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A Must for Civil Services (Pre) Examination, State PCS & Other Competitive Exams

GENERAL SCIENCE

Coverage of Important Facts from NCERT Books (Class 6-12)

Topical Coverage of Syllabus and Previous Years' Questions with more than 3000 MCQs and 5 Practice Sets

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CONTENTS

TOPICS FOCUS & TREND OF QUESTIONS

PHYSICS

Mechanics
The important topics in this chapter are fundamental units and dimensions, various types of weak and strong forces, newton's law of motion and inertia, different types of energy and conservation of energy, mass and weight, planets and satellites. Questions asked in previous exams are related to concepts such as force, energy, circular motion of satellites, escape velocity etc.

Properties of Matter
From examination point of view significant topics are stress, strain, elasticity, surface tension, capillarity, viscosity, stoke's law and bernoulli's theorem. Most of the questions asked in previous exams from this section arere garding elastic limit, fracture point, capillary action and viscous flow.

Oscillations and Waves
This chapter deal with important topics such as oscillatory motion including SHM and wave motion, speed, characteristics, properties of sound wave including doppler's effect. Previous year's exam questions were based on amplitude and wavelength of wave motion as well as reflection, refraction and diffraction of sound waves.

Heat and Its Transmission
Important topics are various scales of temperature measurement, laws of thermodynamics, specific and latent heat, humidity, convection, conduction and radiation and properties of black body. Questions were asked on various mode of transmission of heat and specific and latent heat.

Optics
This is the most important chapter from the perspective of competitive examination. Important topics from examination point of view are light and related properties of reflection, refraction and total internal reflection, properties of concave, convex and spherical mirrors, lenses, behaviour of prism, dispersion, scattering and interference of light.

Electricity and Magnetism
Significant topics in this chapter are electric field, capacitor, resistance, conductors and semiconductors, electric cell, magnetism and earth's magnetic field, ferromagnetism and electro magnetic induction, working principles of transformer and dynamo. Questions have asked recurrently on above topics in previous year's examinations.

Modern Physics
Important topics in this chapter are nuclear fission and fusion, radioactive decay, photoelectric effect, electromagnetic waves and devices based on electromagnetic radiations, electronics, nano technology, radar and Solar system. Previous exam questions were based on process involved in nuclear reactors, nuclear forces, devices based on photoelectric effect and properties of comets, asteroids and meteors in solar system.

CHEMISTRY

General Chemistry
This chapter will introduce the reader to the chemistry and matter concepts related to classification of matter, solution, colloids and suspensions are important from examination point of view since questions have been asked in the past about it.

Atomic Structure and Chemical Bonding
This chapter discusses vital topics like atoms, molecules, subatomic particles, and bonds. From an examination point of view the topics of carbon dating, geological dating, electrovalent, covalent and van der waals forces are important. The concepts related to valency are also very important.

Classification of Elements
This chapter presents the concepts related to the periodic table. From examination point of view the new super heavy element unseptium, and various blocks of periodic table and periodic properties are important.

Chemical Reactions and Equations
This chapter discusses the types of chemical reactions, catalysts and batteries. Questions relating to oxidation and reduction fuel cells can appear in the exam.

Elements and Compounds
This chapter discusses important metals, non-metals and their properties. It also discusses concepts relating to acids, bases and salts. From examination point of view, all the toxic materials and nutrition related materials are important.

Organic Chemistry
This chapter introduces the reader to various organic compounds and fuels. From examination point of view –fuels, hydrocarbons and petroleum are extremely important.

Environmental Chemistry
This is the most important section in Chemistry from examination point of view as questions are asked in almost every exam. Some important topics are abiotic, biotic and energy components, different types of pollution and pollutants and pollution control. This chapter carries nearly as much importance as all other chapters combined in terms of both importance and relevance.

Chemistry in Everyday Life
It is important to understand various synthetic materials like cement, glass, fertilizers, pesticides, explosives from examination point of view. Operation of fire-extinguisher, various chemicals in medicine, chemicals in food need to be understood thoroughly – since there is great scope for questions from that section.

BIOLOGY

Cell Biology
Some important topics are cell cycle and cell division, enzymes and inhibitors. Most of the questions which were asked in past were related to mitosis, meosis, enzymes and inhibitors.

Biological Classification
The concepts related to bacteria, virus, protozoa are very important – especially to understand more advanced concepts in biotechnology, pathology etc. Questions relating to gram staining, modes of transmission can be asked in the exam.

Structural Organisation of Plants and Animals
Concepts of xylem and phloem, meristmatic tissues, sapwood and hardwood, types of tissues, blood are not only interesting but also important. From exam perspective, questions relating to blood groups – the antigens, antibodies and donor groups appear very frequently.

Human Physiology
Concepts relating to digestive system, respiratory system, cardiovascular, neural, endocrinal and excretory system are the most important. From the examination perspective, questions can primarily be asked regarding the role of various vitamins, importance of proteins, various disorders associated with various systems, tables related to various glands are extremely important. Nutrition itself is one of the most important topics for preliminary examination.

Plant Physiology
The topics of photosynthesis, mineral nutrition in plants are most important. Questions related to xylem, phloem transportation and transpiration have appeared in the past.

Reproduction in Plants and Humans
The concepts associated with a sexual and sexual reproduction are important since they help understand various issues related with biology. Questions related to sexually transmitted diseases, and reproductive healths have been asked in the previous exams.

Genetics and Evolution
One of the most important and interesting topics to understand because it forms the basis for biotechnology, green revolution and other associated topics. From exam point of view, the concepts of recessive allele, mendels laws, theory of evolution and genetic disorders are important.

Ecology
This chapter introduces the reader to ecology – from a biological and terminological perspective. Understanding these terms are important not only to gain a grasp on the environment and biodiversity subject in syllabus, but also because questions related to them can appear directly in the exam.

Biology in Human Welfare
The concepts related to economically important plants, biofertilizers and vaccination are important from examination point of view. Questions have been asked in the past about Principal Vaccines.

SCIENCE AND TECHNOLOGY

Computer and Information Technology

In almost all the competitive examinations questions are asked frequently from this section. Some of the important topics are types of computers, super computers in India and world, input and output devices, types of memory, software, types of network, cyber crimes etc.

Telecommunication

Questions are asked from this topic in all exams regarding the current developments in the telecommunication technology. Some of the important topics from examination perspective are optical fibre, wireless communication, mobile operating systems, GPRS, types of television etc.

Biotechnology

Biotechnology is one of the hot topics now-a-days, from which questions are asked in most of the competitive examinations. mportant topics from examination perspective are uses of biotechnology, genetic engineering, cloning, genetically modified crops (Bt brinjal), biodiesel etc.

Indian Space Programme

After analysing question papers of various examinations, it has been found that questions are asked in most of the competitive examinations regarding the developments in Indian space programme. Some of the important topics from examination point of view are INSAT, IRS, various space launching stations of India and world, types of launch vehicles used in India, IRNSS, GPS, glonass, galileo, GIS, various space missions of India, cryogenic technology, international space mission etc.

Indian Nuclear Programme

This is one of the most important topics from which questions are asked on regular basis regarding the latest developments in the field of nuclear technology and the basic concepts of nuclear technology. Some of the important topics from examination perspective are various parts of a nuclear reactor and their functions, types of nuclear reactors used in India, India's important nuclear installations and their location along with the types of fuel used, various applications of radio isotopes, radioactive wastes etc.

Indian Defence Programme

In almost all the competitive examinations questions are asked regarding latest developments in the Indian Defence system. Some of the important topics are types of missiles inducted in Indian defence forces, range of missiles, types of radars, naval ships, submarines, tanks, aircrafts etc.

Chapter one
Mechanics

Mechanics is the branch of science (physics) concerned with the behaviour of physical bodies, when subjected to forces or displacements, and the subsequent effects of the bodies on their environment.

Physical Quantity

- It is a physical property of a body, or substance, or of a phenomenon, that can be quantified by measurement.

Measurement of a Physical Quantity

- It is done by assigning a value to a physical quantity by comparing it with a standard value (calibrated value) of that physical quantity which is called **unit**.
- To know the value (or magnitude) of a physical quantity we generally measure it in different system of units.

Errors in Measurement

- The difference between the true value and the measured value of a quantity is known as error.
  There are mainly three types of error occurs in measurement.
  - **Absolute Error** It is the difference of true value and measured value.
  - **Relative Error** It is defined as the ratio of absolute error to mean value.
  - **Percentage Error** It is defined as fractional error multiplied by 100.

