1\left[\frac{sec}{sec}\right]^{-2} = 10^5$$

$\therefore$ 1 $N = 10^5$ *Dyne*

(2) Conversion of gravitational constant (G) from C.G.S. to M.K.S. system

The value of G in C.G.S. system is 6.67×10^{-8} C.G.S. units while its dimensional formula is $[M^{-1}L^3T^{-2}]$

So $\quad G = 6.67 \times 10^{-8}\ cm^3/g\ s^2$

By using $$n_2 = n_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c = 6.67\times10^{-8}\left[\frac{gm}{kg}\right]^{-1}\left[\frac{cm}{m}\right]^3\left[\frac{sec}{sec}\right]^{-2}$$

$$= 6.67\times10^{-8}\left[\frac{gm}{10^3\,gm}\right]^{-1}\left[\frac{cm}{10^2\,cm}\right]^3\left[\frac{sec}{sec}\right]^{-2} = 6.67\times10^{-11}$$

$\therefore \quad G = 6.67 \times 10^{-11}$ M.K.S. units

(4) **To check the dimensional correctness of a given physical relation :** This is based on the '*principle of homogeneity*'. According to this principle the dimensions of each term on both sides of an equation must be the same.

If $X = A \pm (BC)^2 \pm \sqrt{DEF}$,

then according to principle of homogeneity $[X] = [A] = [(BC)^2] = [\sqrt{DEF}]$

If the dimensions of each term on both sides are same, the equation is dimensionally correct, otherwise not. A dimensionally correct equation may or may not be physically correct.

Example : (1) $F = mv^2 / r^2$

By substituting dimension of the physical quantities in the above relation –

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

i.e. $$[MLT^{-2}] = [MT^{-2}]$$

As in the above equation dimensions of both sides are not same; this formula is not correct dimensionally, so can never be physically.

UNIT-2

SCALARS & VECTORS

SCALARS AND VECTORS

2. *What are scalar and vector quantities ? Give examples.*

Scalar quantities. *The physical quantities which have only magnitude and no direction are called scalar quantities or scalars.* A scalar quantity can be specified by a single number, along with the proper unit.

Examples : Mass, volume, density, time, temperature, electric current, etc.

Vector quantities. *The physical quantities which have both magnitude and direction and obey the laws of vector addition are called vector quantities or vectors.* A vector quantity is specified by a number with a unit and its direction.

Examples : Displacement, velocity, force, momentum, etc.

REPRESENTATION OF A VECTOR

4. *With the help of a suitabie example, explain how is a vector quantity represented.*

Representation of a vector. *A vector quantity is represented by a straight line with an arrowhead over it.* The length of the line gives the magnitude and the arrowhead gives the direction. Suppose a body has a velocity of 40 kmh^{-1} due east. If 1 cm is chosen to

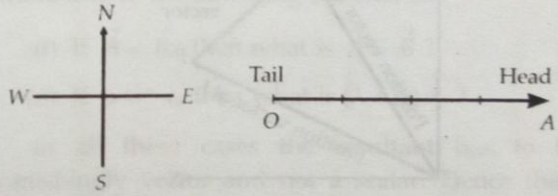
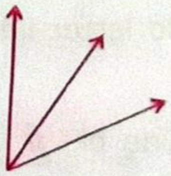


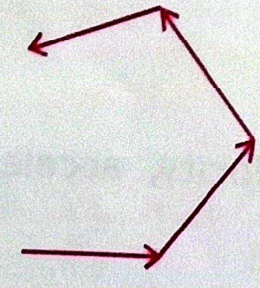
Fig. Representation of a vector.

DIFFERENT TYPES OF VECTORS:

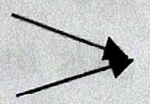
1. **Linear vectors:**
   The vectors are said to be linear vectors if they lie in same line.
2. **Coplanar vectors:** The vectors are said to be coplanar vectors if they lie in same plane.
3. **Same vectors:** Two vectors are said to be same vectors if they have same length and same direction(i.e.they may be parallel)
4. **Co-initial vectors:** Two vectors are said to be co-initial,if their tails are joined together i.e. their starting points are same



5. **Same order vectors:** The vectors are said to be in same order if tail of one vector joins the arrow head of other vector.



6. **Opposite order vectors:** Two vectors are said to be opposite vectors if their heads join together



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7. **Unit vector:** Unit vector of a vector has same direction as that of original vector with unity magnitude(i.e.magnitude is one).

Unit vector of $\vec{A}$ is denoted by $\hat{A}$ or $\hat{n}$

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8. **Zero vector or null vector:** It has zero magnitude and arbitrary direction i.e. its direction may be considered along any direction .It can be denoted as-

$$\vec{0} = 0\hat{i} + 0\hat{j} + 0\hat{k}$$

9 Parallel vectors:

$\vec{A}$ is said to be parallel to $\vec{B}$ if $\vec{A} = m\vec{B}$ and m=scalar=constant(+ve or −ve).

Parallel vectors are of two types

(i)like vectors: In this case m=scalar=+ve constant. i.e. $\vec{A}$ and $\vec{B}$ both have same direction

$\vec{A} = 5N$ along East

$\vec{B} = 10N$ along East$=2(5N$ along East$)=2\vec{A}$

Here $m = +2 = +ve$

(ii)unlike vectors: In this case m=scalar=−ve constant i.e. $\vec{A}$ and $\vec{B}$ both have opposite direction

$\vec{A} = 5N$ along East

$\vec{B} = 10N$ along West$= -10N$ along East

$= -2(5N$ along East$) = -2\vec{A} = m\vec{A}$

Here $m = -2 = -ve$

Note: This unlike vector is termed antiparallel vector in some books though by definition all are parallel

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Conditions for two vectors to be parallel:

If $\vec{A} = a_1\hat{i} + a_2\hat{j} + a_3\hat{k}$ and $\vec{B} = b_1\hat{i} + b_2\hat{j} + b_3\hat{k}$

and $\vec{A} \parallel \vec{B}$ i.e. $\vec{A} = m\vec{B}$ then we get

$$\boxed{\frac{a_1}{b_1} = \frac{a_2}{b_2} = \frac{a_3}{b_3}}$$

Proof: $\vec{A} = m\vec{B}$

$$\Rightarrow a_1\hat{i} + a_2\hat{j} + a_3\hat{k} = m(b_1\hat{i} + b_2\hat{j} + b_3\hat{k}) = mb_1\hat{i} + mb_2\hat{j} + mb_3\hat{k}$$

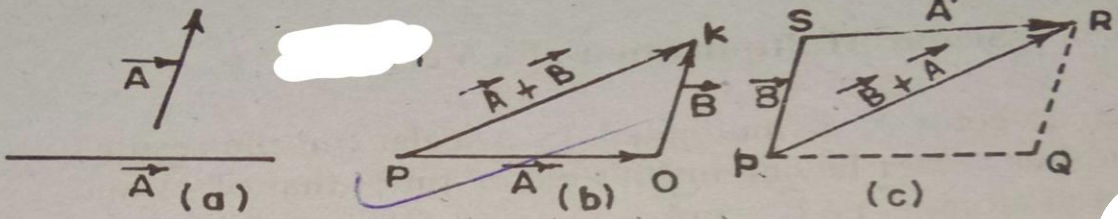
$$\Rightarrow a_1 = mb_1 \;,\; a_2 = mb_2 \;,\; a_3 = mb_3$$

$$\Rightarrow \frac{a_1}{b_1} = \frac{a_2}{b_2} = \frac{a_3}{b_3} = m$$

Addition of Vectors

Vector quantities cannot, in general, be added algebraically. The addition of two or more vectors is done by triangle, parallelogram law or the polygon law of vector additions.

Suppose $\vec{A}$ and $\vec{B}$ are two vectors as shown in Fig. (a) To find $\vec{A}+\vec{B}$ draw $\vec{B}$ vector from the head of $\vec{A}$ vector parallel to the dirction of $\vec{B}$, The vector joining the tail of A vector to head of B vector gives $\vec{A}+\vec{B}$ (fig (b))



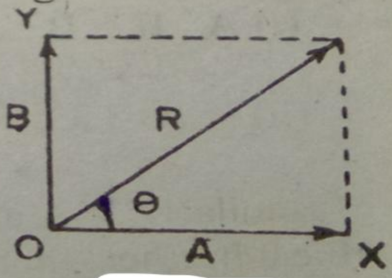
It can be shown that : $\vec{A}+\vec{B}=\vec{B}+\vec{A}$ (Commutative)

Similarly : $(\vec{A}+\vec{B})+\vec{C}=\vec{A}+(\vec{B}+\vec{C})$ (Associative)

Triangle law of vector addition : If two vectors are represented bóth in magnitude and direction by two sides of a triangle, taken in order, then their resultant is represented (in magnitude and direction) by the third side of the triangle taken is opposite order.

In fig. (b). two vectors $\vec{A}$ and $\vec{B}$ are represented by two sides $\vec{PO}$ and $\vec{OK}$ of the triangle POK. It is seen that the resultant of A and B is PK i.e third side of the triangle POK.

Parallelogram law of vector addition : If two vectors acting, simultaneouly at a point are represented both in magnitude and direction by two adjacent sides of a parallelogram, then their resultant is represented (in magnitude and direction) by the diagonal of the parallelogram passing through this point.



Rectangular Component of a Vector

Any vector $\vec{R}$ can be resolved to two rectangular components A and B whose magnitude are given by

$|\vec{A}| = |\vec{R}|\cos\theta,\ |\vec{B}| = |\vec{R}|\sin\theta$

7

Where θ is the angle between $\vec{A}$ and $\vec{B}$

Scalar Multiplication of a Vector :

When a vector $\vec{A}$ is multiplied by a scalar 'm' the result is another vector having magnitude m times that of $\vec{A}$ and directed along $\vec{A}$ i.e $\vec{R} = m\vec{A}$

Product of two Vectors :

There are two ways in which two vectors can be multiplied together.

(i) Dot Product *or* Scalar Product

(ii) Cross Product *or* Vector Product

If $\vec{A}$ and $\vec{B}$ are two vectors making an angle θ with each other, then their *Scalar Product* $\vec{A} \cdot \vec{B}$ is given by

$\vec{A} \cdot \vec{B} = |\vec{A}|\,|\vec{B}|\cos\theta$ (Scalar)

If $\theta = 0$, (Parallel), $\vec{A} \cdot \vec{B} = |\vec{A}|\,|\vec{B}|$ and

for $\theta = 90^0$ (Perpendicular), $\vec{A} \cdot \vec{B} = 0$

It can be proved that

(i) $\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A}$ (Commutative)

(ii) $\vec{A} \cdot (\vec{B} + \vec{C}) = \vec{A} \cdot \vec{B} + \vec{A} \cdot \vec{C}$ (distributive)

Similarly, if $\vec{A}$ and $\vec{B}$ ar two vector making an angle θ with each other, then their *vector product* $\vec{A} \times \vec{B}$ is given by

$\vec{A} \times \vec{B} = |\vec{A}|\,|\vec{B}|\sin\theta\ \hat{n}$

This product is a vector quantity. Here $\hat{n}$ is the unit vector along the direction perpendicular to the plane containing $\vec{A}$ and $\vec{B}$

if $\theta = 0$, $\vec{A} \times \vec{B} = (0)\,\hat{n}$ = a null vector

and if $\theta = 90^0$, $\vec{A} \times \vec{B} = |A|\,|B|\,\hat{n}$

it can be proved that

(i) $\vec{A} \times \vec{B} = -\vec{B} \times \vec{A}$ (non commutative)

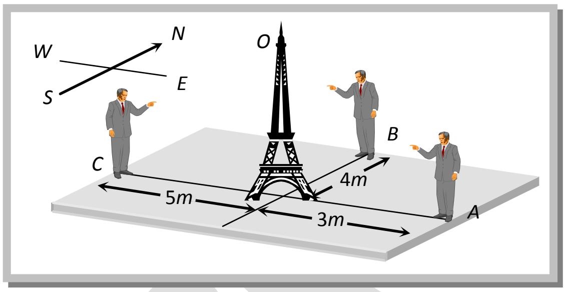
(ii) $\vec{A} \times (\vec{B} + \vec{C}) = \vec{A} \times \vec{B} + \vec{A} \times \vec{C}$ (distributive)

UNIT-3

KINEMATICS

Position.

Any object is situated at point *O* and three observers from three different places are looking for same object, then all three observers will have different observations about the position of point *O* and no one will be wrong. Because they are observing the object from their different positions.



Observer '*A*' says : Point *O* is 3 *m* away in west direction.

Observer '*B*' says : Point *O* is 4 *m* away in south direction.

Observer '*C*' says : Point *O* is 5 *m* away in east direction.

Therefore position of any point is completely expressed by two factors: Its distance from the observer and its direction with respect to observer.

That is why position is characterised by a vector known as position vector.

Let point *P* is in a *xy* plane and its coordinates are (x, y). Then position vector $(\vec{r})$ of point will be $x\hat{i} + y\hat{j}$ and if the point *P* is in a space and its coordinates are (x, y, z) then position vector can be expressed as $\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$.

Rest and Motion.

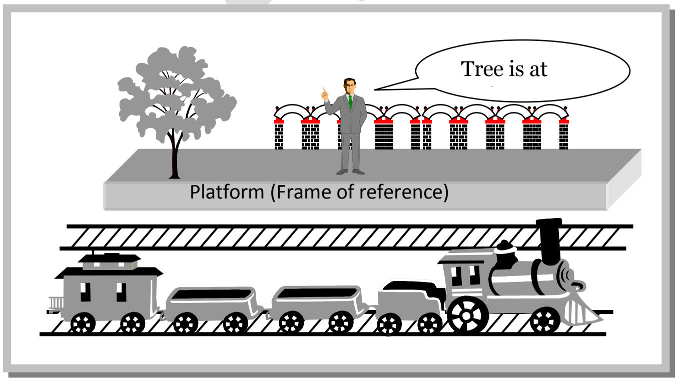
If a body does not change its position as time passes with respect to frame of reference, it is said to be at rest.

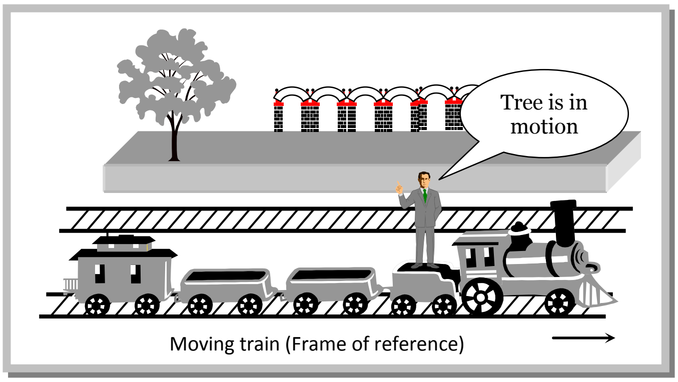
And if a body changes its position as time passes with respect to frame of reference, it is said to be in motion.

Frame of Reference : It is a system to which a set of coordinates are attached and with reference to which observer describes any event.

A passenger standing on platform observes that tree on a platform is at rest. But when the same passenger is passing away in a train through station, observes that tree is in motion. In both conditions observer is right. But observations are different because in first situation observer stands on a platform, which is reference frame at rest and in second situation observer moving in train, which is reference frame in motion.

So rest and motion are relative terms. It depends upon the frame of references.



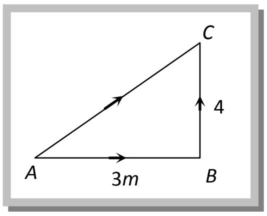


Distance and Displacement.

(1) **Distance :** It is the actual path length covered by a moving particle in a given interval of time.

(i) If a particle starts from A and reach to C through point B as shown in the figure.

Then distance travelled by particle $= AB + BC = 7\,m$



(ii) Distance is a scalar quantity.

(iii) Dimension : $[M^0L^1T^0]$

(iv) Unit : *metre* (S.I.)

(2) **Displacement :** Displacement is the change in position vector *i.e.*, A vector joining initial to final position.

(i) Displacement is a vector quantity

(ii) Dimension : $[M^0L^1T^0]$

(iii) Unit : *metre* (S.I.)

(iv) In the above figure the displacement of the particle $\overrightarrow{AC} = \overrightarrow{AB} + \overrightarrow{BC}$

$$\Rightarrow |\,AC\,| = \sqrt{(AB)^2 + (BC)^2 + 2(AB)(BC)\cos 90^o} = 5m$$

(3) **Comparison between distance and displacement :**

(i) The magnitude of displacement is equal to minimum possible distance between two positions.

So distance $\geq$ |Displacement|.

(ii) For a moving particle distance can never be negative or zero while displacement can be.

(zero displacement means that body after motion has came back to initial position)

i.e., Distance > 0 but Displacement > = or < 0

(iii) For motion between two points displacement is single valued while distance depends on actual path and so can have many values.

(iv) For a moving particle distance can never decrease with time while displacement can. Decrease in displacement with time means body is moving towards the initial position.

(v) In general magnitude of displacement is not equal to distance. However, it can be so if the motion is along a straight line without change in direction.

Speed and Velocity.

(1) **Speed :** Rate of distance covered with time is called speed.

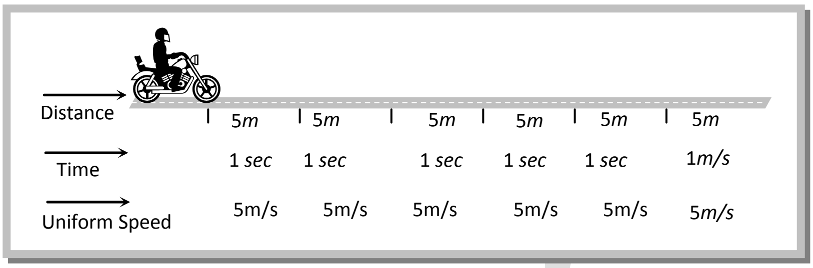
(i) It is a scalar quantity having symbol υ.

(ii) Dimension : $[M^0L^1T^{-1}]$

(iii) Unit : *metre/second* (S.I.), *cm/second* (C.G.S.)

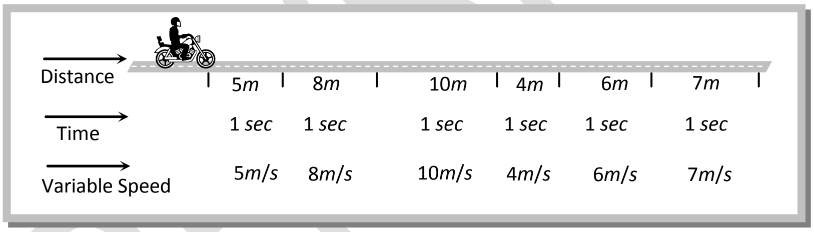
(iv) Types of speed :

(a) **Uniform speed :** When a particle covers equal distances in equal intervals of time, (no matter how small the intervals are) then it is said to be moving with uniform speed. In given illustration motorcyclist travels equal distance (= 5*m*) in each second. So we can say that particle is moving with uniform speed of 5 *m*/*s*.



