NATURE OF MATTER

Matter : It is anything that occupies space and has mass, therefore, it is the substance composing everything perceptible to the senses. Physical Sciences deal mainly with the study of matter and energy. Gravitation and inertia are the basic distinguishing properties of matter and any entity exhibiting these properties when at rest is matter. All material bodies have mass, which is a measure of inertia.

MEASUREMENTS

The most important thing for physical sciences, is to measure various quantities accurately. A recent branch of technology 'INSTRUMENTATION' is concerned with the development of new device that are able to make the finest measurements of a growing range of phenomena. Measurement consists of the comparison of two quantities with a known one. Every measurement compares a physical quantity to be measured with some fixed standard, known as the unit of measurement. The unit adopted for measuring fundamental quantities, *i.e., mass, length* and *time* are called *fundamental units*. The units of physical quantities which can be expressed in term of fundamental units are called *derived units*, e.g., the unit of momentum (p) is a derived unit ($p = mv$).

SYSTEMS OF UNITS

Several systems of units have been in use for describing measurement. The system of fundamental units are C.G.S. (Centimetre, Gram, Second) system, the F.P.S. (Foot, Pond, Second) system or British system and the M.K.S. (Metre, Kilogram and Second) system and this system is mostly used in the study of physical quantity as it has the advantage of converting all the units in the multiples of ten only.

Multiples and fraction are indicated by appropriate prefixes. Multiple upto 1000 are indicated by the following prefixes: deca (10), hecto (100), and kilo (1000). Fraction upto 1000 are expressed as follows : deci (1/10), centi (1/100) and milli (1/1000). For multiples and fraction above 1000, the following prefixes have been adopted.

Multiples		Fraction	
Mega (M)	10^6	Micro (μ)	10^{-6}
Giga (G) —	10^9	Nano (n)	10^{-9}
Tera (T) —	10^{12}	Pico (p) —	10^{-12}
		Fermi (f) —	10^{-15}
		Atto (a) —	10^{-18}

In 1969, the International Committee on Weights and Measures, an auxiliary of the General conference, recognised the use of some units which were in widespread use.

Some of the common units and their SI equivalent units are given below :

A. Length

1 angstrom (Å)	—	0.1 nano metre (nm)
1 engineer's chain		30.48 metre (m)
1 foot	—	0.304 metre (m)
1 inch	—	0.0254 metre (m)
1 mile	—	1.609 kilometre (km)
1 nautical mile	—	1.852 kilometre (km)

B. General

1 acre	—	4047 sq metre
1 fluid ounce	—	28.41 cubic centimetre
1 gallon	—	4.546 cubic decimetre
1 pint	—	0.586 cubic decimetre
1 grain	—	64.80 milligram
1 maund	—	37.32 kilogram
1 ounce	—	28.35 kilogram
1 pound	—	0.453 kilogram
1 quintal	—	100 kg
1 seer	—	0.933 kilogram
1 tola	—	11.66 gram
1 knot	—	1.852 km/hour
1 gallon	—	4.456 litres
1 AU (Astronomical Unit)	—	1.5×10^{11} m

SYSTEME INTERNATIONALE (SI) UNIT

The General Conference of Weight and Measure gave official status to a single practical system, the international system of units. The system is a modernised version of the metric system. It has seven basic units and two supplementary units. These units are given below :

Quantity	*Unit*	*Abbreviation*	*Year of Adoption*
Length	metre	m	1960
Mass	kilogram	kg	1960
Time	second	s	1967
Electric current	ampere	A	1948
Temperature	Kelvin	K	1967
Luminous intensity	Candela	cd	1967
Amount of substance	mole	mol	1971
Plane angle	radian	rad	1960
Solid angle	steradian	Sr	1960

MECHANICS

Mechanics is the branch of physics which deals with the action of force or forces on material bodies, whether they are at rest or in motion.

Motion : The continuous change of position of a body with respect to a fixed reference is called motion of that body. There are various kinds of motion.

One dimensional motion : Walking, bus running on the roads are the examples of one dimensional motion.

Two dimensional motion : Projectile motion, a carrom coin, a billiard ball over plane etc. are the examples of two dimensional motion.

Three dimensional motion : The object moving in the space involving all the three dimensions.

Displacement : When a body moves from one point to another point the distance measured along the straight line joining the two point gives the displacement undergone by the body, irrespective of the actual path traversed by the body. It has both magnitude and direction, *i.e.*, it is a vector quantity.