System of Units

- Physical quantities are measured in four system of units as below.
  - CGS (Centimetre, Gram, Second)
  - FPS (Foot, Pound, Second)
  - MKS (Metre, Kilogram, Second)
  - SI system (International System of Units).

Fundamental Quantities

- The physical quantities which are independent to each other are called **fundamental quantities** and their units are called **fundamental units**.
- The most accepted one is SI system which was adopted in 1971 by conference of weights and measures held in Geneva.
- There are *seven* fundamental quantities in SI system

Fundamental Quantities in SI System

S.No.	Fundamental quantity	Fundamental unit	Symbol
1.	Length	Metre	m
2.	Mass	Kilogram	kg
3.	Time	Second	s
4.	Electric current	Ampere	A
5.	Temperature	Kelvin	K
6.	Luminous intensity	Candela	cd
7.	Amount of substance	Mole	mol

- There are also two supplementary fundamental units in SI system.
  - **Radian (rad)** It is unit of plane angle.
  - **Steradian (sr)** It is unit of solid angle.

Derived Quantities

- The physical quantities which are obtained with the help of fundamental quantities are called **derived quantities** and their units are called **derived units**.
  For example, Velocity, Force, Work, Density, Momentum etc are derived quantities.

Some Important Derived Units

Physical quantity	Unit (SI)	Symbol
Force	newton	N
Energy	joule	J
Speed	metre/second	ms^{-1}
Angular velocity	radian/second	rad s^{-1}
Frequency	hertz	Hz
Moment of inertia	kilogram metre square	kg m^2
Momentum	kilogram metre/second	kg ms^{-1}
Angular momentum	kilogram metre square/second	kg m^2 s^{-1}
Pressure	pascal	Pa
Power	watt	W
Surface tension	newton per metre	Nm^{-1}
Viscosity	newton second per metre square	Nsm^{-2}
Thermal conductivity	watt per metre Kelvin	Wm^{-1} K^{-1}
Electric charge	coulomb	C
Potential	volt	V
Capacitance	farad	F
Electrical resistance	ohm	Ω
Inductance	henry	H
Magnetic flux	weber	Wb
Luminous flux	lumen	lm
Impulse	newton second	Ns

Unit of Length

- The SI unit of length is metre (m). One metre is the distance travelled by light in vacuum in $\frac{1}{29,97,92,458}$ of a second.

Some Other Units of Length

- **Light year** The distance travelled by light in one year in vacuum.

$$1 \text{ light year} = 9.46 \times 10^{15} \text{ m}$$

- **Parsec** (Parallactic Second) The distance at which an arc of length equals to one astronomical unit subtends an angle of one second at a point.
  - 1 parsec = 3.085×10^{16} m
  - 1 AV = 1.49×10^{11} m
  - 1 nanometre or nm = 10^{-9} m
  - 1 Fermi = 10^{-15} m
  - 1 micron or μm = 10^{-6}
  - 1 angstrom or Å = 10^{-10} m
  - X-unit = 10^{-14} m
  - 1 yard = 0.9144 m

- Area is related with square of length, some units of area are
  - 1 barn = 10^{-28} m^2
  - 1 acre = 4047 m^2
  - 1 hectare = 10^4 m^2
- Volume is related with cube of length, some units of volume are

10 millilitre (mL) = 1 centilitre (cL)
= 0.018 pint (0.021 US pint)
100 centilitre (cL) = 1 litre (L) = 1.76 pint
10 litre (L) = 1decalitre (daL)
= 2.2 gallon (2.63 US gallon)
1 cubic centimetre (cm^3) = 1 millilitre (mL)
1 barrel = 159 litre

Unit of Mass

- The SI unit of mass is **kilogram**. One kilogram is defined as the mass of 5.0188×10^{25} atoms of carbon–12.

Other Units of Mass

- 1 gram = $\frac{1}{1000}$ kg = 10^{-3} kg
- 1 milligram = $\frac{1}{1000}$ g = 10^{-6} kg
- 1 Atomic Mass Unit (amu) = 1.66×10^{-27} kg
- 1 quintal = 100 kg
- 1 tonne or metric ton = 1000 kg
- 1 slug = 14.57 kg
- 1 Chandra Sekhar Limit (CSL) = 1.4 times the mass of sun = 2.8×10^{30} kg

Unit of Time

- The SI unit of time is **second**. One second is defined as $\frac{1}{86400}$ part of a mean solar day.

Other Units of Time

- 1 microsecond = 10^{-6} s
- 1 picosecond = 10^{-12} s
- 1 Lunar month = 29.5 day
- 1 nanosecond = 10^{-9} s
- 1 shake = 10^{-8} s

Important Prefixes to Units

peta (P) = 10^{15}	exa (E) = 10^{18}
giga (G) = 10^9	tera (T) = 10^{12}
kilo (K) = 10^3	mega (M) = 10^6
deca (da) = 10	hecto (h) = 10^2
centi (c) = 10^{-2}	deci (d) = 10^{-1}
micro = 10^{-6}	milli (m) = 10^{-3}
pico (p) = 10^{-12}	nano (n) = 10^{-9}
zatto (a) = 10^{-18}	femto(f) = 10^{-15}

Scalar and Vector Quantities

On the basis of magnitudes and direction, *physical quantities are categorised as below*

- **Scalars Physical quantities** which have only magnitude and no direction are called scalars quantities e.g., length, mass, time etc.
- **Vectors Physical quantities** which have both magnitude as well as direction are called vectors quantities e.g., force, displacement, impulse etc.
  - A vector obeys triangle law and parallelogram law of addition of two vectors. Zero vector or null vector, unit vector, etc are some special types of vectors.

Dimensions

- The dimensions of a physical quantity are the powers to which the fundamental units are raised in order to obtain the units of that quantity.
- The fundamental quantities mass, length, time, temperature, luminous intensity, amount of substance and current are respectively represented as M, L, T, θ, cd, N and A.
- The dimension of the physical quantity shall be written in the manner $[M^a L^b T^c \theta^d]$.

where, a, b, c and d are exponents.

- *Some Important dimensional Formulae are*
  - Velocity $= \frac{\text{Displacement}}{\text{Time}} = \frac{[L]}{[T]} = [LT^{-1}]$
  - Density $= \frac{\text{Mass}}{\text{Volume}} = \frac{[M]}{[L^3]} = [ML^{-3}]$

Kinematics

- The branch of Physics which deals with the study of motion of material objects etc is called mechanics. **Kinematics** is a branch of mechanics which deals with the study of motion of the objects without taking into account the cause of their motion.

Rest and Motion

- An object is said to be at **rest** if it does not change its position with respect to its surroundings with time and said to be in **motion** if it changes its position with respect to its surroundings with time.
- *Basic types of motion are*
  - **Rectilinear motion** The motion in which particle moves along a straight line, such as *moving car on horizontal road, motion under gravity etc.*
  - **Angular motion** The motion in which particle moves along a curved track, such as *particle going on a circle, projectile motion, rotation of machine shaft etc.*
  - **Rotational motion** If a body rotates about a given axis, its motion is called rotational motion, such as *motion of a fan.*

Distance and Displacement

- The length of the actual path travelled by an object during motion in a given interval of time is called the **distance** travelled by the object.
- The change in position of the object along a particular direction in a given interval of time is called the **displacement** of the object.
- Displacement can be positive, negative or zero but distance cannot be negative.
- Distance is a scalar quantity and displacement is vector quantity.
- If an object travels equal distances in equal intervals of time, then it is said to be in **uniform motion**.
- If an object travels unequal distances in equal intervals of time, then it is said to be in **non-uniform motion**.

Speed

- The distance covered by a moving body in a unit time interval is called its speed.

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

- The speed at an instant of time is known as instantaneous speed.
- An object is said to be moving with uniform speed if it covers equal distances in equal intervals of time.
- An object is said to be moving with non-uniform or **variable speed** if it covers unequal distances in equal intervals of time.
- **Average speed** of an object is the ratio of the total distance travelled to the total time taken to cover this distance.

$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

- When a body travels equal distances with speeds v_1 and v_2, then average speed is the **harmonic mean** of the two speeds.

$$\frac{2}{v} = \frac{1}{v_1} + \frac{1}{v_2} \Rightarrow v = \frac{2v_1v_2}{v_1 + v_2}$$

- When a body travels for equal times with speeds v_1 and v_2, then average speed is the **arithmetic mean** of the two speeds.

$$v = \frac{v_1 + v_2}{2}$$

Velocity

- The time rate of change of displacement of a body is called its velocity.