(b) **Non-uniform (variable) speed :** In non-uniform speed particle covers unequal distances in equal intervals of time. In the given illustration motorcyclist travels 5*m* in 1st second, 8*m* in 2nd second, 10*m* in 3rd second, 4*m* in 4th second *etc.*

Therefore its speed is different for every time interval of one second. This means particle is moving with variable speed.



(c) **Average speed :** The average speed of a particle for a given 'Interval of time' is defined as the ratio of distance travelled to the time taken.

$$\text{Average speed} = \frac{\text{Distance travelled}}{\text{Time taken}}\ ; \quad v_{av} = \frac{\Delta s}{\Delta t}$$

(d) **Instantaneous speed :** It is the speed of a particle at particular instant. When we say "speed", it usually means instantaneous speed.

The instantaneous speed is average speed for infinitesimally small time interval (*i.e.*, $\Delta t \to 0$). Thus

$$\text{Instantaneous speed } v = \lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t} = \frac{ds}{dt}$$

(2) **Velocity :** Rate of change of position *i.e.* rate of displacement with time is called velocity.

(i) It is a scalar quantity having symbol v .

(ii) Dimension : $[M^0L^1T^{-1}]$

(iii) Unit : *metre*/*second* (S.I.), *cm*/*second* (C.G.S.)

(iv) Types

(a) **Uniform velocity :** A particle is said to have uniform velocity, if magnitudes as well as direction of its velocity remains same and this is possible only when the particles moves in same straight line without reversing its direction.

(b) **Non-uniform velocity :** A particle is said to have non-uniform velocity, if either of magnitude or direction of velocity changes (or both changes).

(c) **Average velocity** : It is defined as the ratio of displacement to time taken by the body

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Time taken}}; \quad \vec{v}_{av} = \frac{\Delta \vec{r}}{\Delta t}$$

Acceleration.

The time rate of change of velocity of an object is called acceleration of the object.

(1) It is a vector quantity. It's direction is same as that of change in velocity (Not of the velocity)

(2) There are three possible ways by which change in velocity may occur

(3) Dimension : $[M^0L^1T^{-2}]$

(4) Unit : *metre/second*^{2} (S.I.); *cm/second*^{2} (C.G.S.)

(5) Types of acceleration :

(i) **Uniform acceleration :** A body is said to have uniform acceleration if magnitude and direction of the acceleration remains constant during particle motion.

Note : ❑ If a particle is moving with uniform acceleration, this does not necessarily imply that particle is moving in straight line. *e.g.* Projectile motion.

(ii) **Non-uniform acceleration :** A body is said to have non-uniform acceleration, if magnitude or direction or both, change during motion.

(iii) **Average acceleration :** $\vec{a}_{av} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$

The direction of average acceleration vector is the direction of the change in velocity vector as $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$

Equations of Kinematics.

These are the various relations between *u*, *v*, *a*, *t* and *s* for the moving particle where the notations are used as :

u = Initial velocity of the particle at time $t = 0$ *sec*

v = Final velocity at time t *sec*

a = Acceleration of the particle

s = Distance travelled in time t *sec*

s_n = Distance travelled by the body in n^{th} *sec*

(1) **When particle moves with zero acceleration**

(i) It is a unidirectional motion with constant speed.

(ii) Magnitude of displacement is always equal to the distance travelled.

(iii) $v = u, \quad s = u\,t \qquad [\text{As } a = 0]$

(2) **When particle moves with constant acceleration**

(i) Acceleration is said to be constant when both the magnitude and direction of acceleration remain constant.

(ii) There will be one dimensional motion if initial velocity and acceleration are parallel or anti-parallel to each other.

(iii) Equations of motion in scalar from — Equation of motion in vector from

$\upsilon = u + at$	$\vec{v} = \vec{u} + \vec{a}t$
$s = ut + \frac{1}{2}at^2$	$\vec{s} = \vec{u}t + \frac{1}{2}\vec{a}t^2$
$\upsilon^2 = u^2 + 2as$	$\vec{v}.\vec{v} - \vec{u}.\vec{u} = 2\vec{a}.\vec{s}$
$s = \left(\frac{u+v}{2}\right)t$	$\vec{s} = \frac{1}{2}(\vec{u} + \vec{v})t$
$s_n = u + \frac{a}{2}(2n-1)$	$\vec{s}_n = \vec{u} + \frac{\vec{a}}{2}(2n-1)$

Newton's First Law.

A body continue to be in its state of rest or of uniform motion along a straight line, unless it is acted upon by some external force to change the state.

(1) If no net force acts on a body, then the velocity of the body cannot change *i.e.* the body cannot accelerate.

(2) Newton's first law defines inertia and is rightly called the law of inertia. Inertia are of three types :

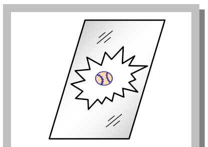
Inertia of rest, Inertia of motion, Inertia of direction

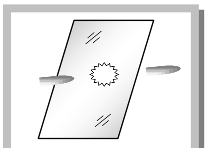
(3) **Inertia of rest :** It is the inability of a body to change by itself, its state of rest. This means a body at rest remains at rest and cannot start moving by its own.

Example : (i) A person who is standing freely in bus, thrown backward, when bus starts suddenly.

When a bus suddenly starts, the force responsible for bringing bus in motion is also transmitted to lower part of body, so this part of the body comes in motion along with the bus. While the upper half of body (say above the waist) receives no force to overcome inertia of rest and so it stays in its original position. Thus there is a relative displacement between the two parts of the body and it appears as if the upper part of the body has been thrown backward.

(ii) A bullet fired on a window pane makes a clean hole through it while a stone breaks the whole window because the bullet has a speed much greater than the stone. So its time of contact with glass is small. So in case of bullet the motion is transmitted only to a small portion


Cracks bv the


Hole bv the

of the glass in that small time. Hence a clear hole is created in the glass window, while in case of ball, the time and the area of contact is large. During this time the motion is transmitted to the entire window, thus creating the cracks in the entire window.

(4) **Inertia of motion :** It is the inability of a body to change itself its state of uniform motion *i.e.,* a body in uniform motion can neither accelerate nor retard by its own.

Example : (i) When a bus or train stops suddenly, a passenger sitting inside tends to fall forward. This is because the lower part of his body comes to rest with the bus or train but the upper part tends to continue its motion due to inertia of motion.

(ii) A person jumping out of a moving train may fall forward.

(iii) An athlete runs a certain distance before taking a long jump. This is because velocity acquired by running is added to velocity of the athlete at the time of jump. Hence he can jump over a longer distance.

Newton's Second Law.

(1) The rate of change of linear momentum of a body is directly proportional to the external force applied on the body and this change takes place always in the direction of the applied force.

(2) If a body of mass m, moves with velocity $\vec{v}$ then its linear momentum can be given by $\vec{p} = m\vec{v}$ and if force $\vec{F}$ is applied on a body, then

$$\vec{F} \propto \frac{d\vec{p}}{dt} \Rightarrow F = K\frac{d\vec{p}}{dt}$$

or $$\vec{F} = \frac{d\vec{p}}{dt}$$ (K = 1 in C.G.S. and S.I. units)

or $$\vec{F} = \frac{d}{dt}(m\vec{v}) = m\frac{d\vec{v}}{dt} = m\vec{a}$$ (As $a = \frac{d\vec{v}}{dt}$ = acceleration produced in the body)

$\therefore$ $$\vec{F} = m\vec{a}$$

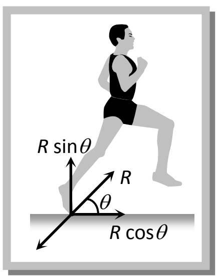
Force = mass $\times$ acceleration

Newton's Third Law.

To every action, there is always an equal (in magnitude) and opposite (in direction) reaction.

(1) When a body exerts a force on any other body, the second body also exerts an equal and opposite force on the first.

(2) Action and reaction never act on the same body. If it were so the total force on a body would have always been zero *i.e.* the body will always remain in equilibrium.



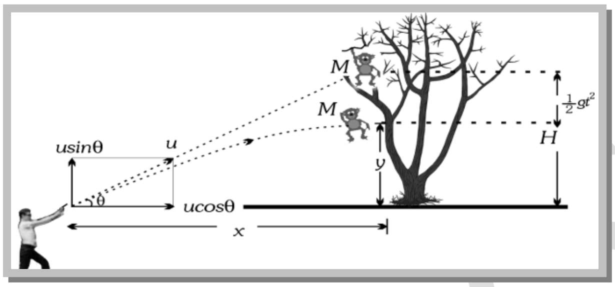
(3) While walking a person presses the ground in the backward direction (action) by his feet. The ground pushes the person in forward direction with an equal force (reaction). The component of reaction in horizontal direction makes the person move forward.

(4) It is difficult to walk on sand or ice.

PROJECTILE MOTION

Introduction.

A hunter aims his gun and fires a bullet directly towards a monkey sitting on a distant tree. If the monkey remains in his position, he will be safe but at the instant the bullet leaves the barrel of gun, if the monkey drops from the tree, the bullet will hit the monkey because the bullet will not follow the linear path.



The path of motion of a bullet will be parabolic and this motion of bullet is defined as projectile motion.

If the force acting on a particle is oblique with initial velocity then the motion of particle is called projectile motion.

Projectile.

A body which is in flight through the atmosphere but is not being propelled by any fuel is called projectile.

Example: (i) A bomb released from an aeroplane in level flight

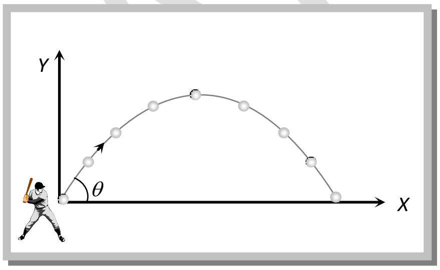
(ii) A bullet fired from a gun

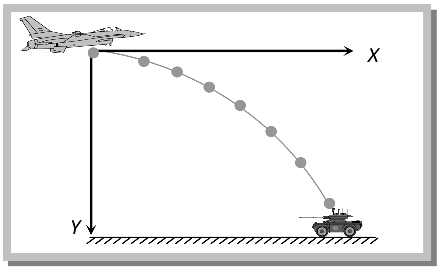
(iii) An arrow released from bow

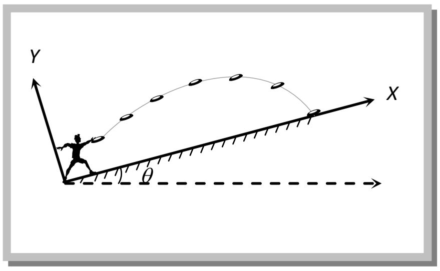
(iv) A Javelin thrown by an athlete

Types of Projectile Motion.

(1) Oblique projectile motion (2) Horizontal projectile motion (3) Projectile motion on an inclined plane





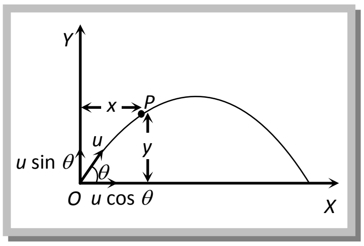


Oblique Projectile.

In projectile motion, horizontal component of velocity (u cosθ), acceleration (g) and mechanical energy remains constant while, speed, velocity, vertical component of velocity (u sin θ), momentum, kinetic energy and potential energy all changes. Velocity, and KE are maximum at the point of projection while minimum (but not zero) at highest point.

(1) **Equation of trajectory :** A projectile thrown with velocity u at an angle θ with the horizontal. The velocity u can be resolved into two rectangular components.

$v \cos\theta$ component along X–axis and $u \sin\theta$ component along Y–axis.



For horizontal motion $x = u\cos\theta \times t \Rightarrow t = \dfrac{x}{u\cos\theta}$ .... (i)

For vertical motion $y = (u\sin\theta)t - \dfrac{1}{2}gt^2$ .... (ii)

From equation (i) and (ii) $y = u\sin\theta\left(\dfrac{x}{u\cos\theta}\right) - \dfrac{1}{2}g\left(\dfrac{x^2}{u^2\cos^2\theta}\right)$

$$y = x\tan\theta - \frac{1}{2}\frac{gx^2}{u^2\cos^2\theta}$$

This equation shows that the trajectory of projectile is parabolic because it is similar to equation of parabola

$$y = ax - bx^2$$

Note : ❑ Equation of oblique projectile also can be written as

$y = x\tan\theta\left[1 - \dfrac{x}{R}\right]$ (where R = horizontal range = $\dfrac{u^2\sin 2\theta}{g}$)

(2) **Time of flight :** The total time taken by the projectile to go up and come down to the same level from which it was projected is called time of flight.

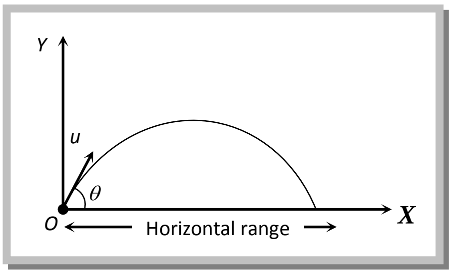
For vertical upward motion $0 = u\sin\theta - gt \Rightarrow t = (u\sin\theta/g)$

Now as time taken to go up is equal to the time taken to come down so

Time of flight $T = 2t = \dfrac{2u\sin\theta}{g}$

(3) **Horizontal range :** It is the horizontal distance travelled by a body during the time of flight.

So by using second equation of motion



$$R = u\cos\theta \times T = u\cos\theta \times (2u\sin\theta/g) = \frac{u^2\sin 2\theta}{g}$$

$$R = \frac{u^2\sin 2\theta}{g}$$

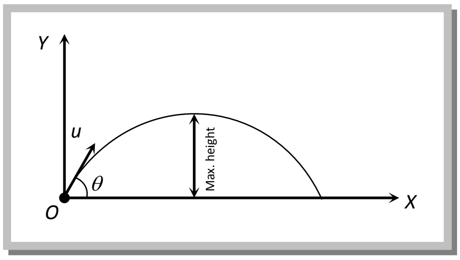
(i) Maximum range : For range to be maximum

$$\frac{dR}{d\theta} = 0 \Rightarrow \frac{d}{d\theta}\left[\frac{u^2\sin 2\theta}{g}\right] = 0$$

$\Rightarrow \cos 2\theta = 0$ *i.e.* $2\theta = 90^\circ \Rightarrow \theta = 45^\circ$ and $R_{max} = (u^2/g)$

i.e., a projectile will have maximum range when it is projected at an angle of 45° to the horizontal and the maximum range will be (u^2/g).

(4) **Maximum height :** It is the maximum height from the point of projection, a projectile can reach.



So, by using $v^2 = u^2 + 2as$

$$0 = (u\sin\theta)^2 - 2gH$$

$$H = \frac{u^2 \sin^2\theta}{2g}$$

(i) Maximum height can also be expressed as

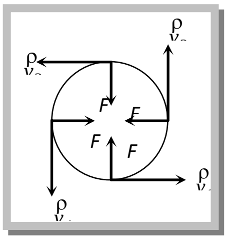
$$H = \frac{u_y^2}{2g} \text{ (where } u_y \text{ is the vertical component of initial velocity).}$$

(ii) $H_{max} = \dfrac{u^2}{2g}$ (when $\sin^2\theta$ = max = 1 *i.e.*, $\theta = 90^o$)

i.e., for maximum height body should be projected vertically upward. So it falls back to the point of projection after reaching the maximum height.

CIRCULAR MOTION

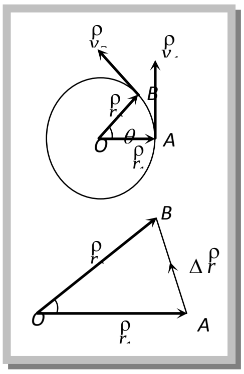
Circular motion is another example of motion in two dimensions. To create circular motion in a body it must be given some initial velocity and a force must then act on the body which is always directed at right angles to instantaneous velocity.



Since this force is always at right angles to the displacement due to the initial velocity therefore no work is done by the force on the particle. Hence, its kinetic energy and thus speed is unaffected. But due to simultaneous action of the force and the velocity the particle follows resultant path, which in this case is a circle. Circular motion can be classified into two types – Uniform circular motion and non-uniform circular motion.

Variables of Circular Motion.

(1) **Displacement and distance:** When particle moves in a circular path describing an angle θ during time t (as shown in the figure) from the position. A to the position B, we see that the magnitude of the position vector $\vec{r}$ (that is equal to the radius of the circle) remains constant. *i.e.*, $|\vec{r}_1| = |\vec{r}_2| = r$ and the direction of the position vector changes from time to time.



(i) Displacement **:** The change of position vector or the displacement $\Delta\vec{r}$ of the particle from position A to the position B is given by referring the figure.

$$\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$$

$$\Rightarrow \Delta r = |\Delta\vec{r}| = |\vec{r}_2 - \vec{r}_1| \quad \Delta r = \sqrt{r_1^2 + r_2^2 - 2r_1 r_2 \cos\theta}$$

Putting $r_1 = r_2 = r$ we obtain $\Delta r = \sqrt{r^2 + r^2 - 2r.r\cos\theta}$

$$\Rightarrow \Delta r = \sqrt{2r^2(1-\cos\theta)} = \sqrt{2r^2\left(2\sin^2\frac{\theta}{2}\right)}$$

$$\Delta r = 2r\sin\frac{\theta}{2}$$

(ii) Distance **:** The distanced covered by the particle during the time t is given as

d = length of the arc AB = $r\ \theta$

(iii) Ratio of distance and displacement **:** $\frac{d}{\Delta r} = \frac{r\theta}{2r\sin\theta/2} = \frac{\theta}{2}\text{cosec}\,(\theta/2)$

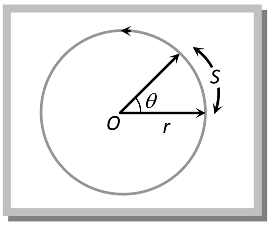
(2) **Angular displacement (θ) :** The angle turned by a body moving on a circle from some reference line is called angular displacement.

(i) Dimension = $[M^0L^0T^0]$ (as $\theta = arc/\text{radius}$) .

(ii) Units = Radian or Degree. It is some times also specified in terms of fraction or multiple of revolution.