Vector and Scalar Quantities : Vector quantities are those which have both magnitude and direction *e.g.*, displacement, velocity, force etc. and scalar quantities are those quantities which have only magnitude but no direction *e.g.*, speed, mass, time, potential etc.

Speed : It is the rate of change of position of a body with respect to time along straight or curved path.

$$\therefore \quad \text{Speed} = \frac{\text{Total distance moved by the body}}{\text{Time taken}}$$

Velocity : It is the rate of change of position of a body with respect to time in a straight line along a particular direction. It is a vector quantity.

Acceleration : It is the rate of change of velocity. When the change of velocity decreases with time then it is said to be retarded. It is a vector quantity.

Gravitational Acceleration : It is the acceleration due to gravity with which a freely falling body moves towards the earth. It is equal to $9.8 \ m/s^2$.

Equation of Motion : If a body starts moving with initial velocity u under a uniform acceleration a and attains a final velocity v in time interval t, thereby undergoes a displacement s, then the following relations exist .

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

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

(*iii*) $v^2 = u^2 + 2as$

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

where s_n is the distance travelled by a body in nth second.

Force : It is that which changes or tends to change the state of rest or motion of a body.

Inertia : It is the inherent property of objects to remain at rest unless acted upon by a force or to keep a body moving with a constant velocity in the absence of any force acting on it. Galileo discovered the law of inertia.

Momentum (p) : It is the product of mass and velocity of a body. It is a vector quantity

$\therefore \ p = mv$

Laws of Motion

First law : Everybody continues in its state of rest or of uniform motion in a straight line unless compelled by some external force to act otherwise.

Second law : The rate of changed of momentum of a body is proportional to the applied force and takes place in the direction in which the force acts.

Mathematically, $F \propto \frac{\Delta(mv)}{\Delta t}$

$\therefore \quad F = K\frac{\Delta(mv)}{\Delta t}$

where K is the constant of proportionality.

Third law: To every action there is always an equal and opposite reaction. Action and reaction which occurs in pairs act on different bodies. If they acted on the same body, the resultant force would be zero and there could never be accelerated motion.

Impulse : The product of the force and time during which the forces is called the impulse of the force.

Mathematically, $I = \Delta p = F.\Delta t$.

Conservation of Momentum

In the absence of external forces, when two or more bodies interact with one another, their total momentum remains constant.

Mathematically, $MV + mv$ = constant, where M, m and V, v are the masses and velocity of the body.

Application of Conservation of Momentum

In propulsion of rocket, the mass of rocket keeps decreasing due to occupying mass of the gas, therefore velocity and acceleration of the rocket increases.

Circular Motion

When a body of mass 'm' moves in a circle of radius 'r' with a constant speed 'v', the *centripetal acceleration* $\frac{v^2}{r}$ directed towards centre of the circle produces the *centripetal force* F in the direction of the acceleration. It is mathematically expressed by

$$F = \frac{mv^2}{R} = Mr\omega^2 \qquad (\because v = \omega r)$$

By Newton's third law of motion, an equal and opposite force which is its reaction comes into play. This reaction force acts on a body at the centre and is directed away from the centre. It is called *centrifugal force*.

Application of Centripetal Force

1. Banking of roads
2. Bending of a cyclist
3. Conical pendulum
4. Speed grovernor

Application of Centrifugal Force

A device centrifuges is used to separate one material from another. The heavier material are thrown outward and collected at appropriate plane. The similar device known as the separator is used to separate cream from milk. The milk is being heavier than cream and is forced to throw outward push of the spinning bond and is drawn off. The cream which is lighter stays near the centre and is drawn off from that point. The similar theory is used in the dry cleaning machine etc.

GRAVITATION

The Gravitational Force

Newton's law of universal gravitation states : The forces between any two particle or masses m_1 and m_2 separated by a distance r, is an attraction acting along the line joining the particle and has the magnitude.

$F = \frac{Gm_1m_2}{r^2}$, where G is the universal gravitational constant. The value of G is equal to 6.67×10^{-11} N.m²/kg².

Variation of 'g': The acceleration due to gravity varies from place to place. This may be due to the height or depth or due to the shape of the earth.

(*i*) Above the surface of the earth the variation is given by

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

Equation (*i*) shows that the greater the distance of the body from the earth the smaller the value of g.

Mathematically, $\Delta g = g\left(1 - \frac{2h}{R}\right)$

(*ii*) Below the surface of the earth, it varies directly as the distance from the centre of the earth, *i.e.*,

$$\Delta g = g\left(1 - \frac{h}{R}\right)$$

(*iii*) Due to the shape of the earth, the equatorial radius of the earth is greater than the polar radius by nearly 22 kms. The value of 'g' is greater at the pole than the equator.