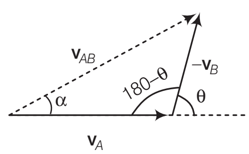
$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}}$$

- The velocity at an instant of time is known as instantaneous velocity.
- An object is said to be moving with **uniform velocity** if it undergoes equal displacements in equal intervals of time.
- An object is said to be moving with **non-uniform** or **variable velocity** if it undergoes unequal displacements in equal intervals of time.
- **Average velocity** of an object is the ratio of the total displacement to the total time taken.

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time taken}}$$

Relative Velocity

Relative velocity of an object with respect to another object is the time rate of change of position of one object with respect to another object. If two objects A and B are moving with velocities v_A and v_B making an angle θ with each other, then magnitude of relative velocity of A with respect to B is given by



$$\mathbf{v}_{AB} = \mathbf{v}_A - \mathbf{v}_B$$
$$|\mathbf{v}_{AB}| = \sqrt{\mathbf{v}_A^2 + \mathbf{v}_B^2 - 2\mathbf{v}_A\mathbf{v}_B \cos\theta}$$

If $\mathbf{v}_{AB}$ makes an angle α with $\mathbf{v}_A$, then

$$\tan\alpha = \frac{\mathbf{v}_B \sin\theta}{\mathbf{v}_A + \mathbf{v}_{AB}\cos\theta}$$

If both objects are moving in same direction (i.e. $\theta = 0°$), then $\mathbf{v}_{AB} = \mathbf{v}_A - \mathbf{v}_B$

If both objects are moving in opposite directions (i.e. $\theta = 180°$), then

$$\mathbf{v}_{AB} = \mathbf{v}_A + \mathbf{v}_B$$

Acceleration

- The time rate of change of velocity of a body is called its acceleration.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken}}$$

- It is a vector quantity and its SI unit is ms^{-2}.
- Acceleration at an instant of time is known as **instantaneous acceleration.**
- When the velocity of a body increases with time, then its acceleration is positive and if velocity decreases with time, then its acceleration is negative called **deceleration or retardation.**
- If acceleration does not change with time, it is said to be **constant acceleration.**

Equations of Uniformly Accelerated Motion

(Along straight line)

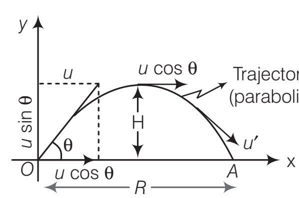
- If a body started its motion with initial velocity u and attains final velocity v in time interval t. The acceleration assumed to be uniform in motion is a and the distance travelled is s, then *equations of motion*

$$v = u + at$$
$$s = ut + \frac{1}{2}at^2$$
$$v^2 = u^2 + 2as$$

- If any body is falling freely under gravity, then a is replaced by g in above equations.
- If an object is thrown vertically upward, then in above equations of motion a is replaced by $(-g)$.
- Distance travelled by a body in a particular nth second is given by $s_n = u + \frac{a}{2}(2n-1)$
- For a body with zero acceleration or constant speed, graph between velocity and time will be a line parallel to time axis and for accelerating or decelerating body the graph will be a straight line inclined to time axis and velocity axis.
- Graph between position (distance)-time for an accelerating or decelerating body is always a parabola whereas acceleration-time graph for uniformly accelerating body is a line parallel to time axis.
- In case of uniform accelerated, the graph between position and velocity is always parabola.
- In case of uniformly accelerated motion, the graph between velocity and time is always a straight line.
- Slope of displacement-time graph gives velocity and slope of velocity-time graph gives acceleration.

Projectile Motion

- When a body is thrown from horizontal making an angle (θ) except $90°$, then its motion under gravity is a curved parabolic path, called trajectory and its motion is called projectile motion.



- The horizontal component of velocity $(u\cos\theta)$ of projectile is responsible for its horizontal motion and remains constant and vertical component of velocity $(u\sin\theta)$ is responsible for its vertical motion.

For examples

- The motion of a bullet shot from the gun
- The motion of a rocket after burn-out
- The motion of a bomb dropped from a aeroplane etc.

Some terms related with the projectile motion are

- **Time of flight** (T) It is the time taken by the projectile to cover the journey from point of projections (O) to end point (A).

  It is given by $T = \dfrac{2u\sin\theta}{g}$

  where, g is acceleration due to gravity.
- **Maximum Height** (H) It is the maximum height attained by the projectile during the journey from "O" to "A" as shown in the diagram.

  It is given by $H = \dfrac{u^2\sin^2\theta}{2g}$
- **Range** (R) It is the distance between starting point (O) and final point (A).

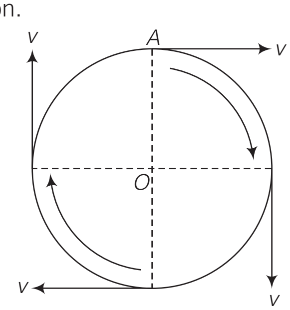
  It is given by $R = \dfrac{u^2\sin 2\theta}{g}$

Properties of Projectile Motion

- Horizontal range is maximum when angle of projection is 45°. Horizontal range is same for angle of projections $\theta°$ and $(90-\theta)°$.
- The horizontal component of velocity remains unchanged during the projectile motion. At the highest point of projectile motion, the direction of motion becomes horizontal as vertical component of velocity becomes zero at that point.
- If we drop down a ball from a height and at the same time thrown another ball in a horizontal direction, then both the balls would strike the earth simultaneously at different places.

Circular Motion

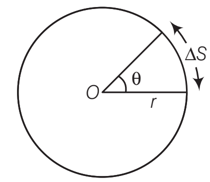
- The motion of an object along a circular path is called circular motion.



- Circular motion with a constant speed is called **uniform circular motion**.
- The direction of motion at any point in circular motion is given by the tangent to the circle at that point.
- In uniform circular motion, the velocity and acceleration both changes.
- In case of non-uniform circular motion, the speed changes from point to point on the circular track.

Angular Displacement and Velocity

- The angle subtended at the centre of a circle by a body moving along the circumference of the circle is called **angular displacement** of the body. Its unit is radian (rad).



$$\text{Angular displacement } (\theta) = \frac{\text{Length of the arc}}{\text{Radius of the circle}} = \frac{\Delta s}{r}$$

- The time rate of change of angular displacement is called **angular velocity**. Its unit is rad s^{-1}.

$$\text{Angular velocity } (\omega) = \frac{\text{Angular displacement}}{\text{Time}} = \frac{\Delta\theta}{\Delta t}$$

- If time period of uniform circular motion is T, then average angular velocity is given by

$$\omega = \frac{2\pi}{T} = 2\pi f \quad \left[\text{where, Frequency } (f) = \frac{1}{\text{Time period } (T)}\right]$$

- Linear velocity in circular motion is given by

  Linear velocity = Angular velocity × radius

  or $v = \omega \times r$

Centripetal Acceleration

- During circular motion an acceleration acts on the body towards the centre, called centripetal acceleration.
- Centripetal acceleration $(a_c) = \dfrac{v^2}{r} = r\omega^2$

  where, v *= uniform speed of the body*

  r *= radius of circular path and*

  ω *= angular velocity.*
- The direction of centripetal acceleration is always towards the centre of the circular path.

Force

- It is an external push or pull which can change or tries to change the state of rest or of uniform motion. SI unit is newton (N) and CGS unit is dyne. 1 N $= 10^5$ dyne.
- If sum of all the forces acting on a body is zero, then body is said to be in equilibrium.
- *In nature, there are four basic types of forces*
  - Gravitational force
  - Electromagnetic force
  - Weak nuclear force
  - Strong nuclear force
- Among these forces, the strong nuclear force is strongest one.

Centripetal Force

- During circular motion a force always acts on the body towards the centre of the circular path, called centripetal force.

$$\text{Centripetal force } (F) = \frac{mv^2}{r} = mr\omega^2$$

where, m = mass of the body.

Centrifugal Force

- In circular motion we experience that a force is acting on us in opposite to the direction of centripetal force called **centrifugal force**. This is an apparent force or imaginary force and also called a pseudo force.