(iii) $2\pi\,\text{rad} = 360^o = 1\,\text{Revolution}$

(iv) Angular displacement is a axial vector quantity.



Its direction depends upon the sense of rotation of the object and can be given by Right Hand Rule; which states that if the curvature of the fingers of right hand represents the sense of rotation of the object, then the thumb, held perpendicular to the curvature of the fingers, represents the direction of angular displacement vector.

(v) Relation between linear displacement and angular displacement $\vec{s} = \vec{\theta} \times \vec{r}$

or $\quad s = r\theta$

(3) **Angular velocity (ω) :** Angular velocity of an object in circular motion is defined as the time rate of change of its angular displacement.

(i) Angular velocity $\omega = \frac{\text{angle traced}}{\text{time taken}} = \underset{\Delta t \to 0}{Lt}\frac{\Delta\theta}{\Delta t} = \frac{d\theta}{dt}$

$$\therefore \qquad \omega = \frac{d\theta}{dt}$$

(ii) Dimension : $[M^0L^0T^{-1}]$

(iii) Units : Radians per second ($rad.s^{-1}$) or Degree per second.

(iv) Relation between angular velocity and linear velocity $\vec{v} = \vec{\omega} \times \vec{r}$

Its direction is the same as that of $\Delta\theta$. For anticlockwise rotation of the point object on the circular path, the direction of ω, according to Right hand rule is along the axis of circular path directed upwards. For clockwise rotation of the point object on the circular path, the direction of ω is along the axis of circular path directed downwards.

(4) **Time period (*T*) :** In circular motion, the time period is defined as the time taken by the object to complete one revolution on its circular path.

(i) Units : second. (ii) Dimension : $[M^0L^0T]$

(iii) Time period of second's hand of watch = 60 *second*. (iv) Time period of minute's hand of watch = 60 *minute* (v) Time period of hour's hand of watch = 12 *hour*

(5) **Frequency (*n*) :** In circular motion, the frequency is defined as the number of revolutions completed by the object on its circular path in a unit time.

(i) Units : s^{-1} or hertz (*Hz*). (ii) Dimension : $[M^0L^0T^{-1}]$

Note : ❑ Relation between time period and frequency : If n is the frequency of revolution of an object in circular motion, then the object completes n revolutions in 1 second. Therefore, the object will complete one revolution in $1/n$ second.

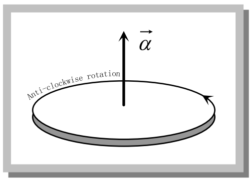
$$\therefore T = 1/n$$

❑ Relation between angular velocity, frequency and time period : Consider a point object describing a uniform circular motion with frequency n and time period T. When the object completes one revolution, the angle traced at its axis of circular motion is 2π radians. It means, when time $t = T$, $\theta = 2\pi$ radians. Hence, angular velocity $\omega = \frac{\theta}{t} = \frac{2\pi}{T} = 2\pi n$ $\quad (\because T = 1/n)$

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

(6) **Angular acceleration (α) :** Angular acceleration of an object in circular motion is defined as the time rate of change of its angular velocity.

(i) If $\Delta\omega$ be the change in angular velocity of the object in time interval t and $t + \Delta t$, while moving on a circular path, then angular acceleration of the object will be



$$\alpha = \underset{\Delta t \to 0}{Lt} \frac{\Delta\omega}{\Delta t} = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$$

(ii) Units : *rad*. s^{-2} (iii) Dimension : $[M^0L^0T^{-2}]$

(iv) Relation between linear acceleration and angular acceleration $\vec{a} = \vec{\alpha} \times \vec{r}$

(v) For uniform circular motion since ω is constant so $\alpha = \frac{d\omega}{dt} = 0$

(vi) For non-uniform circular motion $\alpha \neq 0$

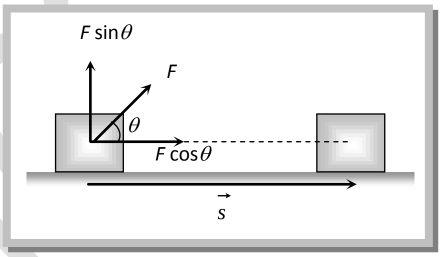
UNIT 4
WORK & FRICTION

Introduction.

The terms 'work', 'energy' and 'power' are frequently used in everyday language. A farmer clearing weeds in his field is said to be working hard. A woman carrying water from a well to her house is said to be working. Work is said to be done when a force applied on the body displaces the body through a certain distance in the direction of force.

Work Done by a Constant Force.

Let a constant force $\vec{F}$ be applied on the body such that it makes an angle θ with the horizontal and body is displaced through a distance s



By resolving force $\vec{F}$ into two components :

(i) $F\cos\theta$ in the direction of displacement of the body.

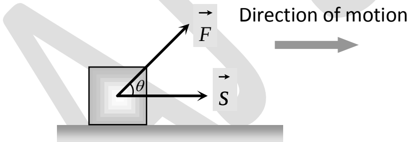
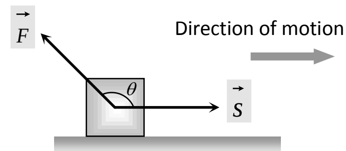
(ii) $F\sin\theta$ in the perpendicular direction of displacement of the body.

Since body is being displaced in the direction of $F\cos\theta$, therefore work done by the force in displacing the body through a distance s is given by

$$W = (F\cos\theta)s = Fs\cos\theta$$

or $$W = \vec{F}.\vec{s}$$

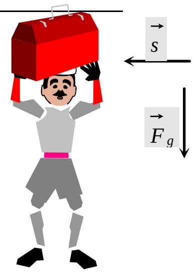
Thus work done by a force is equal to the scalar or dot product of the force and the displacement of the body.

Positive work	Negative work
Positive work means that force (or its component) is parallel to displacement  $0^o \le \theta < 90^o$	Negative work means that force (or its component) is opposite to displacement *i.e.* $90^o < \theta \le 180^o$ 
The positive work signifies that the external force favours the motion of the body.	The negative work signifies that the external force opposes the motion of the body.
Maximum work : $W_{max} = Fs$ When $\cos\theta = \text{maximum} = 1$ *i.e.* $\theta = 0^o$ It means force does maximum work when angle between force and displacement is zero.	Minimum work : $W_{min} = -Fs$ When $\cos\theta = \text{minimum} = -1$ *i.e* $\theta = 180^o$ It means force does minimum [maximum negative] work when angle between force and displacement is 180°.

Nature of Work Done.

Zero work
Under three condition, work done becomes zero $W = Fs\cos\theta = 0$

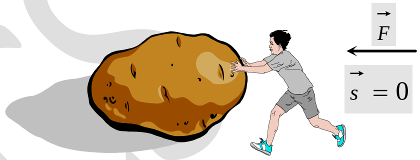
(1) **If the force is perpendicular to the displacement** $[\vec{F} \perp \vec{s}\,]$



Example: (i) When a coolie travels on a horizontal platform with a load on his head, work done against gravity by the coolie is zero

(ii) In case of motion of a charged particle in a magnetic field as force $[\vec{F} = q(\vec{v} \times \vec{B})]$ is always perpendicular to motion, work done by this force is always "0".

(2) **If there is no displacement [*s* = 0]**



Example: (i) When a person tries to displace a wall or heavy stone by applying a force then it does not move, the work done is zero.

(ii) A weight lifter does work in lifting the weight off the ground but does not work in holding it up.

(3) **If there is no force acting on the body [*F* = 0]**

Example: Motion of an isolated body in free space.

Dimension and Units of Work.

Dimension : As work = Force × displacement

$\therefore$ [*W*] = [Force] × [Displacement]

$$= [MLT^{-2}] \times [L] = [ML^2T^{-2}]$$

Units : The units of work are of two types

Absolute units	**Gravitational units**
Joule [S.I.]: Work done is said to be one *Joule*, when 1 *Newton* force displaces the body through 1 *meter* in its own direction. From *W* = *F.s* 1 *Joule* = 1 *Newton* × 1 *metre*	*kg-m* [S.I.]: 1 *Kg-m* of work is done when a force of 1*kg-wt.* displaces the body through 1*m* in its own direction. From *W* = *F s* 1 *kg-m* = 1 *kg-wt* × 1 *metre* = 9.81 *N* × 1 *metre* = 9.81 *Joule*
Erg [C.G.S.] : Work done is said to be one *erg* when 1 *dyne* force displaces the body through 1 *cm* in its own direction. From *W* = *F s* $1\,Erg = 1 Dyne \times 1cm$ **Relation between Joule and erg** 1 *Joule* = 1 *N* × 1 *m* = 10^5 *dyne* × 10^2 *cm* = 10^7 *dyne* × *cm* = 10^7 *Erg*	*gm-cm* [C.G.S.] : 1 *gm-cm* of work is done when a force of 1*gm-wt* displaces the body through 1*cm* in its own direction. From *W* = *F s* 1 *gm-cm* = 1*gm-wt* × 1*cm.* = 981 *dyne* × 1*cm* = 981 *erg*

FRICTION

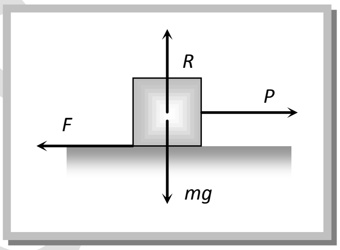
Introduction.

If we slide or try to slide a body over a surface the motion is resisted by a bonding between the body and the surface. This resistance is represented by a single force and is called friction.

The force of friction is parallel to the surface and opposite to the direction of intended motion.

Types of Friction.

(1) **Static friction :** The opposing force that comes into play when one body tends to move over the surface of another, but the actual motion has yet not started is called static friction.



(i) If applied force is P and the body remains at rest then static friction $F = P$.

(ii) If a body is at rest and no pulling force is acting on it, force of friction on it is zero.

(iii) Static friction is a self-adjusting force because it changes itself in accordance with the applied force.

(2) **Limiting friction :** If the applied force is increased the force of static friction also increases. If the applied force exceeds a certain (maximum) value, the body starts moving. This maximum value of static friction upto which body does not move is called limiting friction.

(i) The magnitude of limiting friction between any two bodies in contact is directly proportional to the normal reaction between them.

$$F_l \propto R \text{ or } F_l = \mu_s R$$

(ii) Direction of the force of limiting friction is always opposite to the direction in which one body is at the verge of moving over the other

(iii) Coefficient of static friction : (a) μ_s is called coefficient of static friction and defined as the ratio of force of limiting friction and normal reaction $\mu_s = \frac{F}{R}$

(b) Dimension : $[M^0 L^0 T^0]$

(c) Unit : It has no unit.

(d) Value of μ_s lies in between 0 and 1

(e) Value of μ depends on material and nature of surfaces in contact that means whether dry or wet ; rough or smooth polished or non-polished.

(f) Value of μ does not depend upon apparent area of contact.

(3) **Kinetic or dynamic friction :** If the applied force is increased further and sets the body in motion, the friction opposing the motion is called kinetic friction.

(i) Kinetic friction depends upon the normal reaction.

$F_k \propto R$ or $F_k = \mu_k R$ where μ_k is called the coefficient of kinetic friction

(ii) Value of μ_k depends upon the nature of surface in contact.

(iii) Kinetic friction is always lesser than limiting friction $F_k < F_l \quad \therefore \; \mu_k < \mu_s$

i.e. coefficient of kinetic friction is always less than coefficient of static friction. Thus we require more force to start a motion than to maintain it against friction. This is because once the motion starts actually ; inertia of rest has been overcome. Also when motion has actually started, irregularities of one surface have little time to get locked again into the irregularities of the other surface.

(iv) Types of kinetic friction

(a) **Sliding friction** : The opposing force that comes into play when one body is actually sliding over the surface of the other body is called sliding friction. *e.g.* A flat block is moving over a horizontal table.

(b) **Rolling friction** : When objects such as a wheel (disc or ring), sphere or a cylinder rolls over a surface, the force of friction comes into play is called rolling friction.

❑ Rolling friction is directly proportional to the normal reaction (R) and inversely proportional to the radius (r) of the rolling cylinder or wheel.

$$F_{rolling} = \mu_r \frac{R}{r}$$

μ_r is called coefficient of rolling friction. It would have the dimensions of length and would be measured in *metre*.

❑ Rolling friction is often quite small as compared to the sliding friction. That is why heavy loads are transported by placing them on carts with wheels.

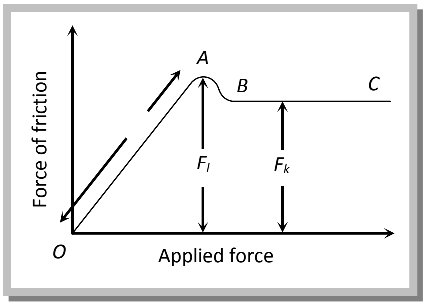
❑ In rolling the surfaces at contact do not rub each other.

❑ The velocity of point of contact with respect to the surface remains zero all the times although the centre of the wheel moves forward.

Graph Between Applied Force and Force of Friction.

(1) Part OA of the curve represents static friction (F_s). Its value increases linearly with the applied force

(2) At point A the static friction is maximum. This represent limiting friction (F_l).



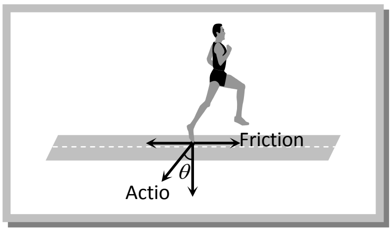
(3) Beyond A, the force of friction is seen to decrease slightly. The portion BC of the curve therefore represents the kinetic friction (F_k).

(4) As the portion BC of the curve is parallel to x-axis therefore kinetic friction does not change with the applied force, it remains constant, whatever be the applied force.

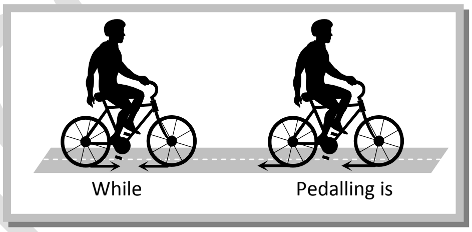
Friction is a Cause of Motion.

It is a general misconception that friction always opposes the motion. No doubt friction opposes the motion of a moving body but in many cases it is also the cause of motion. For example :

(1) In moving, a person or vehicle pushes the ground backwards (action) and the rough surface of ground reacts and exerts a forward force due to friction which causes the motion.If there had been no friction there will be slipping and no motion.



(2) In cycling, the rear wheel moves by the force communicated to it by pedalling while front wheel moves by itself. So, when pedalling a bicycle, the force exerted by rear wheel on ground makes force of friction act on it in the forward direction (like walking). Front wheel moving by itself experience force of friction in backward direction (like rolling of a ball). [However, if pedalling is stopped both wheels move by themselves and so experience force of friction in backward direction.]



From these examples it is clear that without friction motion cannot be started, stopped or transferred from one body to the other.

Methods of Changing Friction.

We can reduce friction

(1) By polishing.

(2) By lubrication.

(3) By proper selection of material.

(4) By streamlining the shape of the body.

(5) By using ball bearing.

Also we can increase friction by throwing some sand on slippery ground. In the manufacturing of tyres, synthetic rubber is preferred because its coefficient of friction with the road is larger.

UNIT 5

GRAVITATION

GRAVITATION

Introduction.

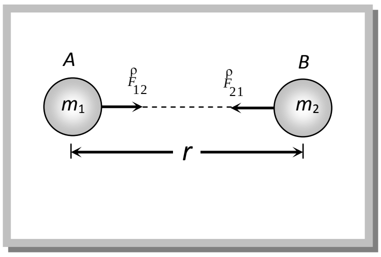
Newton at the age of twenty-three is said to have seen an apple falling down from tree in his orchid. This was the year 1665. He started thinking about the role of earth's attraction in the motion of moon and other heavenly bodies.

By comparing the acceleration due to gravity due to earth with the acceleration required to keep the moon in its orbit around the earth, he was able to arrive the Basic Law of Gravitation.

Newton's law of Gravitation .

Newton's law of gravitation states that every body in this universe attracts every other body with a force, which is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres. The direction of the force is along the line joining the particles.

Thus the magnitude of the gravitational force F that two particles of masses m_1 and m_2 separated by a distance r exert on each other is given by



$$F \propto \frac{m_1 m_2}{r^2}$$

or $$F = G\frac{m_1 m_2}{r^2}$$

Vector form : According to Newton's law of gravitation

$$\vec{F}_{12} = \frac{-Gm_1m_2}{r^2}\hat{r}_{21} = \frac{-Gm_1m_2}{r^3}\vec{r}_{21} = \frac{-Gm_1m_2}{|\vec{r}_{21}|^3}\vec{r}_{21}$$

$\hat{r}_{12}$ = unit vector from A to B

$\hat{r}_{21}$ = unit vector from B to A,

$\vec{F}_{12}$ = gravitational force exerted on body A by body B

Here negative sign indicates that the direction of $\vec{F}_{12}$ is opposite to that of $\hat{r}_{21}$.

Similarly $$\vec{F}_{21} = \frac{-Gm_1m_2}{r^2}\hat{r}_{12} = \frac{-Gm_1m_2}{r^3}\vec{r}_{12} = \frac{-Gm_1m_2}{|\vec{r}_{12}|^3}\vec{r}_{12}$$

$$= \frac{Gm_1m_2}{r^2}\hat{r}_{21} \quad [\because \hat{r}_{12} = -\hat{r}_{21}]$$

$\therefore$ It is clear that $\vec{F}_{12} = -\vec{F}_{21}$. Which is Newton's third law of motion.

Here G is constant of proportionality which is called 'Universal gravitational constant'.

If $m_1 = m_2$ and $r = 1$ then $G = F$

i.e. universal gravitational constant is equal to the force of attraction between two bodies each of unit mass whose centres are placed unit distance apart.

Important points

(i) The value of G in the laboratory was first determined by Cavendish using the torsional balance.

(ii) The value of G is 6.67×10^{-11} $N{-}m^2$ kg^{-2} in S.I. and 6.67×10^{-8} $dyne$- cm^2-g^{-2} in C.G.S. system.

(iii) Dimensional formula $[M^{-1}L^3T^{-2}]$.

(iv) The value of G does not depend upon the nature and size of the bodies.

(v) It also does not depend upon the nature of the medium between the two bodies.

(vi) As G is very small hence gravitational forces are very small, unless one (or both) of the masses is huge.

Acceleration Due to Gravity

The force of attraction exerted by the earth on a body is called gravitational pull or gravity.

We know that when force acts on a body, it produces acceleration. Therefore, a body under the effect of gravitational pull must accelerate.