(*iv*) Due to the rotation of the earth, the value of 'g' increases when a body moves from the equetor towards the pole.

i.e., $\Delta g = g\left(1 - \frac{R\omega^2}{g}\cos^2\alpha\right)$

where α is the altitude.

Keplar's Law of Planetary Motion

J. Keplar formulated three laws on the observation of motion of plane of first astronomer Mr. Tycho Brake. These are following :

1. ***The law of orbit :*** The path of the small body is a conic section having the large body as one focus. The particular section is determined by the speed of the small body at a given instant.

2. ***The law of area :*** The area swept out in a given time by the radius vector joining the large body to the small body is always the same.

3. ***The law of periods :*** For closed orbits (ellipses) the ratio $\frac{(\text{orbital period})^2}{(\text{semi major axis})^2}$ is always the same.

Satellite : A satellite is any body revolving around a large body under the influence of the latter e.g., moon is a satellite of the earth. If the time period of the satellite be exactly equal to the period of revolution of the earth, then it will appear to be stationary at the same place on the earth. This is called parking orbit.

Weightlessness : When a gravitational force on any body is opposed by an equal and opposite inertial force, a weightless state is produced, it is relative only and it does not mean that gravitational force has seemed to act, it is only that their is no relative acceleration.

Escape Velocity : It is the minimum velocity required to accelerate the body to reach infinity from the earth

Mathematically, $v_e = \sqrt{\frac{2GM}{R}} = \sqrt{2gR}$

= 11.2 km/sec on the earth surface.

It is numerically equal to $\sqrt{2}$ times the orbital velocity near the earth's suface.

The Electrostatic Force : It exists between any two electric charges. It is attractive between opposite charges and repulsive between like charge. It is also in contrast to gravitation which is always attractive between any two given masses.

Mathematically, $F_e = \frac{Kq_1q_2}{r^2}$ where q_1, q_2 are the charges and r is the distance between them.

K – proportionality constant which is equal to $\frac{1}{4\pi\varepsilon_0}$ or 9.0×10^{-12} Nm^2/C^2

The Magnetic Force : It exists between any two magnets.

The Moment of a Force : The turning effect of a force is called moment of the force or torque. The moment of the force is given by the product of the magnitude of the force and the length of the corresponding force arm. If F be the magnitude of force and l be the length of the force arm, then mathematically it is given by

$$\tau = F \times l$$

Couple : Two equal and opposite forces acting at different points of a body are said to form a couple. The action of a couple tends to rotate the object in one direction.

Centre of Gravity : It is the point at which the weight of the body may be considered to act. When a body is suspended from its centre of gravity, it will remain in equilibrium, the centre of gravity of a body may lie outside. The position of centre of gravity of anybody determines its stability.

Friction : When a body moves or tends to move over another, the oppositing force set up in the plane of contact of the surface is called frictional force. The origin of frictional force is due to surface irregularities at molecular scales. Friction is of two types : (*i*) Static friction, (*ii*) Kinetic friction. Static friction is a self-adjusting force.

The law of static friction states :

1. The maximum force of static friction is independent of the area of contact

2. The maximum force of static friction is proportional to the normal force.

Kinetic Friction is the force of friction which is less than the limiting friction and is called into play when the body moves with a uniform speed. The law of kinetic friction are similar to those of static friction.

Rolling Friction : When a body rolls over a surface, the frictional force developed is known as the rolling friction.

Importance of Friction : Friction is necessary in many everyday activities like walking or gripping objects. It is a serious nuisance in device that move continuously like electric motor and rail-road trains. Friction become an evil for us when there is too little friction and conditions are slippery.

FLUID MECHANICS

Pressure : If a force F acts perpendicular to the surface of a fluid (liquid or gas) of area, A, then the pressure P is given by

$$P = \frac{F}{A}$$

The S.I. unit of pressure is N/m^2 or Pascal.

Pascal's Law : It states that pressure applied to a liquid at (rest) at one point is transmitted equally in all directions throughout the liquid.

Application of Pascal's Law

The city pumping station can pump water to our houses only because of the force explained by Pascal's law. The principle of the hydraulic press is based on Pascal's law and it is used in many common appliances such that on automobile as the hydraulic break. Hydraulic pressure operates the wing flaps of many planes. It also compresses cotton, paper, cloth bales into comparatively small bundles.

Buoyancy : When a body is immersed in a liquid (or gas) the liquid exerts an upward thrust over it. This upward thrust is called buoyancy.