Applications of centripetal and centrifugal forces

- Cyclist inclined itself from vertical to obtain required centripetal force. To take a safe turn cyclist slower down his speed and moves on a path of larger radius, to balance decreased value of friction due to bending.
- Roads are banked at turns to provide required centripetal force for taking a turn. The component of normal reaction force provides required centripetal force.
- For taking turn on a curved road, the **frictional force** is acting between the tyres of the vehicle and the road acts as centripetal force.
- If a car takes a turn with a speed greater than the safe limit, then inner tyres leave the roads first in turning of car because inner tyres were moving in smaller radius, hence larger centrifugal force were acting on these tyres so more chances of skidding.
- If a bucket containing water is revolved fast in a vertical plane, the water may not fall even when bucket is completely inverted because a centrifugal force equal or greater than the weight of water pushes the water to the bottom of the bucket.
- For orbital motion of electrons around the nucleus, **electrostatic force** of attraction is acting between the electrons and the nucleus as centripetal force.
- Cream is separated from milk when it is rotated in a vessel about the same axis. During rotation lighter particles of cream experience a lesser force than the heavier particles of milk. Therefore, lighter particles tend to adopt a path of smaller radius and move towards the centre. The heavier particles tend to adopt a path of larger radius and move towards the circumference and hence cream is separated from milk.
- For revolution of the earth around the sun, gravitational force of attraction between the earth and the sun acts as centripetal force.
- **Torque or Moment of a Force** It is the product of the force and the perpendicular distance of the force from the axis of rotation. It produces rotational effect. It is a vector quantity.

Newton's Laws

Newton's First Law

- A body continues in its state of rest or of uniform motion in a straight line unless an external force acts on it. It is based on **law of inertia**.
- Inertia is the property of a body by virtue of which it opposes any change in its state of rest or of uniform motion in a straight line.

Inertia of Rest

- It is the property of a body by virtue of which it cannot change its state of rest on its own.
  - When a bus or train at rest starts, to move suddenly, the passengers sitting in it jerk in backward direction due to their inertia of rest.
  - The dust particles come out from a carpet when it is beaten with a stick due to their inertia of rest.
  - A passenger jumping out from a rapidly moving bus or train is advised to jump in forward direction and run forward for a short mile due to inertia of rest.

Inertia of Motion

- It is the property of a body by virtue of which it cannot change its state of uniform motion on its own.
- When a running bus or train stops suddenly, the passengers sitting in it jerk in forward direction due to inertia of motion.

Momentum

The momentum of a moving body is equal to the product of its mass and its velocity.

Its unit is $kg\text{-}ms^{-1}$. It is a vector quantity and its direction is in the direction of velocity of the body.

Momentum = Mass × velocity

$$\mathbf{p} = m \times \mathbf{v}$$

Conservation of Linear Momentum

The linear momentum of a system of particles remains conserved if the external force acting on the system is zero. Rocket propulsion and engine of jet aeroplane works on principle of conservation of linear momentum. In rocket, ejecting gas exerts a forward force which helps in accelerating the rocket upward.

Conservation of Angular Momentum

If external torque on a system is zero, angular momentum will remain conserve. It is known as principle of conservation of angular momentum.

Newton's Second Law

- The rate of change of momentum of a body is directly proportional to the force applied on it and change in momentum takes place in the direction of applied force.

$$F = \frac{\Delta p}{\Delta t} = \frac{m\Delta v}{\Delta t} = ma$$

where, m is mass of the body and is constant.

- If the resultant force on a body is zero, the body is said to be in equilibrium.

Newton's Third Law

- For every action, there is an equal and opposite reaction and both act on two different objects.
- Rocket is propelled by the principle of Newton's third law of motion.

Impulse

- A large force which acts on a body for a very short interval of time and produces a large change in its momentum is called an impulsive force.
- The impulse of a force acting on a body is equal to the product of the large force and small time interval for which it acts on a body.

$$\text{Impulse}\,(I) = \text{Force} \times \text{time}$$

- Its unit is newton-second.
- Impulse of a force applied on a body is equal to the change in linear momentum of that body.

$$\text{Impulse} = \text{Force} \times \text{time} = \text{Change in momentum}$$

or
$$\text{Force} = \frac{\text{Change in momentum}}{\text{Time}}$$

  – A fielder lowers its hand when catching a cricket ball because by lowering his hands, he increases the time of contact for stopping the ball and therefore fielder has to apply lesser force to stop the ball. The ball will also exert lesser force on the hands of the fielder and the fielder will not get hurt.
  – Wagons of a train are provided with the buffers to increase the time of impact during jerks and therefore, decreases the damage. The vehicles like scooter, car, bus, truck etc. are provided with shockers.

Friction

- Friction is a force which opposes the relative motion of the two bodies when one body actually moves or tries to move over the surface of another body.
- The cause of friction is the strong atomic or molecular forces of attraction acting on the two surfaces at the point of actual contact.

Types of Friction

- **Static friction** The opposing force that comes into play when one body tends to move over the surface of another body but the actual motion has yet not started is called static friction. Static friction is a self-adjusting force and it adjusts itself so that it becomes equal to the applied force.
- **Limiting friction** The maximum static frictional force which comes into play, when one body is just at the verge of moving over the surface of the another body.

  Limiting friction $(f_s) = \mu_s R = \mu_s mg$

  where, μ_s *= coefficient of limiting friction.*
- **Kinetic friction** The opposing force that comes into play when one body actually moves over the surface of another body, is called kinetic friction.

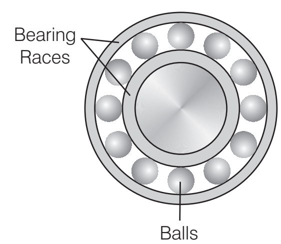
  Kinetic friction is of two types
  – **Sliding friction** It comes into play when one body slides over the surface of the another body.
  – **Rolling friction** It comes into play when one body rolls over the surface of the another body.
- Rolling friction is lesser than sliding friction. Therefore, it is easier to roll a body than to slide it.
- It is easier to drive a bicycle when its tyres are fully inflated because it decreases rolling friction.
- Velocity of the point of contact of the wheel with respect to the floor remains zero all the time while the centre of the wheel moves forward in rolling motion.
- The limiting frictional force is independent of the area of contact but depends on the nature of the material of the surfaces in contact and their roughness or smoothness.
- The ratio of limiting friction (F) to the normal reaction (R) is called **coefficient of friction** (μ) between two surfaces.

  Coefficient of friction $(\mu) = \dfrac{F}{R}$
- The angle between the normal reaction (R) and the resultant of limiting friction (F) is called **angle of friction** (θ).

  where, $\tan\theta = \dfrac{F}{R} = \mu$

Application of Friction

- A **ball bearing** is a type of rolling-element that uses balls to maintain the separation between the bearing races as shown in the diagram. The purpose of a ball bearing is to reduce rotational friction and to support loads (weight). It is possible by using atleast two races to contain the balls and transmit the loads through the balls.



- In most of the applications one race is stationary and the other is attached to the rotating assembly (e.g. hub or shaft). As one of the bearing races rotates it causes the balls to rotate as well. Because the balls are rolling they have a much lower coefficient of friction than if two flat surfaces were sliding against each other. Hence, ball bearing also minimises the energy loss due to wear and tear caused by friction.
- Friction is necessary for walking, to apply brakes in vehicles, for holding nuts and bolts in a machinery etc.
- Friction can be decreased by polishing the surfaces by using lubricants or by using ball bearings.
- Tyres are made of synthetic rubber because its coefficient of friction with road is larger and therefore, large force of friction acts on it, which stops sliding at turns.
- The tyres are threading which also increases the friction between the tyres and the road.
- When pedal is applied to a bicycle, the force of friction on rear wheel is in forward direction and on front wheel is in the backward direction.

Lever

It is a simple machine in which a straight or inclined rod is made to turn or rotate at a point freely or independently. There are three points related to lever namely load, effort and fulcrum.

Load The weight carried by the lever is called load.

Effort To operate lever, the force applied externally is called effort.

Fulcrum The fixed point about which the rod of lever moves independently is called fulcrum.

Work, Energy and Power

Work

- Work done by a constant force (**F**) is equal to the dot product of the force applied on a body and the displacement (**s**) of the body.

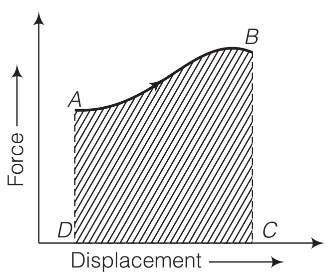
$$W = \mathbf{F} \cdot \mathbf{s} = Fs \cos\theta$$

where, θ is the angle between **F** *and* **s**.

- Work is a scalar quantity. Its SI unit is joule and CGS unit is erg. 1 joule $= 10^7$ erg.
- Work done by a force is positive if angle between F and s is acute angle and negative if angle θ is obtuse angle.
- Work done by a force is zero when
  - Body is not displaced actually, i.e. $\mathbf{s} = 0$
  - Body is displaced perpendicular to the direction of force i.e. $\theta = 90°$.