The acceleration produced in the motion of a body under the effect of gravity is called acceleration due to gravity, it is denoted by g.

Consider a body of mass m is lying on the surface of earth then gravitational force on the body is given by

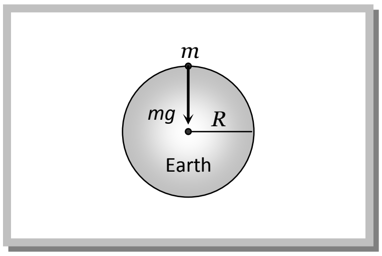
$$F = \frac{GMm}{R^2} \qquad .....(i)$$

Where M = mass of the earth and R = radius of the earth.

If g is the acceleration due to gravity, then the force on the body due to earth is given by

Force = mass × acceleration

or $\quad F = mg \qquad .....(ii)$



From (i) and (ii) we have $mg = \frac{GMm}{R^2}$

$$\therefore \quad g = \frac{GM}{R^2} \qquad .....(iii)$$

$$\Rightarrow \quad g = \frac{G}{R^2}\left(\frac{4}{3}\pi R^3\rho\right)$$ [As mass (M) = volume ($\frac{4}{3}\pi R^3$) × density (ρ)]

$$\therefore \quad g = \frac{4}{3}\pi\rho GR \qquad .....(iv)$$

Important points

(i) From the expression $g = \frac{GM}{R^2} = \frac{4}{3}\pi\rho GR$ it is clear that its value depends upon the mass radius and density of planet and it is independent of mass, shape and density of the body placed on the surface of the planet. *i.e.* a given planet (reference body) produces same acceleration in a light as well as heavy body.

(ii) The greater the value of (M/R^2) or ρR, greater will be value of g for that planet.

(iii) Acceleration due to gravity is a vector quantity and its direction is always towards the centre of the planet.

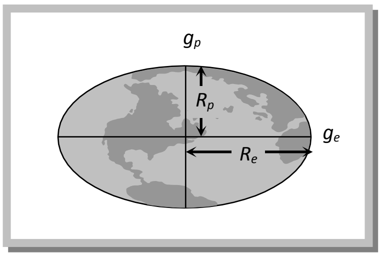
(iv) Dimension $[g] = [LT^{-2}]$

(v) it's average value is taken to be 9.8 m/s^2 or 981 cm/sec^2 or 32 $feet/sec^2$, on the surface of the earth at mean sea level.

(vi) The value of acceleration due to gravity vary due to the following factors : (a) Shape of the earth, (b) Height above the earth surface, (c) Depth below the earth surface and (d) Axial rotation of the earth.

Variation in g Due to Shape of Earth.

Earth is elliptical in shape. It is flattened at the poles and bulged out at the equator. The equatorial radius is about 21 *km* longer than polar radius, from $g = \frac{GM}{R^2}$



At equator $\quad g_e = \frac{GM}{R_e^2}$ .....(i)

At poles $\quad g_p = \frac{GM}{R_p^2}$ .....(ii)

From (i) and (ii) $\quad \frac{g_e}{g_p} = \frac{R_p^2}{R_e^2}$

Since $R_{equator} > R_{pole}$ $\therefore$ $g_{pole} > g_{equator}$ and $g_p = g_e + 0.018 \ ms^{-2}$

Therefore the weight of body increases as it is taken from equator to the pole.

Variation in g With Height.

Acceleration due to gravity at the surface of the earth

$$g = \frac{GM}{R^2} \quad .....(i)$$

Acceleration due to gravity at height h from the surface of the earth

$$g' = \frac{GM}{(R+h)^2} \quad .....(ii)$$

From (i) and (ii) $\quad g' = g\left(\frac{R}{R+h}\right)^2$ .....(iii)

$$= g\frac{R^2}{r^2} \qquad \text{.....(iv)} \qquad [\text{As } r = R + h]$$

Important points

(i) As we go above the surface of the earth, the value of g decreases because $g' \propto \frac{1}{r^2}$.

(ii) If $r = \infty$ then $g' = 0$, *i.e.*, at infinite distance from the earth, the value of g becomes zero.

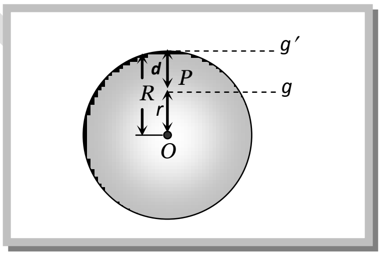
(iii) If $h << R$ *i.e.*, height is negligible in comparison to the radius then from equation (iii) we get

$$g' = g\left(\frac{R}{R+h}\right)^2 = g\left(1+\frac{h}{R}\right)^{-2} = g\left[1-\frac{2h}{R}\right] \qquad [\text{As } h << R]$$

Variation in *g* With Depth.

Acceleration due to gravity at the surface of the earth

$$g = \frac{GM}{R^2} = \frac{4}{3}\pi\rho GR \qquad \text{.....(i)}$$



Acceleration due to gravity at depth d from the surface of the earth

$$g' = \frac{4}{3}\pi\rho G(R-d) \qquad \text{.....(ii)}$$

From (i) and (ii) $\qquad g' = g\left[1-\frac{d}{R}\right]$

Important points

(i) The value of g decreases on going below the surface of the earth. From equation (ii) we get $g' \propto (R-d)$.

So it is clear that if d increase, the value of g decreases.

(ii) At the centre of earth $d = R \;\; \therefore \;\; g' = 0$, *i.e.*, the acceleration due to gravity at the centre of earth becomes zero.

(iii) Decrease in the value of g with depth

Absolute decrease $\Delta g = g - g' = \frac{dg}{R}$

Fractional decrease $\frac{\Delta g}{g} = \frac{g-g'}{g} = \frac{d}{R}$

Percentage decrease $\frac{\Delta g}{g} \times 100\,\% = \frac{d}{R} \times 100\,\%$

(iv) The rate of decrease of gravity outside the earth (if $h << R$) is double to that of inside the earth.

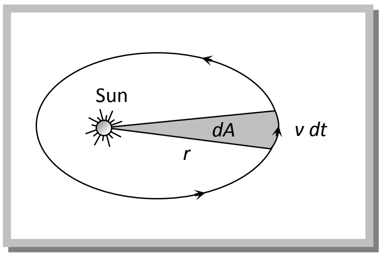
(4) **Comparison between mass and weight of the body**

Mass *(m)*	**Weight *(W)***
It is a quantity of matter contained in a body.	It is the attractive force exerted by earth on any body.
Its value does not change with g	Its value changes with g.
Its value can never be zero .	At infinity and at the centre of earth its value is zero.
Its unit is kilogram and its dimension is $[M]$.	Its unit is Newton or *kg-wt* and dimension are $[MLT^{-2}]$
It is determined by a physical balance.	It is determined by a spring balance.
It is a scalar quantity.	It is a vector quantity.

Kepler's Laws of Planetary Motion.

Planets are large natural bodies rotating around a star in definite orbits. The planetary system of the star sun called solar system consists of nine planets, viz., Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto. Out of these planets Mercury is the smallest, closest to the sun and so hottest. Jupiter is largest and has maximum moons (12). Venus is closest to Earth and brightest. Kepler after a life time study work out three empirical laws which govern the motion of these planets and are known as *Kepler's laws of planetary motion*. These are,

(1) **The law of Orbits** : Every planet moves around the sun in an elliptical orbit with sun at one of the foci.



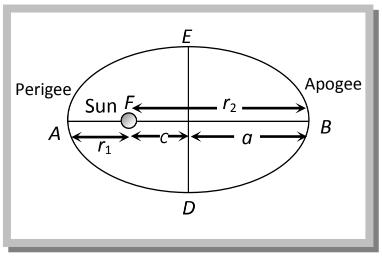
(2) **The law of Area** : The line joining the sun to the planet sweeps out equal areas in equal interval of time. *i.e.* areal velocity is constant. According to this law planet will move slowly when it is farthest from sun and more rapidly when it is nearest to sun. It is similar to law of conservation of angular momentum.

$$\text{Areal velocity } = \frac{dA}{dt} = \frac{1}{2}\frac{r(vdt)}{dt} = \frac{1}{2}rv$$

$$\therefore \quad \frac{dA}{dt} = \frac{L}{2m} \qquad \left[\text{As } L = mvr\,;\; rv = \frac{L}{m}\right]$$

(3) **The law of periods** : The square of period of revolution (T) of any planet around sun is directly proportional to the cube of the semi-major axis of the orbit.

$$T^2 \propto a^3 \text{ or } T^2 \propto \left(\frac{r_1 + r_2}{2}\right)^3$$



Proof : From the figure $AB = AF + FB$

$$2a = r_1 + r_2 \quad \therefore a = \frac{r_1 + r_2}{2} \qquad \text{where } a = \text{semi-major axis}$$

r_1 = Shortest distance of planet from sun (perigee).

r_2 = Largest distance of planet from sun (apogee).

UNIT 6
OSCILLATIONS & WAVES

OSCILLATIONS

Periodic Motion.

A motion, which repeat itself over and over again after a regular interval of time is called a periodic motion and the fixed interval of time after which the motion is repeated is called period of the motion.

Examples :

(i) Revolution of earth around the sun (period one year)

(ii) Motion of hour's hand of a clock (period 12-hour)

Oscillatory or Vibratory Motion.

Oscillatory or vibratory motion is that motion in which a body moves to and fro or back and forth repeatedly about a fixed point in a definite interval of time. In such a motion, the body is confined with in well-defined limits on either side of mean position.

Oscillatory motion is also called as harmonic motion.

Example :

(i) The motion of the pendulum of a wall clock.

(ii) The motion of a load attached to a spring, when it is pulled and then released.

Harmonic and Non-harmonic Oscillation.

Harmonic oscillation is that oscillation which can be expressed in terms of single harmonic function (*i.e.* sine or cosine function). *Example* : $y = a\sin\omega t$ or $y = a\cos\omega t$

Non-harmonic oscillation is that oscillation which can not be expressed in terms of single harmonic function. It is a combination of two or more than two harmonic oscillations. *Example* : $y = a\sin\omega t + b\sin 2\omega t$

Some Important Definitions.

(1) **Time period :** It is the least interval of time after which the periodic motion of a body repeats itself.

S.I. units of time period is second.

(2) **Frequency :** It is defined as the number of periodic motions executed by body per second. S.I unit of frequency is hertz (*Hz*).

(3) **Angular Frequency :** Angular frequency of a body executing periodic motion is equal to product of frequency of the body with factor 2π. Angular frequency $\omega = 2\ \pi n$

S.I. units of ω is *Hz* [S.I.] ω also represents angular velocity. In that case unit will be *rad/sec.*

(4) **Displacement :** In general, the name displacement is given to a physical quantity which undergoes a change with time in a periodic motion.

(5) **Phase :** phase of a vibrating particle at any instant is a physical quantity, which completely express the position and direction of motion, of the particle at that instant with respect to its mean position. In oscillatory motion the phase of a vibrating particle

is the argument of *sine* or *cosine* function involved to represent the generalised equation of motion of the vibrating particle.

$y = a\sin\theta = a\sin(\omega t + \phi_0)$ here, $\theta = \omega t + \phi_0$ = phase of vibrating particle.

Simple Harmonic Motion.

Simple harmonic motion is a special type of periodic motion, in which a particle moves to and fro repeatedly about a mean position under a restoring force which is always directed towards the mean position and whose magnitude at any instant is directly proportional to the displacement of the particle from the mean position at that instant.

Restoring force $\propto$ Displacement of the particle from mean position.

$$F \propto -x$$

$$F = -kx$$

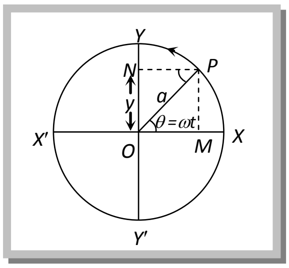
Where k is known as force constant.

Its S.I. unit is Newton/meter and dimension is $[MT^{-2}]$.

Displacement in S.H.M..

The displacement of a particle executing S.H.M. at an instant is defined as the distance of particle from the mean position at that instant.

As we know that simple harmonic motion is defined as the projection of uniform circular motion on any diameter of circle of reference. If the projection is taken on y-axis.



then from the figure $y = a\sin\omega t$

$$y = a\sin\frac{2\pi}{T}t$$

$$y = a\sin 2\pi n t$$

$$y = a\sin(\omega t \pm \phi)$$

where a = Amplitude, ω = Angular frequency, t = Instantaneous time,

T = Time period, n = Frequency and ϕ = Initial phase of particle

If the projection of P is taken on X-axis then equations of S.H.M. can be given as

$$x = a\cos(\omega t \pm \phi)$$

$$x = a\cos\left(\frac{2\pi}{T}t \pm \phi\right)$$

$$x = a\cos(2\pi n t \pm \phi)$$

Important points

(i) $y = a\sin\omega t$ when the time is noted from the instant when the vibrating particle is at mean position.

(ii) $y = a\cos\omega t$ when the time is noted from the instant when the vibrating particle is at extreme position.

(iii) $y = a\sin(\omega t \pm \phi)$ when the vibrating particle is ϕ phase leading or lagging from the mean position.

(iv) Direction of displacement is always away from the equilibrium position, particle either is moving away from or is coming towards the equilibrium position.

Velocity in S.H.M..

Velocity of the particle executing S.H.M. at any instant, is defined as the time rate of change of its displacement at that instant.

In case of S.H.M. when motion is considered from the equilibrium position

$$y = a\sin\omega t$$

so $$v = \frac{dy}{dt} = a\omega\cos\omega t$$

$\therefore$ $$v = a\omega\cos\omega t \quad \text{......(i)}$$

or $$v = a\omega\sqrt{1-\sin^2\omega t} \quad [\text{As } \sin\omega t = y/a]$$

or $$v = \omega\sqrt{a^2 - y^2} \quad \text{.....(ii)}$$

Acceleration in S.H.M..

The acceleration of the particle executing S.H.M. at any instant, is defined as the rate of change of its velocity at that instant. So acceleration $A = \frac{dv}{dt} = \frac{d}{dt}(a\omega\cos\omega t)$

$$A = -\omega^2 a\sin\omega t \quad \text{......(i)}$$

$$A = -\omega^2 y \quad \text{......(ii) [As } y = a\sin\omega t\text{]}$$

Various physical quantities in S.H.M. at different position :

Physical quantities	Equilibrium position (y = 0)	Extreme Position ($y = \pm a$)
Displacement $y = a\sin\omega t$	Minimum (Zero)	Maximum (a)
Velocity $v = \omega\sqrt{a^2 - y^2}$	Maximum ($a\omega$)	Minimum (Zero)
Acceleration $\lvert A\rvert = \omega^2 y$	Minimum (Zero)	Maximum ($\omega^2 a$)

Wave.

A wave is a disturbance which propagates energy and momentum from one place to the other without the transport of matter.

(1) **Necessary properties of the medium for wave propagation :**

(i) Elasticity : So that particles can return to their mean position, after having been disturbed.

(ii) Inertia : So that particles can store energy and overshoot their mean position.

(iii) Minimum friction amongst the particles of the medium.

(iv) Uniform density of the medium.

(2) **Characteristics of wave motion :**

(i) It is a sort of disturbance which travels through a medium.

(ii) Material medium is essential for the propagation of mechanical waves.

(3) **Mechanical waves :** The waves which require medium for their propagation are called mechanical waves.

Example : Waves on string and spring, waves on water surface, sound waves, seismic waves.

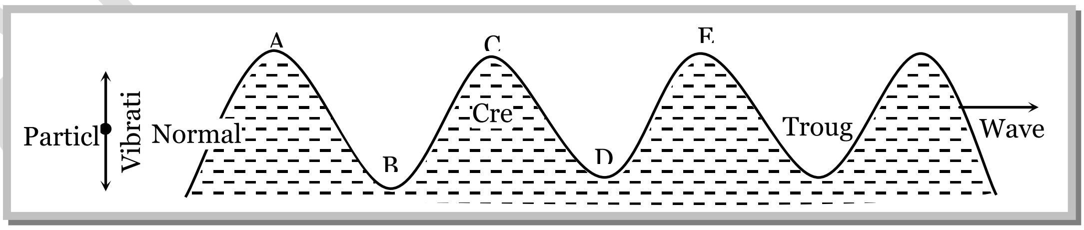
(4) **Non-mechanical waves :** The waves which do not require medium for their propagation are called non- mechanical or electromagnetic waves.

Examples : Light, heat (Infrared), radio waves, γ- rays, *X*-rays *etc*.

(5) **Transverse waves :** Particles of the medium execute simple harmonic motion about their mean position in a direction perpendicular to the direction of propagation of wave motion.

(i) It travels in the form of crests and troughs.

(ii) A crest is a portion of the medium which is raised temporarily above the normal position of rest of the particles of the medium when a transverse wave passes through it.

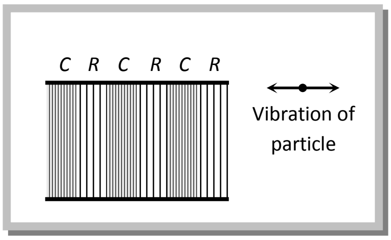


(iii) A trough is a portion of the medium which is depressed temporarily below the normal position of rest of the particles of the medium, when transverse wave passes through it.

(iv) Examples of transverse wave motion : Movement of string of a sitar or violin, movement of the membrane of a Tabla or Dholak, movement of kink on a rope, waves set-up on the surface of water.

(v) Transverse waves can be transmitted through solids, they can be setup on the surface of liquids. But they can not be transmitted into liquids and gases.

(6) **Longitudinal waves :** If the particles of a medium vibrate in the direction of wave motion the wave is called longitudinal.



(i) It travels in the form of compression and rarefaction.

(ii) A compression (C) is a region of the medium in which particles are compressed.

(iii) A rarefaction (R) is a region of the medium in which particles are rarefied.

(iv) Examples sound waves travel through air in the form of longitudinal waves, Vibration of air column in organ pipes are longitudinal, Vibration of air column above the surface of water in the tube of resonance apparatus are longitudinal.

(v) These waves can be transmitted through solids, liquids and gases because for these waves propagation, volume elasticity is necessary.

(7) **One dimensional wave :** Energy is transferred in a single direction only.

Example : Wave propagating in a stretched string.

(8) **Two dimensional wave :** Energy is transferred in a plane in two mutually perpendicular directions.

Example : Wave propagating on the surface of water.

(9) **Three dimensional wave :** Energy in transferred in space in all direction.

Example : Light and sound waves propagating in space.

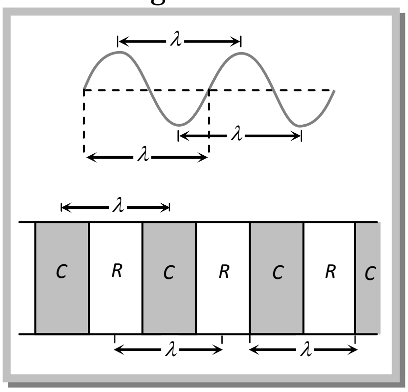
Important Terms Regarding Wave Motion.

(1) **Wavelength :** (i) It is the length of one wave.

(ii) Wavelength is equal to the distance travelled by the wave during the time in which any one particle of the medium completes one vibration about its mean position.

(iii) Wavelength is the distance between any two nearest particles of the medium, vibrating in the same phase.

(iv) Distance travelled by the wave in one time period is known as wavelength.



(v) In transverse wave motion :

λ = Distance between the centres of two consecutive crests.

λ = Distance between the centres of two consecutive troughs.

λ = Distance in which one trough and one crest are contained.

(vi) In longitudinal wave motion :

λ = Distance between the centres of two consecutive compression.

λ = Distance between the centres of two consecutive rarefaction.

λ = Distance in which one compression and one rarefaction contained.

(2) **Frequency :** (i) Frequency of vibration of a particle is defined as the number of vibrations completed by particle in one second.

(ii) It is the number of complete wavelengths traversed by the wave in one second.

(iii) Units of frequency are hertz (*Hz*) and per second.

(3) **Time period :** (i) Time period of vibration of particle is defined as the time taken by the particle to complete one vibration about its mean position.

(ii) It is the time taken by the wave to travel a distance equal to one wavelength.

(4) **Relation between frequency and time period :** Time period = 1/Frequency ⇒ $T = 1/n$

(5) **Relation between velocity, frequency and wavelength :** $v = n\lambda$

Velocity (v) of the wave in a given medium depends on the elastic and inertial property of the medium.

Frequency (n) is characterised by the source which produces disturbance. Different sources may produce vibration of different frequencies. Wavelength (λ) will differ to keep $n\lambda = v$ = constant

Sound Waves.

The energy to which the human ears are sensitive is known as sound. In general all types of waves are produced in an elastic material medium, Irrespective of whether these are heard or not are known as sound.

According to their frequencies, waves are divided into three categories :

(1) **Audible or sound waves :** Range 20 *Hz* to 20 *KHz.* These are generated by vibrating bodies such as vocal cords, stretched strings or membrane.

(2) **Infrasonic waves :** Frequency lie below 20 *Hz.*

Example : waves produced during earth quake, ocean waves *etc.*

(3) **Ultrasonic waves :** Frequency greater than 20 *KHz.* Human ear cannot detect these waves, certain creatures such as mosquito, dog and bat show response to these. As velocity of sound in air is 332 m/sec so the wavelength of ultrasonics $\lambda < 1.66$ *cm* and for infrasonics $\lambda > 16.6$ *m*.

Note : ❑ **Supersonic speed :** An object moving with a speed greater than the speed of sound is said to move with a supersonic speed.

❑ **Mach number :** It is the ratio of velocity of source to the velocity of sound.

$$\text{Mach Number} = \frac{\text{Velocity of source}}{\text{Velocity of sound}}.$$

❑ Difference between sound and light waves :

(i) For propagation of sound wave material medium is required but no material medium is required for light waves.

(ii) Sound waves are longitudinal but light waves are transverse.

(iii) Wavelength of sound waves ranges from 1.65 *cm* to 16.5 meter and for light it ranges from 4000 Å to 2000 Å.

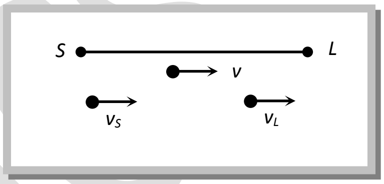
Doppler Effect.

Whenever there is a relative motion between a source of sound and the listener, the apparent frequency of sound heard by the listener is different from the actual frequency of sound emitted by the source.

When the distance between the source and listener is decreasing the apparent frequency increases. It means the apparent frequency is more than the actual frequency of sound. The reverse is also true.

General expression for apparent frequency $n' = \frac{[(v+v_m)-v_L]n}{[(v+v_m)-v_S]}$

Here n = Actual frequency; v_L = Velocity of listener;



v_S = Velocity of source

v_m = Velocity of medium and

v = Velocity of sound wave

Sign convention : All velocities along the direction S to L are taken as positive and all velocities along the direction L to S are taken as negative. If the medium is stationary $v_m = 0$ then $n' = \left(\frac{v-v_L}{v-v_S}\right)n$

APPLICATIONS OF DOPPLER'S EFFECT:-

Principle of Doppler's effect is used in **RADAR** to determine the position, distance and velocity of fast moving objects in SKY relative to the ground. Electromagnetic waves used in RADAR do not require a medium for propagation.

Also used in **SONAR** to determine the position, distance and velocity of submarines relative to the Ocean.

Used in **ASTROPHYSICS** to locate position, distance and velocity of Stars. The light received from the stars are found to have Doppler's shift to frequency towards red end of the spectrum. This indicates stars are moving away from us.

Check speed of Automobiles: - A traffic officer can calculate the speed of an approaching or receding automobile by noting a change in the pitch of its horn. If the speed crosses safe limit, the driver can be booked for rash driving.

UNIT 7

HEAT & THERMODYNAMICS

HEAT

The energy associated with configuration and random motion of the atoms and molecules with in a body is called internal energy and the part of this internal energy which is transferred from one body to the other due to temperature difference is called heat.

(1) As it is a type of energy, it is a scalar.

(2) Dimension : $[ML^2T^{-2}]$.

(3) Units : *Joule* (S.I.) and *calorie* (Practical unit)

One calorie is defined as the amount of heat energy required to raise the temperature of one *gm* of water through $1°C$ (more specifically from $14.5°C$ to $15.5°C$).

(4) As heat is a form of energy it can be transformed into others and *vice-versa*.

(5) When mechanical energy (work) is converted into heat, the ratio of work done (W) to heat produced (Q) always remains the same and constant, represented by J.

$$\frac{W}{Q} = J \qquad \text{or} \qquad W = JQ$$

J is called mechanical equivalent of heat and has value 4.2 J/cal. J is not a physical quantity but a conversion factor which merely express the equivalence between *Joule* and *calories*.

$$1\ calorie = 4.186\ Joule \simeq 4.12\ Joule$$

Temperature.

Temperature is defined as the degree of hotness or coldness of a body. The natural flow of heat is from higher temperature to lower temperature.

Two bodies are said to be in thermal equilibrium with each other, when no heat flows from one body to the other. That is when both the bodies are at the same temperature.

(1) Temperature is one of the seven fundamental quantities with dimension $[\theta]$.

(2) It is a scalar physical quantity with S.I. unit kelvin.

(3) When heat is given to a body and its state does not change, the temperature of the body rises and if heat is taken from a body its temperature falls *i.e.* temperature can be regarded as the effect of cause "heat".

Scales of Temperature.

The Kelvin temperature scale is also known as thermodynamic scale. The S.I. unit of temperature is *kelvin* and is defined as (1/273.16) of the temperature of the triple point of water. The triple point of water is that point on a *P-T* diagram where the three phases of water, the solid, the liquid and the gas, can coexist in equilibrium.

In addition to kelvin temperature scale, there are other temperature scales also like Celsius, Fahrenheit, Reaumer, Rankine *etc*.

Thermal Expansion.

When matter is heated without any change in state, it usually expands. According to atomic theory of matter, a symmetry in potential energy curve is responsible for thermal expansion. As with rise in temperature the amplitude of vibration and hence energy of atoms increases, hence the average distance between the atoms increases. So the matter as a whole expands.

(1) Thermal expansion is minimum in case of solids but maximum in case of gases because intermolecular force is maximum in solids but minimum in gases.

(2) Solids can expand in one dimension (linear expansion), two dimension (superficial expansion) and three dimension (volume expansion) while liquids and gases usually suffers change in volume only.

(3) The coefficient of linear expansion of the material of a solid is defined as the increase in its length per unit length per unit rise in its temperature.

$$\alpha = \frac{\Delta L}{L} \times \frac{1}{\Delta T}$$

Similarly the coefficient of superficial expansion $\beta = \frac{\Delta A}{A} \times \frac{1}{\Delta T}$

and coefficient of volume expansion $\gamma = \frac{\Delta V}{V} \times \frac{1}{\Delta T}$

The value of α, β and γ depends upon the nature of material. All have dimension $[\theta^{-1}]$ and unit per °C.

(4) As $\alpha = \frac{\Delta L}{L} \times \frac{1}{\Delta T}$, $\beta = \frac{\Delta A}{A} \times \frac{1}{\Delta T}$ and $\gamma = \frac{\Delta V}{V} \times \frac{1}{\Delta T}$

$\therefore$ $\Delta L = L\alpha \Delta T$, $\Delta A = A\beta \Delta T$ and $\Delta V = V\gamma \Delta T$

Final length $L' = L + \Delta L = L(1 + \alpha \Delta T)$ .....(i)

Final area $A' = A + \Delta A = A(1 + \beta \Delta T)$ .....(ii)

Final volume $V' = V + \Delta V = V(1 + \gamma \Delta T)$ .....(iii)

(5) If L is the side of square plate and it is heated by temperature ΔT, then its side becomes L'.

The initial surface area $A = L^2$ and final surface $A' = L'^2$

$$\therefore \quad \frac{A'}{A} = \left(\frac{L'}{L}\right)^2 = \left(\frac{L(1 + \alpha \Delta T)}{L}\right)^2 = (1 + \alpha \Delta T)^2 = (1 + 2\alpha \Delta T)$$ [Using Binomial theorem]

or $A' = A(1 + 2\alpha \Delta T)$

Comparing with equation (ii) we get $\beta = 2\alpha$

Similarly for volumetric expansion $\frac{V'}{V} = \left(\frac{L'}{L}\right)^3 = \left(\frac{L(1 + \alpha \Delta T)}{L}\right)^3 = (1 + \alpha \Delta T)^3 = (1 + 3\alpha \Delta T)$ [Using Binomial theorem]

or $V' = V(1 + \gamma \Delta T)$

Comparing with equation (iii), we get $\gamma = 3\alpha$

So $\alpha : \beta : \gamma = 1 : 2 : 3$

(i) Hence for the same rise in temperature

Percentage change in area = 2 × percentage change in length.

Percentage change in volume = 3 × percentage change in length.

(ii) The three coefficients of expansion are not constant for a given solid. Their values depends on the temperature range in which they are measured.

(iii) The values of α, β, γ are independent of the units of length, area and volume respectively.

(iv) For anisotropic solids $\gamma = \alpha_x + \alpha_y + \alpha_z$ where α_x, α_y, and α_z represent the mean coefficients of linear expansion along three mutually perpendicular directions.

Specific Heat.

(1) **Gram specific heat :** When heat is given to a body and its temperature increases, the heat required to raise the temperature of unit mass of a body through 1°*C* (or *K*) is called specific heat of the material of the body.

If *Q* heat changes the temperature of mass *m* by ΔT

Specific heat $c = \frac{Q}{m\Delta T}$.

Units : *Calorie/gm* × °*C* (practical), *J/kg* × *K* (S.I.) Dimension : $[L^2T^{-2}\theta^{-1}]$

Latent Heat.

(1) When a substance changes from one state to another state (say from solid to liquid or liquid to gas or from liquid to solid or gas to liquid) then energy is either absorbed or liberated. This heat energy is called latent heat.

(2) No change in temperature is involved when the substance changes its state. That is, phase transformation is an isothermal change. Ice at 0°*C* melts into water at 0°*C*. Water at 100°*C* boils to form steam at 100°*C*.

(3) The amount of heat required to change the state of the mass *m* of the substance is written as : $\Delta Q = mL$, where *L* is the latent heat. Latent heat is also called as Heat of Transformation.

(4) Unit : *cal/gm* or *J/kg* and Dimension : $[L^2T^{-2}]$

(5) Any material has two types of latent heats

(i) Latent heat of fusion : The latent heat of fusion is the heat energy required to change 1 *kg* of the material in its solid state at its melting point to 1 *kg* of the material in its liquid state. It is also the amount of heat energy released when at melting point 1 *kg* of liquid changes to 1 *kg* of solid. For water at its normal freezing temperature or melting point (0°*C*), the latent heat of fusion (or latent heat of ice) is

$$L_F = L_{\text{ice}} \approx 80\ cal/g \approx 60\ kJ/mol \approx 336\ kilo\ joule/kg.$$

(ii) Latent heat of vaporisation : The latent heat of vaporisation is the heat energy required to change 1 *kg* of the material in its liquid state at its boiling point to 1 *kg* of the material in its gaseous state. It is also the amount of heat energy released when 1 *kg* of vapour changes into 1 *kg* of liquid. For water at its normal boiling point or condensation temperature (100°*C*), the latent heat of vaporisation (latent heat of steam) is

$$L_V = L_{\text{steam}} \approx 540\ cal/g \approx 40.8\,kJ/mol \approx 2260\ kilo\,joule/kg$$

(iv) Latent heat of vaporisation is more than the latent heat of fusion. This is because when a substance gets converted from liquid to vapour, there is a large increase in volume. Hence more amount of heat is required. But when a solid gets converted to a liquid, then the increase in volume is negligible. Hence very less amount of heat is required. So, latent heat of vaporisation is more than the latent heat of fusion.

Joule's Law.

Whenever heat is converted into mechanical work or mechanical work is converted into heat, then the ratio of work done to heat produced always remains constant.

i.e. $W \propto Q$ or $\frac{W}{Q} = J$

This is Joule's law and J is called mechanical equivalent of heat.

Important points

(1) From $W = JQ$ if $Q = 1$ then $J = W$. Hence the amount of work done necessary to produce unit amount of heat is defined as the mechanical equivalent of heat.

(2) J is neither a constant, nor a physical quantity rather it is a conversion factor which used to convert *Joule* or *erg* into *calorie* or *kilo calories* vice-versa.

(3) Value of $J = 4.2\frac{J}{calorie} = 4.2\times10^7\frac{erg}{calorie} = 4.2\times10^3\frac{J}{kilocalorie}$.

First Law of Thermodynamics.

It is a statement of conservation of energy in thermodynamical process.

According to it heat given to a system (ΔQ) is equal to the sum of increase in its internal energy (ΔU) and the work done (ΔW) by the system against the surroundings.

$$\Delta Q = \Delta U + \Delta W$$

Important points

(1) It makes no distinction between work and heat as according to it the internal energy (and hence temperature) of a system may be increased either by adding heat to it or doing work on it or both.

(2) ΔQ and ΔW are the path functions but ΔU is the point function.

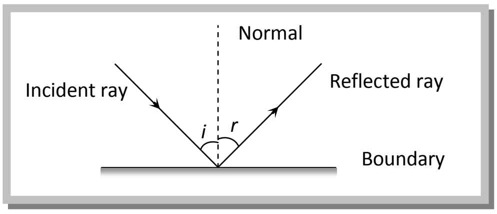
(3) In the above equation all three quantities ΔQ, ΔU and ΔW must be expressed either in *Joule* or in *calorie*.

(4) Just as zeroth law of thermodynamics introduces the concept of temperature, the first law introduces the concept of internal energy.

UNIT 8
OPTICS

Reflection of Light

When a ray of light after incidenting on a boundary separating two media comes back into the same media, then this phenomenon, is called reflection of light.



⇒ $\angle i = \angle r$

⇒ After reflection, velocity, wave length and frequency of light remains same but intensity decreases

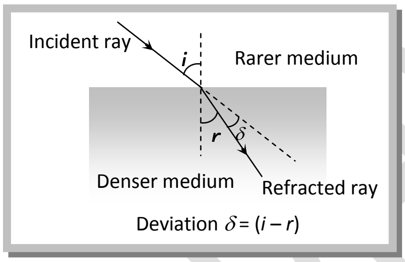
⇒ There is a phase change of π if reflection takes place from denser medium

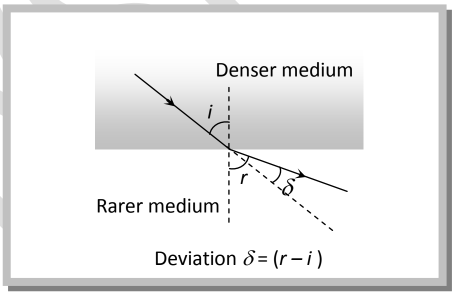
Note : ❑ After reflection velocity, wavelength and frequency of light remains same but intensity decreases.

If light ray incident normally on a surface, after reflection it retraces the path.

Refraction of Light

The bending of the ray of light passing from one medium to the other medium is called refraction.





Snell's law

The ratio of sine of the angle of incidence to the angle of refraction (r) is a constant called refractive index *i.e.* $\frac{\sin i}{\sin r} = \mu$ (a constant). For two media, Snell's law can be written as ${}_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{\sin i}{\sin r}$

$\Rightarrow \mu_1 \times \sin i = \mu_2 \times \sin r$ *i.e.* $\mu \sin \theta =$ constant

Also in vector form : $\hat{\boldsymbol{i}} \times \hat{\boldsymbol{n}} = \boldsymbol{\mu}(\hat{\boldsymbol{r}} \times \hat{\boldsymbol{n}})$

Refractive Index.

Refractive index of a medium is that characteristic which decides speed of light in it. It is a scalar, unit less and dimensionless quantity

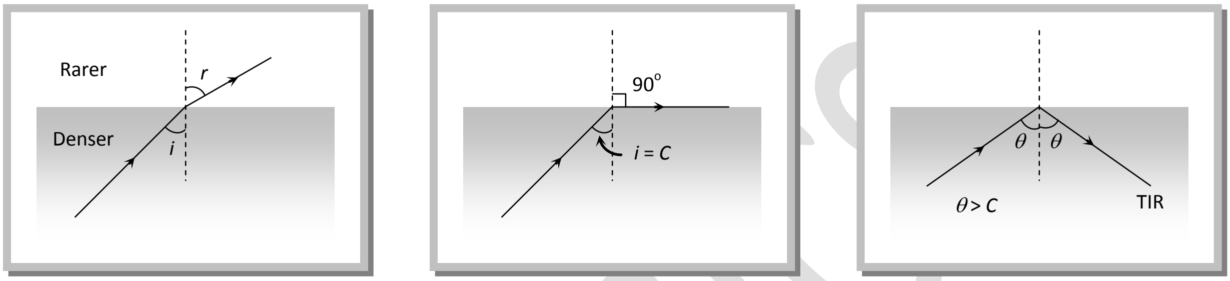
.(1) **Types :** It is of following two types

Absolute refractive index	Relative refractive index
(i) When light travels from air to any transparent medium then R.I. of medium *w.r.t.* air is called it's absolute R.I. *i.e.* ${}_{\text{air}}\mu_{\text{medium}} = \frac{c}{v}$	(i) When light travels from medium (1) to medium (2) then R.I. of medium (2) *w.r.t.* medium (1) is called it's relative R.I. *i.e.* ${}_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{v_1}{v_2}$ (where v_1 and v_2 are the speed of light in medium 1 and 2 respectively).