Work done by a variable force

- Work done by a force is equal to the area under the force-displacement graph, along with proper sign and is given by $W = \int \mathbf{F} \cdot d\mathbf{s}$



- Work done by force = Area *ABCDA*
- If we throw a ball upward, work done against gravity is given by, $W = mgh$

where, m = mass of the body,
g = acceleration due to gravity and
h = height through which the ball is raised.

- The centripetal force acts on a body perpendicular to the direction of motion. Therefore, work done by or against centripetal force in circular motion is zero.
- If a coolie is carrying a load on his head and moving on a horizontal platform, then work done by force of gravity is zero as displacement is perpendicular to the direction of force of gravity.

Energy

- Energy of a body is its capacity of doing work. It is a scalar quantity and its SI unit is joule.

M Energy can be transformed into work and *vice-versa* with the help of some mechanical device.

There are two types of Mechanical Energy, which are as follows

Kinetic Energy

- The energy possessed by a body by virtue of its motion is called its kinetic energy.
- Kinetic energy of the body of mass m moving with velocity v is given by $K = \frac{1}{2}mv^2 = \frac{p^2}{2m}$

where, $p = mv$ = *momentum of the body.*

Potential Energy

- The energy possessed by any object by virtue of its position or configuration is called its potential energy.
- Gravitational potential energy, $U = mgh$

where, m = mass of the body
g = acceleration due to gravity and
h = height through which body is lifted.

Different Forms of Energy

Solar Energy

- It is the emission of energy by the sun, used in solar cooker, solar water heater, solar cell etc. Others are Fossil energy, Wind energy, Hydroelectric energy, Nuclear Energy.

Fossil Energy

- Fossil fuels are non-renewable sources of energy such as anaerobic decomposition of buried dead organisms. Fossil fuels contain coal, petroleum and natural gas.

Hydroelectric Energy

- The production of electrical power through the use of the gravitational force of falling or flowing water. In our country, more than 23% of water is used in production of hydroelectric power.

Nuclear Energy

- It is found that when U^{235} nucleus break-up into lighter nuclei on being bombardment by slow moving neutron, a large amount of energy released is called nuclear energy. Nuclear reactors and nuclear bombs are the sources of nuclear energy.

Einstein's Mass-Energy Relation

- According to this relation, the mass can be transformed into energy and *vice-versa*.
- When Δm mass is disappeared, then produced energy

$$E = \Delta mc^2$$

where, c = *speed of light in vacuum.*

Conservative and Non-conservative forces

- Conservative forces are non-dissipative forces like gravitational force, electrostatic force etc.
- For the conservative forces, work done during a round trip is always zero.
- Non-conservative forces are dissipative in nature like frictional force, viscous force etc.

Law of Conservation of Energy

- Energy can neither be created nor be destroyed, only one type of energy can be transformed into other form of energy.
- Only for conservative forces, (total mechanical energy) initially = (total mechanical energy) finally

Power

- The rate of doing work by a body is called its power.

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}}; \; P = \frac{W}{t} = \frac{\mathbf{F}.\mathbf{s}}{t} = \mathbf{F}.\mathbf{v} = Fv\cos\theta$$

where, θ *is the angle between* $\mathbf{F}$ *and* $\mathbf{v}$.

- It is a scalar quantity and its SI unit is joule second^{-1} or watt.
- Other units are kilowatt and horse power.

$$1 \text{ kilowatt} = 1000 \text{ W} \quad \text{and} \quad 1 \text{ HP} = 746 \text{ W}$$

Collision

- Collision between two or more particles is the interaction for a very short interval of time in which they apply relatively strong forces on each other.
- For a collision, physical contact of two bodies is not necessary.
- A collision in which momentum of the system as well as kinetic energy of the system remains conserved, is called an elastic collision.
- In an elastic collision, all involved forces are conservative forces.
- A collision in which only momentum remains conserved but kinetic energy of the system does not remain conserved, is called an **inelastic collision**.
- If after collision two colliding bodies gets sticked with each other and moves with a common velocity, then collision is said to be **perfectly inelastic**.
- In perfectly inelastic collision, the loss of kinetic energy during collision do not recover at all and two bodies stick together after collision.

Centre of Mass

- Every physical system of particles (body) is associated with a certain point whose motion is characterised by the system as a whole, and when a system moves under an external force, then this point moves in a similar way as a single particle moves under the same external force.

  This is called centre of mass of the system. For uniform rod and solid spherical body, it is at the geometrical centre.

Moment of Inertia

- Moment of Inertia of a body with respect to axis of rotation is the summation of product of the masses of its particles and square of respective distances from axis of rotation.

Definitions Related to Moment of Inertia

- **Radius of Gyration** Radius of gyration is defined as the distance of a point from axis of rotation at which the total mass of the body is supposed to be concentrated, such that its moment of inertia would be same.

$$I = MK^2$$

- **Theorem of Parallel Axes** Moment of inertia about any parallel axis will be sum of moment of inertia about centre of mass and product of mass and square of distance between the two axes.
- **Theorem of Perpendicular Axes** For a laminar body, moment of inertia about perpendicular axis will be the sum of moments of inertia about two other mutually perpendicular axes.

Gravitation

- Each and every massive body attracts each other by virtue of their masses. This phenomenon is called **gravitation**.

Newton's Law of Gravitation

- The gravitational force acting between two point objects is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

$$\text{Gravitational force } (F) = \frac{Gm_1m_2}{r^2}$$

where, G *is universal gravitational constant.*
Its value is $6.67 \times 10^{-11} \text{ N-m}^2 \text{ kg}^{-2}$.

- Gravitational force is a central as well as conservative force.

Acceleration Due to Gravity of Earth

- The uniform acceleration produced in a freely falling body due to the earth's gravitational pull, is called acceleration due to gravity, $g = \frac{GM}{R^2}$
  where, M = mass of the earth, R = radius of the earth.
- The value of g changes slightly from place to place but its value near the earth's surface is 9.8 ms^{-2}.
- Gravitational force is the weakest force in nature. It is 10^{36} times smaller than electrostatic force and 10^{38} times smaller than nuclear force.

Factors Affecting Acceleration due to Gravity

- **Shape of Earth** Earth is not completely spherical its radius at equator is approximately 42 km greater than its radius at poles.
- The value of g is maximum at poles and minimum at equator. The difference in value of g at poles and at equator is 3.4 cms^{-2}.
- **Rotation of Earth about its Own Axis** If ω is the angular velocity of rotation of earth about its own axis, then acceleration due to gravity at any place on the earth is given by $g' = g - R\omega^2 \cos^2 \lambda$
  where, λ = latitude of the place, R = radius of the earth.
  At poles, $\lambda = 90°$ and at equator $\lambda = 0°$ Therefore, there is no effect of rotation of the earth at poles and maximum at equator.
- **Effect of Altitude** The value of g at height h from the earth's surface is given by

$$g' = \frac{g}{\left(1 + \frac{h}{R}\right)^2} \approx g\left(1 - \frac{2h}{R}\right) \text{ if } h << R$$

  Therefore, g decreases with altitude.
- **Effect of Depth** The value of g at depth from the earth's surface is given by $g' = g\left(1 - \frac{h}{R}\right)$
  Therefore, g decreases with depth and becomes zero at centre of the earth.

Gravitational Field and Potential

- **Gravitational Field** The space surrounding the material body in which its gravitational force can be experienced.
- **Gravitational Potential** It is the work done in carrying unit mass from infinity to a particular point in the field.
- **Gravitational Potential Energy** It is the work done in assembling system of masses from infinity to its present configuration.

Mass and Weight

- The mass of a body is the quantity of matter contained in it. It is a scalar quantity and its SI unit is kg.
- Mass is measured by an ordinary equal arm balance.
- Mass of a body does not change from place to place and remains constant.
- The weight of a body is the force with which it is attracted towards the centre of the earth. Weight of a body (w) = mg
- **The centre of gravity** of a body is that point at which the whole weight of the body appears to act.
- The centre of gravity of a body can be inside the material of the body or outside it. For regularly shaped body, the centre of gravity lies at its geometrical centre.
- It is a vector quantity and its SI unit is newton (N). It is measured by a spring balance.
- Weight of a body is not constant, it changes from place to place.

Weight of a Body in a Lift

- **When lift is at rest or in uniform motion** The weight recorded in spring balance (i.e. apparent weight) is equal to the real weight of the body $w = mg$.
- **When lift is accelerating upward** The weight recorded in spring balance is greater than the real weight of the body $w' = m(g + a)$
- **When lift is accelerating downward** The weight recorded in spring balance is lesser than the real weight of the body. $w' = m(g - a)$.
- **When lift is falling freely under gravity** The apparent weight of the body

$$w' = m(g - g) \qquad (\because a = g)$$
$$w' = 0$$

Therefore, body will experiences weightlessness.