Total Internal Reflection.

When a ray of light goes from denser to rarer medium it bends away from the normal and as the angle of incidence in denser medium increases, the angle of refraction in rarer medium also increases and at a certain angle, angle of refraction becomes 90°, this angle of incidence is called critical angle (C).

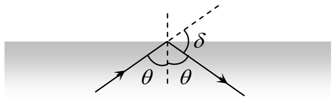
When Angle of incidence exceeds the critical angle than light ray comes back in to the same medium after reflection from interface. This phenomenon is called Total internal reflection (TIR).



Important formula $\mu = \frac{1}{\sin C} = \text{cosec } C$; where $\mu \rightarrow {}_{\text{Rerer}}\mu_{\text{Denser}}$

Note : ❑ When a light ray travels from denser to rarer medium, then deviation of the ray is $\delta = \pi - 2\theta \Rightarrow \delta \rightarrow \text{max.}$ when $\theta \rightarrow \text{min.} = C$

i.e. $\delta_{\max} = (\pi - 2C)$; $C \rightarrow$ critical angle



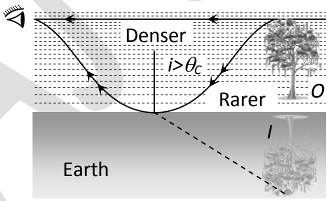
(1) **Dependence of critical angle**

(i) Colour of light (or wavelength of light) : Critical angle depends upon wavelength as $\lambda \propto \frac{1}{\mu} \propto \sin C$

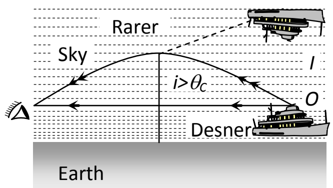
(iii) Temperature : With temperature rise refractive index of the material decreases therefore critical angle increases.

(2) **Examples of total internal reflection (TIR)**

(i)



Mirage : An optical illusion in deserts



Looming : An optical illusion in cold countries

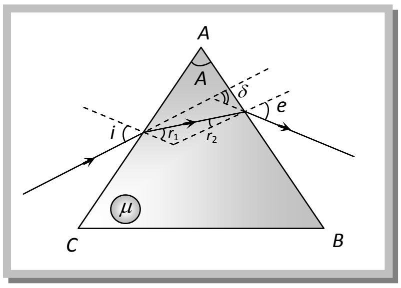
(ii) **Brilliance of diamond:** Due to repeated internal reflections diamond sparkles.

Prism

Prism is a transparent medium bounded by refracting surfaces, such that the incident surface (on which light ray is incidenting) and emergent surface (from which light rays emerges) are plane and non parallel.

i – Angle of incidence, e – Angle of emergence, A – Angle of prism or refracting angle of prism, r_1 and r_2 – Angle of refraction, δ – Angle of deviation

(1) **Refraction through a prism**



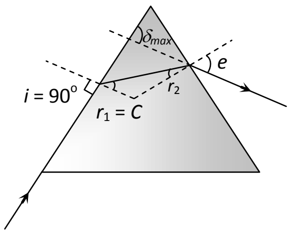
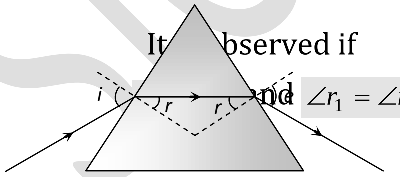
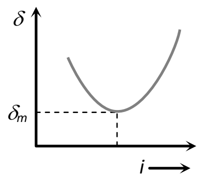
$$A = r_1 + r_2 \text{ and } i + e = A + \delta$$

For surface AC $\mu = \dfrac{\sin i}{\sin r_1}$;

For surface AB $\mu = \dfrac{\sin r_2}{\sin e}$

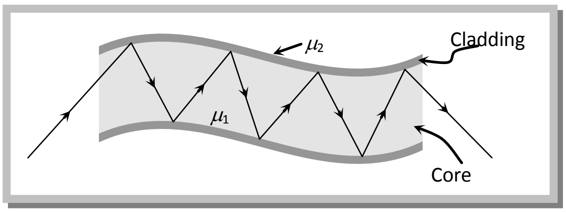
(2) **Deviation through a prism**

For thin prism $\delta = (\mu - 1)A$. Also deviation is different for different colour light e.g. $\mu_R < \mu_V$ so $\delta_R < \delta_V$. And $\mu_{\text{Flint}} > \mu_{\text{Crown}}$ so $\delta_F > \delta_C$

Maximum deviation	**Minimum deviation**
	It bserved if nd $\angle r_1 = \angle r_2 = r$ 
In this condition of maximum deviation $\angle i = 90^o$, $r_1 = C$, $r_2 = A - C$ and from Snell's law on emergent surface $e = \sin^{-1}\left[\dfrac{\sin(A-C)}{\sin C}\right]$	(i) Refracted ray inside the prism is parallel to the base of the prism  (ii) $r = \dfrac{A}{2}$ and $i = \dfrac{A+\delta_m}{2}$ (iii) $\mu = \dfrac{\sin i}{\sin A/2}$ or $\mu = \dfrac{\sin \dfrac{A+\delta_m}{2}}{\sin A/2}$

OPTICAL FIBRE : Optical fibres consist of many long high quality composite glass/quartz fibres. Each fibre consists of a core and cladding. The refractive index of the material of the core (μ_1) is higher than that of the cladding (μ_2).

When the light is incident on one end of the fibre at a small angle, the light passes inside, undergoes repeated total internal reflections along the fibre and finally comes out. The angle of incidence is always larger than the critical angle of the core material with respect to its cladding. Even if the fibre is bent, the light can easily travel through along the fibre



A bundle of optical fibres can be used as a 'light pipe' in medical and optical examination. It can also be used for optical signal transmission. Optical fibres have also been used for transmitting and receiving electrical signals which are converted to light by suitable transducers.

UNIT 9

ELECTROSTATICS AND MAGNETOSTATICS

ELECTROSTATICS

Study of Electricity in which electric charges are static i.e. not moving, is called electrostatics

- **STATIC CLING**
- An electrical phenomenon that accompanies dry weather, causes these pieces of papers to stick to one another and to the plastic comb.
- Due to this reason our clothes stick to our body.

- **ELECTRIC CHARGE :** Electric charge is characteristic developed in particle of material due to which it exert force on other such particles. It automatically accompanies the particle wherever it goes.
- Charge cannot exist without material carrying it
- It is possible to develop the charge by **rubbing two solids having friction.**
- Carrying the charges is called **electrification**.
- Electrification due to friction is called **frictional electricity**.

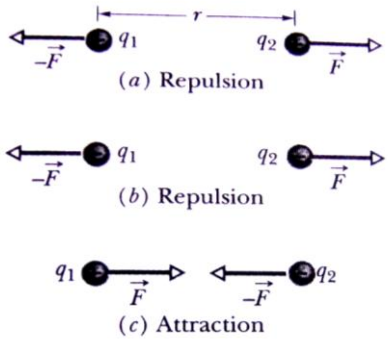
Since these charges are not flowing it is also called static electricity.

There are two types of charges. +ve and –ve.

- Similar charges repel each other,
- Opposite charges attract each other.
- Benjamin Franklin made this nomenclature of charges being +ve and –ve for mathematical calculations because adding them together cancel each other.
- Any particle has vast amount of charges.
- The number of positive and negative charges are **equal**, hence **matter is basically neutral.**
- Inequality of charges give the material a **net** charge which is equal to the difference of the two type of charges.
-

Electric Force - Coulumb's Law

- Coulumb's law in Electrostatics :



Force of Interaction between two stationery point charges is

directly proportional to the product of the charges,

inversely proportional to the square of the distance between them and

acts along the straight line joining the two charges.

If two charges q_1 and q_2 are placed at distance r then,

$$F = c \frac{q_1 q_2}{r^2}$$

where c is a constant .

c is called Coulomb's constant and its value is

$$c = \frac{1}{4\pi\varepsilon_0} \qquad F = \frac{1}{4\pi\varepsilon_0}\,\frac{q_1 q_2}{r^2}$$

The value of c depends upon system of units and on the medium between two charges.It is seen experimentally that if two charges of 1 Coulomb each are placed at a distance of 1 meter in air or vacuum, then they attract each other with a force (F) of 9×10^9 N. Accordingly value of c is 9×10^9 Newton x $m^2/coul^2$

e_0 is permittivity of free space or vacuum and its value is $e_0 = 8.85 \times 10^{-12}$ $coul^2$ / N x m^2
If point charges are immersed in a dielectric medium, then e_0 is replaced by e a quantity-characteristic of the matter involved In such case. For vacuum $e = e_0$

$$F = \frac{1}{4\pi\varepsilon}\,\frac{q_1 q_2}{r^2}$$

Permittivity, Relative Permittivity and Dielectric Constant

Permittivity is a measure of the property of the medium surrounding electric charge which determine the forces between the charges.
Its value is known as Absolute permittivity of that Medium e
More is Permittivity of medium, Less is coulombs Force.
For water, permittivity is 80 times then that of vacuum, hence force between two charges in water will be 1/80 time force in vacuum (or air.)
Relative Permittivity(e_r) : It is a dimension-less characteristic constant, which express absolute permittivity of a medium w.r.t. permittivity of vacuum or air. It is also called
Dielectric constant (K) **$K = e_r = e/e_0$**

- This result leads to the calculation that

$$\varepsilon_r = K = \frac{F \text{ (Force in Vacuum)}}{F' \text{ (Force in Medium)}}$$

$$F = \frac{1}{4\pi\varepsilon}\,\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\,\varepsilon_0\varepsilon_r}\,\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\,\varepsilon_0 K}\,\frac{q_1 q_2}{r^2}$$

- Unit of charge:- In S.I. System of units, the unit of charge is **Coulomb.**
- **One coulomb** is defined as that charge, which, when placed at a distance of 1 m in air or vacuum from an equal and similar charge, repel it with a force of 9×10^9 Newton
- Charge on one electron is 1.6019×10^{-19} coul. Hence

- One coulomb is equivalent to a charge of 6.243×10^{18} electrons

Is electric charge a fundamental quantity?

- No, In S.I. System, the fundamental quantity is **Electric current** and its unit is Ampere. Therefore coulomb is defined in it's terms as under:
- Coulomb is that quantity of charge which passes across any section of a conductor per second when current of one ampere flows through it, i.e.
- 1 coulomb=1 Ampere x 1 sec

In **cgs electrostatic** system, the unit of charge is called as STATECOULUMB or esu of charge.

$$F = \frac{q_1 q_2}{r^2}$$

- In this system electrostatic constant c=1 for vacuum or air,

One stat coulomb is defined that amount of charge which when placed at a distance of 1 cm in air from an equal and similar charge repel it with a force of one dyne.

In **cgs electromagnetic** system, the unit of charge is called ABCOULOMB or emu of charge

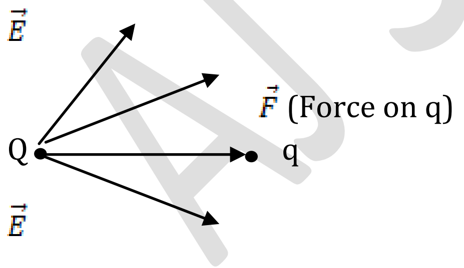
1 Coulomb = 3×10^9 statcoulomb

= 1/10 abcoulomb

1 emu = 3×10^{10} esu of charge

ELECTRIC FIELD

ELECTRIC FIELD-is the environment created by an electric charge (source charge) in the space around it, such that if any other electric charges(test charges)is present in this space, it will come to know of its presence and exert a force on it.



INTENSITY (OR STRENGTH) OF ELECTRIC FIELD AT A LOCATION Is the force exerted on a unit charge placed at that location

: if intensity of electric field at a location is E and a charge 'q' is placed ,then force experienced by this charges F is

Direction of $\vec{F} = q.\vec{E}$ ———— 1 force F is in direction of electric field E

or

$$F = \frac{1}{4\pi E} \frac{Qq}{r^2} \hat{r} \text{ ———— } 3$$

By equ.1and 3 : Intensity of electric field due to Source charge Q is

$$\vec{E} = \frac{1}{4\pi E}\frac{Q}{r^2}\hat{r} \text{———} 4 \qquad \xrightarrow{\vec{E}/q} \vec{F}$$

By coloumb's law we know that in similar situation
if q=1 then

$$\vec{E} = \frac{1}{4\pi E}\frac{Q}{r^2}$$

Relation in F, E and Test $E = \frac{F}{q}$ charge q is

<u>ELECTRIC LINE OF FORCE :</u>

The idea of Lines of Force was given by Michel Faraday. These are imaginary lines which give visual idea of Electric field, its magnitude, and direction.

A line of force is continuous curve the tangent to which at a point gives the direction of Electric field, and its concentration gives the strength of Field.

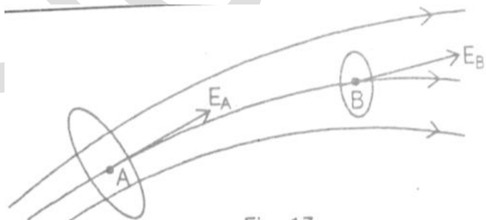


Fig. 17

Electric Field at A is stronger than field at B.

PROPERTIES OF ELECTRIC LINES OF FORCE:

<u>ELECTRIC LINES OF FORCE :</u>
1.start from positive charge and end at negative.
2.Electric Lines of forces are **imaginary** but Electric field they represent is **real.**
3.The tangent drawn at any point on the line of force gives the direction of force acting on a positive charge at that point.
4.**In SI system, the number of electric lines originating or terminating on charge q is q/ε_0 . That means lines associated with unit charge are $1/\varepsilon_0$**
5.Two lines of force never cross each other, because if they do so then at the point of intersection, intensity will have two directions which is absurd.
6. The electric line of force do not pass through a conductor as electric field inside a conductor is zero.
7. Lines of force have tendency to contract longitudinally like a stretched string, producing attraction between opposite charges and edge effect.
8.Electric Lines of force start and end **Normal to the surface** of conductor.

CAPACITOR

It is a device to store charge and in turn store the electrical energy.

Any conductor can store charge to some extent. But we cannot give infinite charge to a conductor. When charge is given to a conductor its potential increases. But charge cannot escape the conductor because air, or medium around conductor is di-electric.

When due to increasing charge the potential increase to such extent that air touching the conductor starts getting ionized and hence charge gets leaked. No more charge can be stored and no more potential increase. This is limit of charging a conductor.

The electric field which can ionize air is $3 \times 10^9\ vm^{-1}$.

CAPACITANCE OF A CONDUCTOR

Term capacitance of a conductor is the ratio of charge to it by rise in its Potential

$$C = \frac{q}{V}$$

In this relation if V=1 then C= q.

Therefore ,*Capacitance of a conductor is equal to the charge which can change its potential by one volt.*Unit of capacitance :Unit of capacitance is farad, (symbol F).

One farad is capacitance of such a conductor whose potential increase by one volt when charge of one coulomb is given to it.

One coulomb is a very large unit. The practical smaller units are
i. Micro farad (μF) = 10^{-6}F.(used in electrical circuits)
Ii Pieco farad (pF) = 10^{-12} used in electronics circuits

Expression for capacitance of a spherical conductor :
If charge q is given to a spherical conductor of radius r, its potential rise by **V =** $\frac{q}{4\pi\epsilon_0 r}$

Therefore capacitance $C = \frac{q}{V} = q/\frac{q}{4\pi\epsilon_0 r} = 4\pi\epsilon_0 r$

Or for a sphere $\boxed{C = 4\pi\epsilon_0 r}$

The capacitor depends only on the radius or size of the conductor.

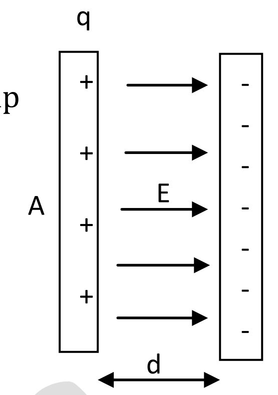
The capacitance of earth (radius 6400 km) is calculated to be 711×10^{-6} coulomb.

PARALLEL PLATE CAPACITOR: -

Since single conductor capacitor does not have large capacitance, parallel plate capacitors are constructed.

Principle : Principle of a parallel plate capacitor is that an uncharged plate brought bear a charged plate decrease the potential of charged plate and hence its capacitance ($C = \frac{q}{V}$) increase. Now it can take more charge. Now if uncharged conductor is earthed, the potential of charged plate further decreases and capacitance further increases. This arrangement of two parallel plates is called parallel plate capacitor.

Expression for capacitance :



Charge q is given to a plate Of area 'A'. Another plate is kept at a distance 'd'.After induction an Electric field E is set-up Between the plates. Here $q = \sigma A$ and $E = \frac{\sigma}{\varepsilon_0}$

The Potential difference between plates is given by

$V = Ed = \frac{\sigma}{\varepsilon_0} d$

Now $C = \frac{q}{V} = \frac{\sigma A}{\frac{\sigma}{\varepsilon_0} d} = \frac{\varepsilon_0 A}{d}$

$$\boxed{C = \frac{\varepsilon_0 A}{d}}$$

If a dielectric of dielectric constant K is inserted between the plates, then capacitance increase by factor K and become

$$\boxed{C = \frac{\varepsilon_0 K A}{d}}$$

Note : The capacitance depends only on its configuration i.e. plate area and distance, and on the medium between them.
The other examples of parallel plate capacitors is

Cylindrical capacitor $C = \frac{4\pi\varepsilon_0 KL}{\log r^2/r_1}$

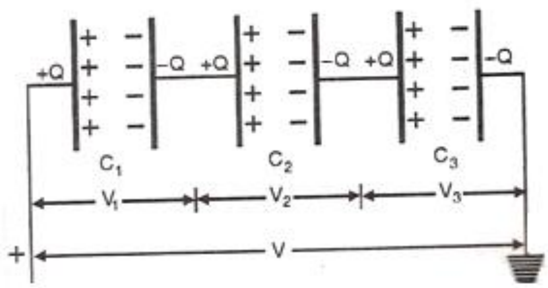
and Spherical capacitor. $C = \frac{4\pi\varepsilon_0 K r_2 r_1}{\log r_2 - r_1}$

Combination of capacitors

Capacitors can be combined in two ways. 1. Series and 2. Parallel.