Weight of a Body at the Moon

- As mass and radius of moon is lesser than the earth, so the force of gravity at the moon is also less than that of the earth. It's value at the moon's surface is $\frac{g}{6}$.

Planets

- The heavenly bodies which revolve around the sun are called planets.
- Our solar system contains eight planets (as Pluto has lost its planet status, now it is considered as a dwarf planet). The order of the planets in the solar system with their increasing distance from the sun is
  1. Mercury, 2. Venus, 3. Earth, 4. Mars,
  5. Jupiter, 6. Saturn, 7. Uranus, 8. Neptune.

Kepler's Laws of Planetary Motion

Kepler's Three Laws are

- All planets revolve around the sun in elliptical orbits with the sun at its one focus.
- The areal speed of a planet around the sun is constant.
- The square of the time period (T) of revolution of a planet around the sun is directly proportional to the cube of the semi-major axis (a) of its elliptical orbit, i.e. $T^2 \propto a^3$.

Satellite

- A heavenly body revolving around a planet in an orbit is called a satellite. Moon is a natural satellite of the earth. *The satellite may be artificial. Artificial satellites are of two types*

Geostationary Satellites

- It revolves around the earth in equatorial orbits which is also called Geostationary or Geosynchronous orbit at a height of approximately 36000 km above the earth's surface. The time period of these satellites is 24 hour exactly equal to the time period of earth's rotation about its own axis.
- These satellites appear stationary with respect to the earth. These satellites are used for communication purpose, and for weather forecasting, in studying the upper region of the atmosphere, in mapping etc.

Polar Satellites

- These satellites revolve around the earth in polar orbits at a height of approximately 800 km. The time period of these satellites is approximately 84 min.
- Weather monitoring which is predicted on the basis of information about moisture present in air, atmospheric pressure etc, obtained through a **polar satellite**.
- We are able to see a live telecast of cricket world cup match or other programme with the help of a communication satellite which is a geostationary satellite.

Time Period of a Satellite

- It is the time taken by a satellite to complete one revolution.

  If satellite is near the earth's surface, then $T = 2\pi\sqrt{\frac{R}{g}} \approx$ 84.6 min

Escape Velocity

The minimum velocity with which when an object is thrown vertically upwards from the earth's surface just crosses the earth's gravitational field and never returns. Escape velocity (v_e) $= \sqrt{\frac{2GM}{R}} = \sqrt{2gR}$

Its value on earth's surface is 11.2 km/s.

Escape velocity $= \sqrt{2}$ (orbital speed of a satellite when it is near the earth's surface) $v_e = \sqrt{2}\, v_o$

Therefore, when orbital speed of a satellite is increased by $\sqrt{2}$ times (41%), then it will escape from its orbit.

- The response of plants to gravity is called geotropism.
- Two types of effects are obtained in plants due to gravity.
  - The roots of plants always grow downward.
  - The stems (or shoots) of plants always grow upward.
- Variation in the length of day time and night time from season to season are due to revolution of the Earth on a tilled axis.

Self Check

Build Your Confidence

1. Variations in the length of day time and night time from season to season are due to **[IAS 2013]**

(a) the Earth's rotation on its axis
(b) the Earth's revolution round the Sun in an elliptical manner
(c) latitudinal position of the place
(d) revolution of the Earth on a tilled axis

2. The known forces of nature can be divided into four classes, *viz*, gravity, electromagnetism, weak nuclear force and strong nuclear force. With reference to them, which one of the following statements is not correct?

(a) Gravity is the strongest of the four **[IAS 2013]**
(b) Electromagnetism acts only on particles with an electric charge
(c) Weak nuclear force causes, radioactivity
(d) Strong nuclear force holds protons and neutrons inside the nucleus of an atom

3. Ball bearings are used in bicycles, cars, etc, because **[IAS 2013]**

(a) the actual area of contact between the wheel and axle is increased
(b) the effective area of contact between the wheel and axle is increased
(c) the effective area of contact between the wheel and axle is reduced
(d) None of the above

4. Satellites used for telecommunication relay are kept in a geostationary orbit. A satellite is said to be in such an orbit when **[IAS 2008]**

1. the orbit is geosynchronous
2. the orbit is circular
3. the orbit lies in the place of the earth's equator
4. the orbit is at an altitude of 22236 km

Which of the statement(s) given above is/are correct?

(a) 1, 2 and 3 (b) 1, 3 and 4
(c) 2 and 4 (d) All of the above

5. Consider the following statements in respect of a jet engine and a rocket **[IAS 2008]**

1. A jet engine uses the surrounding air for its oxygen supply and so is unsuitable for motion in space.
2. A rocket carries its own supply of oxygen in the gas form and fuel.

Which of the statement(s) given above is/are correct?

(a) Only 1 (b) Only 2
(c) Both 1and 2 (d) Neither 1 nor 2

6. Consider the following statements. **[IAS 2008]**

1. Geostationary satellites are used to reflect TV signals and telecast TV programmes from one part of the world to another.
2. Polar satellites are used for weather forecasting.

Which of the statement(s) given above is/are correct?

(a) Only 1 (b) Only 2
(c) Both 1 and 2 (d) Neither 1 nor 2

7. Consider the following statements.

Statement I When a parachutist jumps from a height *h* metre, then graph relating displacement and time will be parabolic.

Statement II When a particle falling under gravity graph relating displacement and time will be straight line.

Which of the statement(s) given above is/are correct?

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

8. Consider the following statements.

Statement I If a gymnast standing on a rotating stool with his arms stretched suddenly lowers his arms. His angular velocity increases.

Statement II A geostationary satellite is at an approximate height of 10000 km.

Which of the above statement(s) is/are correct?

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

9. Consider the following statements. **[IAS 2008]**

1. A force is said to be conservative if the work done by the force on a particle in a round trip is zero.
2. A force is said to be non-conservative if work done by the force on a particle in a round trip is not zero.
3. The gravitational force and the electrostatic force are the examples of non-conservative forces.
4. Viscous force and frictional force are the examples of conservative forces.

Which of the statement(s) given above is/are correct?

(a) 1, 2 and 3
(b) 1 and 2
(c) 3 and 4
(d) 1, 2, 3 and 4

10. A metal ball and a rubber ball of the same mass are dropped from the same height. After hitting the floor, the rubber ball rises higher than the metal ball, why? **[IAS 2008]**

(a) Momentum is not conserved when the metallic ball hits the floor
(b) The rubber ball hits the floor with greater velocity
(c) Momentum is not conserved when rubber ball hits the floor
(d) None of the above

1. (d) **2.** (a) **3.** (c) **4.** (a) **5.** (c) **6.** (a) **7.** (c) **8.** (a) **9.** (b) **10.** (d)

Chapter two
Properties of Matter

Matter is one of the two basic components of the physical science in which the another component is being energy. The distinguishing properties of matter are gravitation and inertia. Any entity exhibiting these properties are matter. Matter is also used as a general term for the substance that make up all observable physical objects

Matter

- Matter is considered as any thing which has weight and occupy space.
- Matter consists of atoms and molecules. It exist in three states: Solid, liquid and gas.
- In **solid**, molecules vibrate about fixed positions.
- In **liquid**, molecules also vibrate but simultaneously they move freely throughout the material. In **gas**, the molecules are much farther apart than in solids and liquids and move at high velocities.

Interatomic Forces

- The electrostatic force of interaction acting between the two or more atoms is called interatomic forces.
- The range of interatomic forces is equal to the order of atomic size, i.e. 10^{-10}m.
- The variation of potential energy U and interatomic force F with the separation r between two atoms is given by $F = -\frac{dU}{dr}$
- A force which changes the configuration of a body, is called a **deforming force**.

Solid

It is that, state of matter which has definite shape and definite volume. In this state molecules are very closely packed i.e. interatomic or intermolecular space is minimum.

Properties of Solids

Some important properties of solids are as follows

Elasticity

- The property of a body by virtue of which it regain its original configuration after the removal of deforming force, is called elasticity.
- Quartz and phosphor bronze are almost perfectly elastic bodies.

Plasticity

- The property of a body by virtue of which it does not regain its original configuration after the removal of deforming force, is called plasticity.

Strain

- The fractional change in configuration i.e. length, volume and shape, is called strain. Strain has no unit.
  On the basis of change in configuration, strain is of three types
  - Longitudinal strain = $\frac{\Delta l}{l}$
  - Volume strain = $\frac{\Delta V}{V}$
  - Shearing strain = θ

Stress

- The internal restoring force acting per unit area of cross-section of a deformed body, is called **stress**.