Series Combination :

If capacitors are connected in such a way that we can proceed from one point to other by only one path passing through all capacitors then all these capacitors are said to be in series.Here three capacitors are connected in series and are connected across a battery of P.D. 'V'.



The charge q given by battery deposits at first plate of first capacitor. Due to induction it attract –q on the opposite plate. The pairing +ve q charges are repelled to first plate of Second capacitor which in turn induce -q on the opposite plate. Same action is repeated to all the capacitors and in this way all capacitors get q charge. As a result ; the charge given by battery q, every capacitor gets charge q.

The Potential Difference V of battery is sum of potentials across all capacitors. Therefore

$V = v_1 + v_2 + v_3$

$v_1 = \frac{q_1}{c_1}$, $v_2 = \frac{q_2}{c_2}$, $v_3 = \frac{q_3}{c_3}$

Equivalent Capacitance : The equivalent capacitance across the combination can be calculated as $C_e = q/V$

Or $1/C_e = V/q$

$= (v_1 + v_2 + v_3) / q$

$= v_1/q + v_2/q + v_3/q$

Or **$1/C_e = 1/C_1 + 1/C_2 + 1/C_3$**

The equivalent capacitance in series decrease and become smaller then smallest member.

In series q is same. Therefore by q=cv, we have

$c_1v_1 = c_2v_2 = c_3v_3$

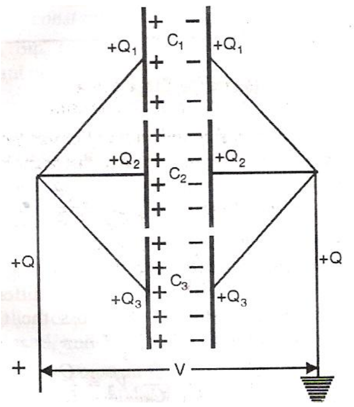
or $v \propto \frac{1}{c}$ i.e. larger c has smaller v, and smaller c has larger v across it.

For 2 capacitor system $C = \frac{c_1c_2}{c_1 + c_2}$, and $v_1 = \frac{c_2}{c_1 + c_2}.v$

If n capacitor of capacitance c are joint in series then equivalent capacitance $C_e = \frac{c}{n}$

Parallel combination :

If capacitors are connected in such a way that there are many paths to go from one point to other. All these paths are parallel and capacitance of each path is said to be connected in parallel. Here three capacitors are connected in parallel and are connected across a battery of P.D. 'V'.



The potential difference across each capacitor is equal and it is same as P.D. across Battery.

The charge given by source is divided and each capacitor gets some charge. The total charge, $q = q_1 + q_2 + q_3$

Each capacitor has charge $q_1=c_1v_1$, $q_2=c_2v_2$, $q_3=c_3v_3$

Equivalent Capacitance : We know that

$q = q_1 + q_2 + q_3$, divide by v $\frac{q}{v} = \frac{q_1}{v} + \frac{q_2}{v} + \frac{q_3}{v}$

or, **$C = c_1+c_2+c_3$**

The equivalent capacitance in parallel increases, and it is more than largest in parallel.

In parallel combination V is same therefore

$(v =) \quad \frac{q_1}{c_1} = \frac{q_2}{c_2} = \frac{q_3}{c_3}$

In parallel combination $q \propto c$. Larger capacitance larger is charge.

Charge distribution : $q_1=c_1v$, $q_2=c_2v$, $q_3=c_3v$.

In 2 capacitor system charge on one capacitor

$q_1 = \frac{c_1}{c_1+c_2+.}.q$

n capacitors in parallel give $C = nc$

MAGNETOSTATICS

Fundamental concepts

(a) A substance which attracts pieces of iron and steel is called a magnet.
(b) The property of attracting or repelling is called magnetism.
(c) Bar magnet is the simplest form of magnet.It has two poles-North pole & South pole.
(d) Both poles of magnet are of equal strength.
(e) Like poles repel each other and unlike poles attract each other.
(f) Iron,steel,nickel are magnetic substances and can be converted into magnets.
(g) 'm'-symbol used to denote Pole strength.
(h) SI unit of pole strength is ampere meter or weber.

Magnetic field

The space surrounding a magnetic pole within which the magnetic effects of pole can be felt is called magnetic field.

Coulomb's Laws in Magnetism :-

The force of attraction or repulsion between two magnetic poles is directly proportional to the product of their pole strengths and inversely proportional to the square of distance between them.

m1= Pole strength of 1st pole
m2= Pole strength of 2nd pole
d = Distance between the poles
F = Force of attraction or repulsion between the poles
According to the statement of Coulomb's law,
$F \propto m1\ m2$

Unit pole is a pole of that much strength which when placed at a distance of 1mt from a similar pole repels it with a force of Newton.

Definition of Weber:- One Weber is a pole of that much strength which when placed at a distance of 1mt from a similar pole repels it with a force of Newton.

MAGNETIC FIELD INTENSITY :- Magnetic field intensity at any point within a magnetic field is the force experienced by a unit north pole placed at that point.The direction of is the direction in which a unit north pole would move if it were free to do so.

MAGNETIC LINES OF FORCE :- These are imaginary closed curves drawn in a magnetic field such that the tangent drawn at any point of the curve gives the direction of resultant magnetic field at that point.

Lines of force start from N- pole and ends on S-pole outside the magnet but start from S pole and ends on N-pole inside the magnet.

MAGNETIC FLUX : Magnetic flux deals with the study of no. of lines of force of magnetic field crossing a certain area.

Let, A= area of the coil placed in the magnetic field B = Magnetic Flux density = Angle between B and the normal to area A

The Area in vector notation can be represented by a vector directed

along the normal to the area and having a length proportional to the magnitude of the area.

Magnetic Flux through the area is given by, =ϕ= BA cos = A(B cos B cos = component of B perpendicular to the area A Magnetic Flux linked with a surface is defined as the product of area and the

component of B perpendicular to the area.

Unit of Flux: - Weber (SI Unit)

Maxwell (CGS Unit)

1 Weber = 108 Maxwell

i) When i.e the coil is held perpendicular to the magnetic field and the normal to the coil is parallel to the magnetic field,= BA

ii) When i.e the normal to the coil is held at to the magnetic field, = BAcos

iii) When i.e coil is held parallel to the magnetic field andthe normal to the coil is held at to the magnetic field,= B A cos =0

MAGNETIC FLUX DENSITY:

It is defined as the magnetic flux crossing unit area, when the areaBis held perpendicular to the magnetic field.

B = , Unit of B = = = Tesla (SI Unit)

CGS Unit of B = Gauss, I Tesla = 104 Gauss

UNIT-10

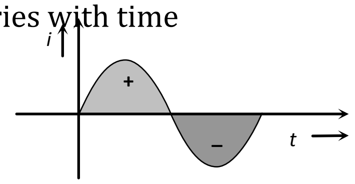
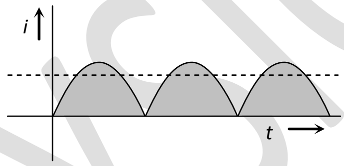
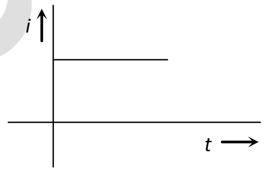
CURRENT ELECTRICITY

CURRENT ELECTRICITY

Electric Current

(1) **Definition :** The time rate of flow of charge through any cross-section is called current. So if through a cross-section, ΔQ charge passes in time Δt then $i_{av} = \frac{\Delta Q}{\Delta t}$ and instantaneous current $i = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$. If flow is uniform then $i = \frac{Q}{t}$. Current is a scalar quantity. It's S.I. unit is *ampere* (A) and C.G.S. unit is *emu* and is called *biot* (Bi), or *ab ampere*. $1A = (1/10)\ Bi$ (*ab amp.*)

(2) **Types of current :** Electric current is of two type :

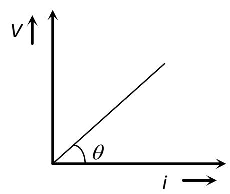
Alternating current (ac)	**Direct current (dc)**	
(i) Magnitude and direction both varies with time  ac → $\boxed{\text{Rectifier}}$ → dc	(i) (Pulsating dc)  dc → $\boxed{\text{Inverter}}$ → ac	(Constant dc) 

Ohm's Law

If the physical circumstances of the conductor (length, temperature, mechanical strain etc.) remains constant, then the current flowing through the conductor is directly proportional to the potential difference across it's two ends *i.e.*

$\boldsymbol{i \propto V}$

$\Rightarrow \boldsymbol{V = iR}$ or $\frac{V}{i} = R$; where R is a proportionality constant, known as electric resistance.



Slope of the line = $\tan\theta = \frac{V}{i} = R$

(1) Ohm's law is not a universal law, the substance which obeys ohm's law are known as ohmic substance for such ohmic substances graph between V and i is a straight line as shown. At different temperatures V-i curves are different.

Resistance

(1) **Definition :** The property of substance by virtue of which it opposes the flow of current through it, is known as the resistance.

(2) **Cause of resistance of a conductor :** It is due to the collisions of free electrons with the ions or atoms of the conductor while drifting towards the positive end of the conductor.

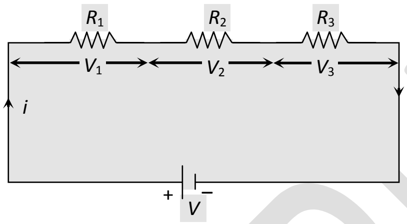
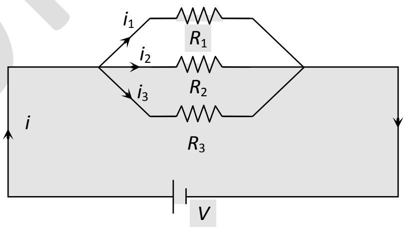
(3) **Formula of resistance :** For a conductor if l = length of a conductor A = Area of cross-section of conductor, n = No. of free electrons per unit volume in conductor, τ = relaxation time then resistance of conductor $\boldsymbol{R} = \rho \dfrac{\boldsymbol{l}}{\boldsymbol{A}} = \dfrac{\boldsymbol{m}}{\boldsymbol{ne^2\tau}} \cdot \dfrac{\boldsymbol{l}}{\boldsymbol{A}}$; where ρ = resistivity of the material of conductor

(4) **Unit and dimension :** It's S.I. unit is *Volt/Amp.* or *Ohm* (Ω). Also 1 *ohm* $= \dfrac{1 volt}{1 Amp} = \dfrac{10^8\ emu \text{ of potential}}{10^{-1}\ emu \text{ of current}}$ = 10^9 *emu* of resistance. It's dimension is $[ML^2T^{-3}A^{-2}]$.

(5) **Conductance (*C*) :** Reciprocal of resistance is known as conductance. $C = \dfrac{1}{R}$

It's unit is $\dfrac{1}{\Omega}$ or Ω^{-1} or "Siemen".

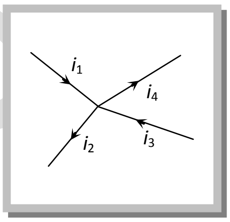
GROUPING OF RESISTANCE

Series	Parallel
(1) 	(1) 
(2) Same current flows through each resistance but potential difference distributes in the ratio of resistance *i.e.* $V \propto R$ Power consumed are in the ratio of their resistance *i.e.* $P \propto R \Rightarrow P_1 : P_2 : P_3 = R_1 : R_2 : R_3$	(2) Same potential difference appeared across each resistance but current distributes in the reverse ratio of their resistance *i.e.* $i \propto \dfrac{1}{R}$ Power consumed are in the reverse ratio of resistance *i.e.* $P \propto \dfrac{1}{R} \Rightarrow P_1 : P_2 : P_3 = \dfrac{1}{R_1} : \dfrac{1}{R_2} : \dfrac{1}{R_3}$
(3) $R_{eq} = R_1 + R_2 + R_3$ equivalent resistance is greater than the maximum value of resistance in the combination.	(3) $\dfrac{1}{R_{eq}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$ or $R_{eq} = (R_1^{-1} + R_2^{-1} + R_3^{-1})^{-1}$ or $R_{eq} = \dfrac{R_1R_2R_3}{R_1R_2 + R_2R_3 + R_2R_1}$ equivalent resistance is smaller than the minimum value of resistance in the combination.
(4) For two resistance in series $R_{eq} = R_1 + R_2$	(4) For two resistance in parallel $R_{eq} = \dfrac{R_1R_2}{R_1 + R_2} = \dfrac{\text{Multiplication}}{\text{Addition}}$

KIRCHOFF'S LAWS

In 1845, a German physicist, **Gustav Kirchoff** developed a set of laws which deal with the conservation of current and energy within Electrical Circuits. These two rules are commonly known as: *Kirchoffs Circuit Laws* with one of Kirchoffs laws dealing with the current flowing around a closed circuit, **Kirchoffs Current Law, (KCL)** while the other law deals with the voltage sources present in a closed circuit, **Kirchoffs Voltage Law, (KVL)**. Kirchoffs First Law – The Current Law, (KCL)

(1) **Kirchoff's first law :** This law is also known as junction rule or current law (*KCL*). According to it the algebraic sum of currents meeting at a junction is zero *i.e.* $\sum i = 0$.



In a circuit, at any junction the sum of the currents entering the junction must equal the sum of the currents leaving the junction. $i_1 + i_3 = i_2 + i_4$

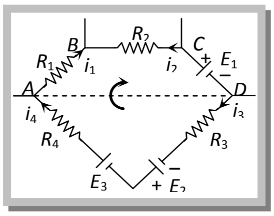
Here it is worthy to note that :

(i) If a current comes out to be negative, actual direction of current at the junction is opposite to that assumed, $i + i_1 + i_2 = 0$ can be satisfied only if at least one current is negative, *i.e.* leaving the junction.

(ii) This law is simply a statement of "*conservation of charge*" as if current reaching a junction is not equal to the current leaving the junction, charge will not be conserved.

(2) **Kirchoff's second law :** This law is also known as loop rule or voltage law (KVL) and according to it "the algebraic sum of the changes in potential in complete traversal of a mesh (closed loop) is zero", *i.e.* $\sum V = 0$

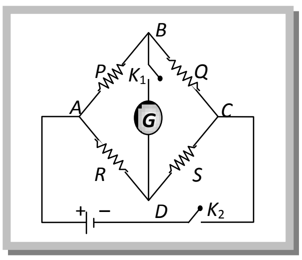
e.g. In the following closed loop.



$- i_1R_1 + i_2R_2 - E_1 - i_3R_3 + E_2 + E_3 - i_4R_4 = 0$

Wheatstone bridge : Wheatstone bridge is an arrangement of four resistance which can be used to measure one of them in terms of rest. Here arms *AB* and *BC* are called ratio arm and arms *AC* and *BD* are called conjugate arms

(i) **Balanced bridge :** The bridge is said to be balanced when deflection in galvanometer is zero *i.e.* no current flows through the galvanometer or in other words $V_B = V_D$. In the balanced condition $\frac{P}{Q} = \frac{R}{S}$, on mutually changing the position of cell and galvanometer this condition will not change.



(ii) **Unbalanced bridge :** If the bridge is not balanced current will flow from *D* to *B* if $V_D > V_B$ *i.e.* $(V_A - V_D) < (V_A - V_B)$ which gives $PS > RQ$.

UNIT-11

ELECTROMAGNETISM & ELECTROMAGNETIC INDUCTION

FORCE ACTING ON A CURRENT CARRYING STRAIGHT CONDUCTOR PLACED IN A UNIFORM MAGNETIC FIELD. :-

A conductor has free electrons in it. When a potential difference is maintained across the two ends of the conductor, the electrons drift from lower to higher potential wth a small velocity and current flows in the conductor. When the electrons move in a magnetic field , they experience a force $\boldsymbol{F}$.

Let us consider a conductor XY placed in a uniform magnetic field $\boldsymbol{B}$ acting inwards at right angle to the plane of paper.

Let, I = Current flowing through the conductor from X to Y.

$\boldsymbol{v}$ = Velocity of the moving charge

dq = small amount of charge moving from x to Y

Force experienced by the charge is, $d\boldsymbol{F}$ = dq ($\boldsymbol{v} \times \boldsymbol{B}$)

If the charge moves a small distance dl in time dt, Then, $d\boldsymbol{F}$ = ($\boldsymbol{d\,l} \times \boldsymbol{B}$) = I ($\boldsymbol{d\,l} \times \boldsymbol{B}$)

Direction of length $\boldsymbol{d\,l}$ is considered as the direction of flow of current from x to Y.

Net force acting on the conductor will be, $\boldsymbol{F}$ = I ($\boldsymbol{l} \times \boldsymbol{B}$) = I $\boldsymbol{l}$ B $\boldsymbol{sin\theta\, n}$

Where, $\boldsymbol{n}$ = Unit vector in a direction perpendicular to the plane containing $\boldsymbol{l\ and\ B}$.

Thus magnitude of Force depends upon the angle between current I and magnetic field

ELECTROMAGNETIC INDUCTION

Electromagnetic Induction is the process in which an E.M.F. is setup in a coil placed in a magnetic field whenever the flux through the coil changes. If the coil forms a part of a close circuit, the E.M.F. causes a current to flow in the circuit.

E.M.F. setup in the coil is called "induced E.M.F" and the current thus produced is termed as"Induced Current".

Experiments show that the magnitude of E.M.F. depends on the rate at which the flux through the coil changes. It also depends on the number of turns on the coil.

There are various ways to change magnetic flux of a coil such as;

(1) By changing the relative position of the coil with respect to a magnet.

(2) By changing current in the coil itself.

(3) By changing current in the neighbouring coil.

(4) By changing area of a coil placed in the magnetic field etc.

FARADAY'S LAW OF ELECTROMAGNETIC INDUCTION

Faraday was the first scientist who performed a number of experiments to discover the facts and figures of electromagnetic induction, he formulated the following laws:

FARADAY'S 1st LAW:- When magnetic flux changes through a circuit, an emf is induced in it.

FARADAY'S 2nd LAW :-The induced emf lasts only as long as the change in the magnetic flux through the circuit continues.

FARADAY'S 3rd LAW:- Induced emf is directly proportional to the rate of change of magnetic flux through the coil.

The negative sign indicates that the induced current is such that the magnetic field due to it opposes the magnetic flux producing it.

LENZ'S LAW

Lenz's law describes that in order to produce an induced emf or induced current some external source of energy must be supplied otherwise no current will induce.