Stress is of two types
- Normal stress
- Tangential stress

Also tangential stress are of two types : compressive and tensile stress

- The maximum deforming force upto which a body retains its property of elasticity is called the **limit of elasticity** of the material body.

Hooke's Law

- Within the limit of elasticity the strain produced in a body is directly proportional to the stress applied to it.

i.e. Strain $\propto$ Stress

or $\frac{\text{Stress}}{\text{Strain}} = \text{constant } (E)$

where, constant E is called **modulus of elasticity.**

Types of Modulus of Elasticity

The modulus of Elasticity is of following types

- **Young's modulus of elasticity**

$$Y = \frac{\text{Normal stress}}{\text{Longitudinal strain}} = \frac{(F/A)}{(l/L)} = \frac{FL}{Al} = \frac{MgL}{pr^2 l}$$

where, L = *initial length of the wire*
l = *change in length*
r = *radius of the wire*
M = *mass suspended to the wire*

Steel is more elastic than rubber as $Y_S > Y_R$.

- **Bulk modulus of elasticity,** K or $B = \dfrac{\text{Normal stress}}{\text{Volumetric strain}}$

$$= \frac{p}{-(\Delta V/V)} = -\frac{pV}{\Delta V}$$

- **Modulus of rigidity,** $n = \dfrac{\text{Tangential stress}}{\text{Shearing strain}} = \dfrac{F/A}{(\theta)} = \dfrac{F}{A\theta}$
- The unit of modulus of elasticity is Nm^{-2} or pascal (Pa).
- The minimum stress required to break a wire is called **breaking stress**.
- Breaking stress is fixed for a material but breaking force varies with change in area of cross-section of the wire.
- The torque required to produce a given twist in a hollow cylinder is greater than that required to produce the same twist in a solid cylinder. Therefore, hollow shaft is stronger than a solid shaft.
- Girders are made I shaped for checking the buckling (bending at middle). Springs are made of steel, not of copper as Young's modulus of elasticity of steel is more than that of copper.

Elastic Limit

- It is the limit of stress and strain upto which a wire remains elastic i.e. when the stretching force is removed, the wire acquires its natural length.

Plastic Behaviour

- If the wire is stretched beyond the elastic limit, the strain increases much more rapidly. If the stretching force is removed, the wire does not comes back to its natural length. Some permanent increase in length takes place, this behaviour of the wire is called plastic behaviour.

Fracture Point

- If the deformation is increased further the plastic behaviour, the wire breaks at a point known as fracture point.

Ductile and Brittle Materials

- If large deformation takes place between the elastic limit and the fracture point, the material is called **ductile**.
- If the wire breaks soon after the elastic limit is crossed, it is called **brittle**.

Elastic Fatigue

It is the property of an elastic body by virtue of which its behaviour becomes less elastic under the action of repeated alternating deforming force. Due to elastic fatigue, the bridges becomes less elastic after a use of long time and therefore are declared unsafe.

Fluid

- A substance which begins to flow under an external force is called a fluid. Liquids and gases are **fluids**.

Fluid Density

- The ratio of mass to the volume of a body is called its **density** (i.e. mass present in its unit volume). It is a scalar quantity having SI unit kg/m^3.

$$\text{Density } (d) = \frac{\text{Mass } (m)}{\text{Volume } (V)}$$

- The density of water is 1000 kg/m^3
  - **Relative density of a solid**

$$= \frac{\text{Weight of the body in air}}{\text{Weight of the same volume of water at } 4°C}$$

$$= \frac{\text{Weight of the body in air}}{\text{Loss in weight of the body in water}}$$

  - **Relative density of a liquid**

$$= \frac{\text{Density of liquid}}{\text{Density of water at } 4°C}$$

$$= \frac{\text{Loss in weight of a solid in liquid}}{\text{Loss in weight of a solid in water}}$$

- The density of water is maximum at 4°C.
- **Hydrometer** It is an instrument used to measure density or relative density of liquid. Its working is based on law of floatation.
- Water is dipolar in nature, therefore it can dissolve more substances than any other liquid.

Fluid Pressure

- **Thrust** (the normal force) exerted by a liquid per unit area of the surface in contact at rest, is called fluid pressure.

Fluid pressure $(p) = \dfrac{F}{A}$

Its unit is Nm^{-2} or Pascal (Pa).

Pressure exerted by a liquid column is given by

$$p = h\rho g$$

where, h = *height of liquid column*
ρ = *density of liquid*
g = *acceleration due to gravity.*

Atmospheric Pressure

The pressure exerted by the atmosphere, is called atmospheric pressure. The value of atmospheric pressure on the earth at sea level is nearly 1.013×10^5 Nm^{-2} or Pascal.

Aneroid barometer is used to measure atmospheric pressure and height of a place.

Other units of atmospheric pressure are torr and bar.

1 torr = 1 mm of mercury column

1 bar = 10^5 Pa

Pascal's Law

- The pressure exerted anywhere at a point of confined fluid is transmitted equally and undiminished, in all directions throughout the liquid.
- Hydraulic lift, hydraulic press, hydraulic brakes works on the basis of Pascal's law.

Buoyancy

- When a body is partially or wholly immersed in a liquid, an upward force acts on it, which is called buoyant force or upthrust and this property of fluids is called buoyancy.
- Buoyant force is equal to the weight of the liquid displaced by the submerged part of the body.
- The buoyant force acts at the centre of gravity of the liquid displaced by the submerged part of the body, which is called 'centre of buoyancy'.

Archimedes' Principle

- When a body is partially or completely immersed in a liquid, it loses some of its weight. The loss in weight is equal to the weight of the liquid displaced by the submerged part of the body.
- If w_1 is the weight and V is the volume of a body in air and its weight becomes w_2 in a liquid of density ρ,

  then, Loss in weight $= w_1 - w_2$

Law of Floatation

- A body will float in a liquid if weight of the body is equal to weight of the liquid displaced by the immersed part of the body.
- In floating condition, the centre of gravity (g) and the centre of buoyancy *(B)* of the floating body must lie on the same straight line.
- The volume and density of a body are V_1 and ρ_1 respectively and if it is immersed in a liquid of density ρ_2 then its volume V_2 submerged in the liquid is given by the relation, $\frac{V_2}{V_1} = \frac{\rho_1}{\rho_2}$.
  - Ice and large icebergs float on water surface as its density (0.92 g/cm^3) is lesser than the density of water.
  - When a piece of ice floats on water, its $\left(\frac{11}{12}\right)$ th part submerged in water and (1/12) th part is outside the water.
  - In sea water, (8/ 9) th part of icebergs is submerged and (1/9) th part is outside the water during floating.
  - It is easier to swim in sea water than in a river as density of sea water is greater than the density of river water. In sea water, buoyant force is greater than that in river water.
  - The density of human body is less than the density of water but the density of human head is greater than the density of water. Therefore, during swimming a person displaces the liquid with hands and legs and total weight of displaced liquid becomes equal to the weight of the body.

Surface Tension

- The property of a liquid by virtue of which it tries to minimise its free surface area is called surface tension.
- Surface tension of a liquid is defined as the force acting perpendicularly per unit length on an imaginary line drawn at the surface of the liquid its unit is newton/metre.

$$\text{Surface tension } (S) = \frac{F}{l}$$

- The minimum surface area of a given amount of liquid is for spherical shape. Therefore, rain drops are spherical.

Factors Affecting Surface Tension

- **Temperature** The surface tension of a liquid decreases with increase in temperature.
- **Soluble Impurities** If the impurities are less soluble in liquid, then its surface tension decreases. If impurities are highly soluble in liquid, then its surface tension increases.

Applications of Surface Tension

- Surface tension of a liquid becomes zero at critical temperature.
- When soap, detergent, dettol, phenyl etc., are mixed in water then its surface tension decreases.
- When salt is added in water, its surface tension increases.
- When oil spreads over the surface of water, its surface tension decreases.
- When kerosene oil is poured over water its surface tension decreases and now weight of a mosquito sitting on water surface is not balanced by surface tension force and it is dipped in water.
- Antiseptics like dettol have low surface tension and therefore it reaches in the tiny cracks of the wound and cleans the germs and bacteria. The surface tension of soap solution in water is less than the surface tension of pure water. Therefore, soap solution cleans greasy strains of clothes better than pure water.

Surface Energy

- The potential energy of the molecules in the surface of liquid is called the surface energy.