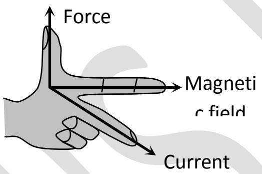
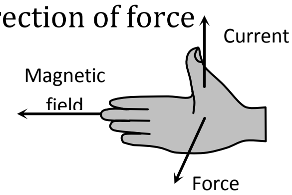
Lenz's law states that" **"The direction of induced current is always such as to oppose the cause which produces it".** That is why a –ve sign is used in Faraday's law.

EXPLANATION

Consider a bar magnet and a coil of wire.

a. When the N-pole of magnet is approaching the face of the coil, it becomes a north face by the induction of current in anticlockwise direction to oppose forward motion of the magnet.

b. When the N-pole of the magnet is receding the face of the coil becomes a south pole due to a clockwise induced current to oppose the backward motion.

Fleming's left-hand rule	**Right-hand palm rule**
Stretch the fore-finger, central finger and thumb left hand mutually perpendicular. Then if the fore-finger points in the direction of field $\vec{B}$ and the central in the direction of current i, the thumb will point in the direction of force 	Stretch the fingers and thumb of right hand at right angles to each other. Then if the fingers point in the direction of field $\vec{B}$ and thumb in the direction of current i, then normal to the palm will point in the direction of force 

UNIT-12

MODERN PHYSICS

LASER:

LASER is an acronym for Light Amplification by the Stimulated Emission of Radiation:A **laser** is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation.

CHARACTERISTICS OF LASER:

i. **Monochromatic** : The light emitted from a laser is *monochromatic*, that is, it is of one wavelength (color). In contrast, ordinary white light is a combination of many different wavelengths (colors).

ii. **Directional**: Lasers emit light that is highly *directional.* Laser light is emitted as a relatively narrow beam in a specific direction. Ordinary light, such as coming from the sun, a light bulb, or a candle, is emitted in many directions away from the source.

Coherent : The light from a laser is said to be *coherent,* which means the wavelengths of the laser light are in phase in space and time.

These three properties of laser light are what make it more of a hazard than ordinary light. Laser light can deposit a great deal of energy within a very small area.

PRINCIPLE OF LASER:

The principle of a laser is based on three separate features:

a) Stimulated emission within an amplifying medium,

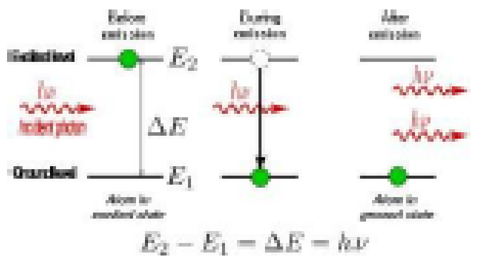
b) Population inversion of electrons

c) Optical resonator.

a) Spontaneous Emission and Stimulated Emission

Spontaneous Emission:-According to the quantum mechanics, an electron within an atom can have only certain values of energy, or energy levels. There are many energy levels that an electron can occupy. If an electron is in the excited state with the energy E2 it may spontaneously decay to the ground state, with energy E1, releasing the difference in energy between the two states as a photon. This process is called **spontaneous emission**, producing fluorescent light. The phase and direction of the photon in spontaneous emission are completely random due to Uncertainty Principle.

Conversely, a photon with a particular frequency would be absorbed by an electron in the ground state. The electron remains in this excited state for a period of time typically less than 10-6 second. Then it returns to the lower state spontaneously by a photon or a phonon. These common processes of absorption and spontaneous emission cannot give rise to the amplification of light. The best that can be achieved is that for every photon absorbed, another is emitted.



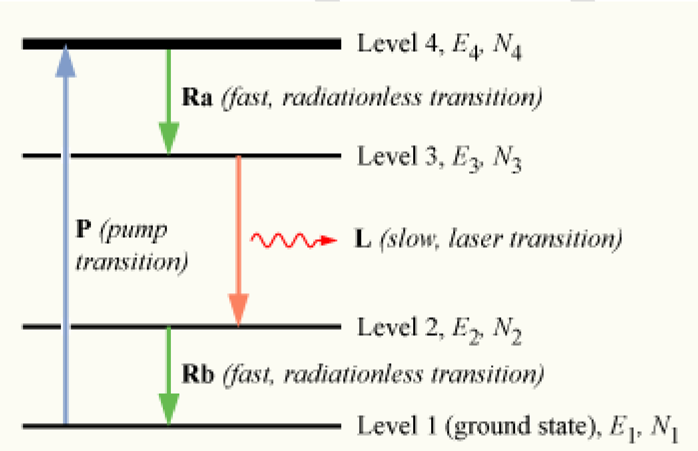
Stimulated Emission:- If the excited-state atom is perturbed by the electric field of a photon with frequency ω, it may release a second photon of the same frequency, in phase with the first photon. The atom will again decay into the ground state. This process is known as stimulated emission.(see Fig.2b)

The emitted photon is identical to the stimulating photon with the same frequency, polarization, and direction of propagation. And there is a fixed phase relationship between light radiated from different atoms. The photons, as a result, are totally coherent. This is the critical property that allows optical amplification to take place.

b) Population Inversion of the Gain Medium :-

If the higher energy state has a greater population than the lower energy state, then the light in the system undergoes a net increase in intensity. And this is called population inversion. But this process cannot be achieved by only two states, because the electrons will eventually reach equilibrium with the de exciting processes of spontaneous and stimulated emission.

Instead, an indirect way is adopted, with three energy levels (E1<E2<E3) and energy population N1, N2 and N3 respectively. (see Fig.3a) Initially, the system is at thermal equilibrium, and the majority of electrons stay in the ground state. Then external energy is provided to excite them to level 3, referred as pumping. The source of pumping energy varies with different laser medium, such as electrical discharge and chemical reaction, etc. In a medium suitable for laser operation, we require these excited atoms to quickly decay to level 2, transferring the energy to the phonons of the lattice of the host material. This wouldn't generate a photon, and labeled as R, meaning radiation less. Then electrons on level 2 will decay by spontaneous emission



APPLICATIONS OF LASER:

Lasers have many important applications.

They are used in common consumer devices such as optical disk drives, laser printers, and barcode scanners.

Lasers are used for both fiber-optic and free-space optical communication.

They are used in medicine for laser surgery and various skin treatments,

Lasers are used in industry for cutting and welding materials.

They are used in military and law enforcement devices for marking targets and measuring range and speed.

Laser lighting displays use laser light as an entertainment medium.

APPENDIXES

Universal physical constants		
Name	**Symbol**	**Value (Unit)**
1. Acceleration due to gravity:	g	= 9.81 m/s^2
2. Atomic mass unit:	amu	= 1.660 X 10^{-24} g
3. Avogadro's number:	N	= 6.023 X 10^{-23}g /mol
4. Bohr magneton (magnetic moment):	β	= 9.273 X 10^{-24} A m^2
5. Boltzmann's constant:	k	= 1.380 X 10^{-23} J/K= 8.620 X 10^{-5} eV/k
6. Electron rest mass:	m_e	= 9.109 X 10^{-31} Kg
7. Electronic charge	e	= 1.602 X 10^{-19} C
8. Faraday's constant	F	= 9.649 X 10^4 C/mol
9. Gas constant	R	= 8.314 J/mol/K
10. Mass of proton	m_p	= 1.673 X 10^{-24} g
11. Mass of electron	m_e	= 9.108 X 10^{-28} g
12. Planck's constant	h	= 6.626 X 10^{-34} Js
13. Permeability of free space	μ_0	= 1.257 X 10^{-6} H/m
14. Velocity of light in free space	c	= 2.998 X 10^8 m/s
15. Permittivity of free space	ε_0	= 8.854 X 10^{-12} F/m
16. Volume of 1kg mole of ideal gas at N.T.P.	V	= 22.41 m^3
17. Magnetic constant	μ_i	= 1.2566 X 10^{-8} H/cm
18. Gravitation constants	G	= 6.670 X 10^{-1}
19. Radius of electron	r_e	= 2.81777 X 10^{-15} m.

Physical Constants

DENSITY
1. Water → 1000 Kgm^{-3}
2. Copper → 8900 Kgm^{-3}
3. Steel → 7800 Kgm^{-3}
4. Brass → 8600 Kgm^{-3}
5. Iron → 7500 Kgm^{-3}

YOUNGS MODULUS
1 .Box wood → 1×1010 Nm^{-2}
2. Teak wood → 1.7×1010 Nm^{-2}
3 .Wrought iron and steel → 20×1010 Nm^{-2}

RIGIDITY MODULUS
1. Aluminium → 2.5×1010 Nm^{-2}
2. Brass → 3.5 to 3.4×1010 Nm^{-2}
3. Cast iron → 5.0×1010 Nm^{-2}
4. Copper → 3.4 to 3.6×1010 Nm^{-2}
5. Steel(Cast) → 7.6×1010 Nm^{-2}
6. Steel(Mild) → 8.9×1010 Nm^{-2}

THERMAL CONDUCTIVITY
1. Card board → 0.04 $Wm^{-1}k^{-1}$
2. Ebonite → 0.7 $Wm^{-1}k$-1
3. Glass → 1 $Wm^{-1}k^{-1}$
4. Wood & Rubber → 0.15 $Wm^{-1}k$-1

SPECIFIC HEAT CAPACITY
1. Brass → 913 $JKg^{-1}K^{-1}$
2. Copper → 385 $JKg^{-1}K^{-1}$
3. Water → 4186 $JKg^{-1}K^{-1}$

BAND GAP
1. Germanium → 0.67 eV
2. Silicon → 1.12 eV

WAVELENGTH
Sodium Vapour Lamp → 5893 A^0
Mercury vapour lamp
1. Red → 6234 A^0
2. Yellow I → 5791 A^0
3. yellow ii → 5770 A^0
4. Green → 5461 A^0
5. Blueish green → 4916 A^0
6. Blue → 4358 A^0
7. Violet I → 4078 A^0
8. Violet ii → 4047 A^0

COMPRESSIBILITY
1. Water → 4.59×10-10 m^2N^{-1}
2. Castor oil → 4.7×10-10 m^2N^{-1}
3. Kerosene → 7.5×10-10 m^2N^{-1}

TEMPERATURE CO-EFFICIENT OF RESISTANCE
1. Aluminium → 0.0043 per ◦C
2. Brass → 0.001 to 0.002 per ◦C
3. Copper → 0.0039 per ◦C

COEFFICIENT OF VISCOSITY (AT ROOM TEMP.)
1. Water → 0.00081 Nsm^{-2}
2. Kerosene → 0.002 Nsm^{-2}
3. Glycerin → 0.3094 Nsm^{-2}

Conversion factors

1. 1 atm = 0.101325 X 10^6 N/m^2 = 760 mm Hg = 10^5 Pascal	21. 1 Gauss = 10^{-4} Wb/m^2
2. 1° = 0.01745 rad	22. 1 gram-calorie = 4.185 J
3. 1 Å =10^{-10} m = 0.1 nm	23. 1 Henry = 1 V-s/A
4. 1 A.hr = 3.6 Kc	24. 1 Hertz = 1 cycle/s
5. 1 ampere = 1 C/s	25. 1 HP = 0.7457 KW
6. 1 Btu = 1.05506 kJ	26. 1 Kgf/mm^2 = 9.81 MN/m^2
7. 1 Btu/lb = 2326 J/Kg	27. 1 KSi/in = 1.1 MN/m^3/^{2}
8. 1 Btu/ft^3 = 37.2589 KJ/m^3	28. 1 lb/Cu.ft = 16.01 kg/m^3
9. 1 bar = 10^{-1} MPa	29. 1 lumen = 0.0016 W (at 0.55 m)
10. 1 Calorie = 4.18 J	30. 1 Newton = 1 kg.m/s^2
11. 1 Coulomb = 1 A-s	31. 1 Oersted = 79.6 A/m
12. 1 Debye = 3.33 X 10^{-30} cm	32. 1 Poise = 0.1 PaS
13. 1 Dyne/Cm = 10^{-3} N/m	33. 1 PSi = 6.89 KN/m^2
14. 1 dyne/cm^2 = 0.1 N/m^2	34. T°C = (T + 273.15) K
15. 1 erg = 10^{-7} J	35. T°F = 5/9 (T + 459.67) K
16. 1 erg/cm = 10^{-5} J/m	36. 1 torr (mm of Hg) = 133.3 N/m^2
17. 1 eV = 1.602 10^{-19} J	37. 1 TR = 3024 KCal
18. 1 eV/entity = 96.49 KJ/mol	38. 1 Watt = 1 Joule/sec
19. 1 eV/particle = 96.49 KJ/mol	39. TR = 3024 Kcal/hg
20. 1 farad = 1 C/V	40. 1 Joule = 10^7 ergs
	41. 1 K-cal = 4.18 kJ

Common Exponent

Symbol	Name	Name of ten	Factor
Y	yatta		10^{24}
Z	zetta		10^{21}
E	exa		10^{18}
p	peta		10^{15}
T	tera	trillion	10^{12}
G	giga	billion	10^9
M	mega	million	10^6
k	kilo	thousand	10^3
h	hecto	hundred	10^2
da	deca	ten	10^1
d	deci	tenth	10^{-1}
c	centi	hundredth	10^{-2}
m	milli	thousandth	10^{-3}
µ	micro	millionth	10^{-6}
n	nano	billionth	10^{-9}
p	pico	trillionth	10^{-12}
f	femto		10^{-15}
a	atto		10^{-18}
z	zepto		10^{-21}
y	yocto		10^{-24}

FORMULAE IN CURRENT ELECTRICITY

1	Electric Current	i=q/t	"q" is charge passing in normal direction through a cross section of conductor in time "t"
2	Drift velocity V_d with Electric field	$V_d = \frac{-e\vec{E\tau}}{m}$	e is charge and m is mass on electron, E is electric field, τ is relaxation time.
3	Current I with Drift velocity V_d	$I = n\,e\,A\,V_d$	n is number density with of free electrons, A is area of cross section.
4	Mobility of charge "μ"	$\mu = V_d / E = \frac{q\tau}{m}$	
5	Mobility and drift velocity	$V_d = \mu_e E$	
6	Resistance, P.D., and Current	R = V / I	V Potential Difference, I Current .
7	Resistance R with specific Res.	$R = \rho \frac{l}{A}$	l is length of conductor and A is area of cross section
8	Specific Resistance, ρ	$\rho = R \frac{A}{l}$	
9	Resistivity with electrons	$\rho = \frac{m}{ne^2\tau}$	
10	Current density J	$\vec{J} = I / \vec{A}$	I is current, J current density, A is area of cross section
11	Conductance G	G = 1/R	
12	Conductivity σ	$\sigma = 1/\rho$	ρ is specific resistance
13	Microscopic form of Ohms Law	$J = \sigma E$	E is electric field
14	Temperature coefficient of Resistance α	$\alpha = \frac{Rt - R_0}{R_0 \, X \, t}$	R_o is resistance at 0_o C. R_t is resistance at t^o and "t" is temperature difference.
15	Resistances in series	$R = R_1+R_2+R_3$	Same current through all resistances (circuit Current
16	Resistances in parallel	$1/R_e = 1/R_1 + 1/R_2 + 1/R_3$	Same P.D. across each resistance (V of cell)
17	In a circuit with a cell	V = E - Ir	V is terminal potential difference
18	n Cells of emf E in series	Emf = nE	
19	Resistance of n cells in series	nr + R	r is internal resistance of one cell, R external Resistance
20	Current in circuit with n cells in series	$I = \frac{nE}{R+nr}$	r is internal resistance of one cell, R external Resistance
21	n cells in parallel, then emf	emf = E	
22	n cells in parallel, resistance	R + r/n	R external resistance, r internal resistance
23	Cells in mixed group, condition for maximum current	$R = \frac{nr}{m}$	n is number of cells in one row, m is number of rows. r is internal resistance, R external resis.
24	Internal resistance of a cell	$r = \left(\frac{E-V}{V}\right) x\, R$	E is emf, V is terminal Potential difference, R is external resistance.
25	Power of a circuit	$P = I.V = I^2R = V^2/R$	
26	Energy consumed	E = I.V.ΔT	ΔT is time duration
27	Kirchoff Law (junction rule)	$\Sigma i = 0$	Sum of currents at junction is zero.
28	Kirchoff Law (Loop rule)	$\Sigma V = 0$	In a loop sum of all p.d.*s* is Zero

Brief History of Indian Nobel Laureates in PHYSICS

The Nobel Prize is the most respected award the world over and here is a list of those Indians who have won this award and made the country proud.

1. Sir C.V. Raman (7 November 1888 – 21 November 1970)

Nobel Prize for Physics (1930) Chandrasekhara Venkata Raman was born on 7th Nov. 1888 in Thiruvanaikkaval, in the Trichy district of Tamil Nadu. He finished school by the age of eleven and by then he had already read the popular lectures of Tyndall, Faraday and Helmoltz. He acquired his BA degree from the Presidency College, Madras, where he carried out original research in the college laboratory, publishing the results in the philosophical magazine. Then went to Calcutta and while he was there, he made enormous contributions to vibration, sound, musical instruments, ultrasonics, diffraction, photo electricity, colloidal particles, X-ray diffraction, magnetron, dielectrics, and the celebrated "RAMAN" effect which fetched him the Noble Prize in 1930. He was the first Asian scientist to win the Nobel Prize. The Raman effect occurs when a ray of incident light excites a molecule in the sample, which subsequently scatters the light. While most of this scattered light is of the same wavelength as the incident light.

2. Dr. Hargobind Khorana (9 January 1922 – 9 November 2011)

Nobel Prize for Medicine and Physiology (1968) Dr. Hargobind Khorana was born on 9th January 1922 at Raipur, Punjab (now in Pakistan). Dr. Khorana was responsible for producing the first man-made gene in his laboratory in the early seventies. This historic invention won him the Nobel Prize for Medicine in 1968 sharing it with Marshall Nuremberg and Robert Holley for interpreting the genetic code and analyzing its function in protein synthesis. They all independently made contributions to the understanding of the genetic code and how it works in the cell. They established that this mother of all codes, the biological language common to all living organisms, is spelled out in three-letter words: each set of three nucleotides codes for a specific amino acid.

3. Dr. Subramaniam Chandrasekar (19 October 1910 – 21 August 1995)

Nobel Prize for physics (1983) Subramaniam Chandrashekhar was born on October 19, 1910 in Lahore, India (later part of Pakistan). He attended Presidency College from 1925 to 1930, following in the footsteps of his famous uncle, Sir C. V. Raman. His work spanned over the understanding of the rotation of planets, stars, white dwarfs, neutron stars, black holes, galaxies, and clusters of galaxies. He won the Nobel Prize in 1983 for his theoretical work on stars and their evolution.

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