 Surface energy $= T \times \Delta A$

 where, T = *surface tension of liquid,*

 ΔA = *increase in surface area.*

Angle of Contact

- The angle between the tangent to the liquid surface and the tangent to the solid surface at the point of contact is known as angle of contact.
- The angle of contact is always measured through the liquid. Angle of contact increases with increase in temperature of liquid.

Capillarity

The phenomenon of rising or falling of liquid column in a capillary tube (glass tube of very fine bore) is called capillarity.

- Water rises in narrow capillary tubes in a tree due to capillarity.
- A blotting paper sucks the ink into their narrow capillary tubes due to capillarity.

Rise of liquid in a capillary tube is given by

$$h = \frac{2S\cos\theta}{r\rho g}$$

where, S = *surface tension of the liquid*

θ = *angle of contact*

r = *radius of the capillary tube*

ρ = *density of the liquid*

- The liquid column of water, milk, etc, rises in capillary tube while mercury column falls.

Cohesive and Adhesive Forces

The intermolecular force of attraction acting between the molecules of same substance is called **cohesive force.**

e.g., Intermolecular force of attraction acting between the molecules of water, mercury etc.

The intermolecular force of attraction acting between the molecules of different substance is called **adhesive force.**

e.g., Intermolecular force of attraction acting between the molecules of paper and gum, paper and ink, etc.

Viscosity

- Viscosity is the property of a fluid by virtue of which an internal frictional force acts between its layers when it is in motion. This force is called **viscous force**.
- **Viscous force** acting between two layers of a liquid is given by

$$F = -\eta A \frac{dv}{dx}$$

where, η = *coefficient of viscosity*

A = *contact area of layers*

$\frac{dv}{dx}$ = *velocity gradient*

If $A = 1\text{ m}^2$ and $\frac{dv}{dx} = 1\text{ s}^{-1}$, then $\eta = F$

- The viscosity of liquids decreases with increase in temperature while the viscosity of gases increases with increase in temperature. The viscosity of liquids except water increases with increase in pressure. The viscosity of water decreases with increases in pressure.
- The viscosity of gases is independent of pressure.

Coefficient of Viscosity

- It is the viscous force acting between two layers of unit area of cross-section having unit velocity gradient. Its unit is N sm^{-2} or Pascal-second (Pa-s)
- Its other unit is poise.

$$1\text{ poise} = \frac{1}{10}\text{ Nsm}^{-2}$$

Stoke's Law

- According to this law, the viscous force depends upon the coefficient of viscosity, velocity of the moving object and its size (i.e. radius).

Terminal Velocity

- When a small spherical body falls through a long liquid column its velocity increases gradually but later on it becomes constant, called terminal velocity.

 Terminal velocity, $v = \frac{2}{9}\frac{r^2(\rho - \sigma)g}{\eta}$

 where, r = *radius of spherical body*

 ρ = *density of the body*

 σ = *density of the liquid*

 η = *coefficient of viscosity of the liquid.*

- The radius of spherical rain drops is very small therefore their terminal velocity is also small, with which they strike the earth's surface.
- When a liquid flow through a pipe, its speed is maximum near axis and minimum near the walls of the pipe.

Equation of Continuity

- When a non-viscous liquid flows through a pipe of non-uniform cross-sectional area in stream-lined flow, (i.e. velocity at every point in the fluid remains constant) then at each section of the tube, the product of area of cross-section of the pipe and velocity of liquid remains constant, i.e. $A \times v$ = constant or $A_1 v_1 = A_2 v_2$ = constant
- Therefore speed (v) of fluid flow becomes faster in narrower pipe.

Flow of Fluid

- When liquid flows, *there are two types of flow*
  - **Steady flow** Rear molecules of fluid follows same path of flow as that of molecules ahead.
  - **Turbulent flow** The path of flow at a point followed by rear molecules are not same as that of molecules ahead. Water flow in high fall or a fast flowing river is generally turbulent.

Bernoulli's Theorem

- If a non-viscous and incompressible liquid is flowing in stream-lined flow then total energy, i.e., sum of pressure energy, kinetic energy and potential energy, per unit volume of the liquid remains constant.

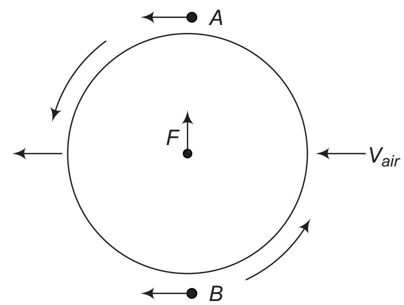
$$p + \frac{1}{2}\rho V^2 + \rho gh = \text{constant}$$

For horizontal flow of fluid, $p + \frac{1}{2}\rho V^2 = \text{constant}$

- Venturi tube and aspirator pump works on Bernoulli's theorem.
- According to Bernoulli's theorem, with increase in velocity of liquid its pressure decreases and *vice-versa*.
- During storms or cyclones, the roofs of the huts or tinned roofs blown off because wind blows with very high speed over the top of the roof and therefore pressure of air decreases. Due to the pressure difference of air above and below the roof, a lifting force acts on the roof. If it is sufficient to balance the weight of the roof it start to fly off.

Magnus Effect : Motion of a Spinning Ball

- When swing bowlers deliver the ball, the ball changes its plane of motion in air.
  The situation is shown in the figure



Spinning Ball

  - Figure represents horizontal plane. The air that goes from the *A* side of the ball in the figure is dragged by the spin of the ball and its speed increases.
  - The air, goes from *B* side of the ball in the figure, suffers an opposite drag and its speed decreases.
  - The pressure of air is reduced on the *A* side and increased on the *B* side as required by the Bernoulli's equation.
  - As a result, as net force *F* acts on the ball from the *B* side to *A* side due to this pressure difference. This causes the deviation of the plane of motion and this is the spinning of the ball.

Self Check

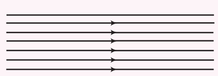
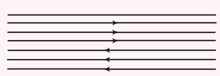
Build Your Confidence

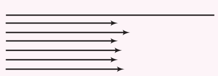
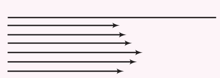
1. Consider the following statements
If there were no phenomenon of capillarity
1. it would be difficult to use a kerosene lamp.
2. one would not be able to use a straw to consume a soft drink.
3. the blotting paper would fail to function.
4. the big trees that we see around would not have grown on the Earth.

Which of the following statement(s) given above is/are correct?
(a) 1, 2 and 3 *(b)* 1, 3 and 4
(c) 2 and 4 *(d)* All of the above

2. Four wires of same material and of dimensions as mentioned below are stretched by a load of same magnitude separately. Which one of them will be elongated maximum? **[IAS 2009]**
(a) Wire of 1m length and 2 mm diameter
(b) Wire of 2m length and 2 mm diameter
(c) Wire of 3m length and 1.5 mm diameter
(d) Wire of 1m length and 1 mm diameter

3. A liquid is flowing in a streamlined manner through a cylindrical pipe. Along a section containing the axis of the pipe, the flow profile will be **[IAS 2008]**

(a)  *(b)* 

(c)  *(d)* 

4. There identical vessels *A*, *B* and *C* are filled with water, mercury and kerosene respectively up to an equal height. The three vessels are provided with identical taps at the bottom of the vessels. Of the three taps are opened simultaneously, then which vessel is emptied first? **[IAS 2009]**
(a) Vessel *B*
(b) All the vessels *A*, *B* and *C* will be emptied simultaneously
(c) Vessel *A*
(d) Vessel *C*

5. Consider the following statements
Statement I The tendency of a liquid drop to contract and occupy minimum area is due to surface tension.
Statement II Blotting of ink is due to capillarity.

Which of the statement(s) given above is/are correct?
(a) Only I
(b) Only II
(c) Both I and II
(d) Neither I nor II

6. Consider the following statements
Statement I An iron ball floats on mercury but gets immersed in water.
Statement II The specific gravity of iron is more than that of mercury.

Which of the statement(s) given above is/are correct?
(a) Only I *(b)* Only II
(c) Both I and II *(d)* Neither I nor II

7. An oil tanker is partially filled with oil and moves forward on a level road with uniform acceleration.
The free surface of oil then
(a) remains horizontal
(b) is inclined to the horizontal with smaller depth at the rear end
(c) is inclined to the horizontal with larger depth at the rear end
(d) assumes parabolic curve

8. An ice cube is floating on the surface of water. How will the water level be affected by melting of this ice cube?
(a) Water level will be raised
(b) Water level will go down
(c) Water level will remain the same
(d) Water level will first rise up then it will go down

9. Consider the following statements
Statement I With the increase of temperature, the viscosity of glycerine increases.
Statement II Rise of temperature increases kinetic energy of molecules.

Which of the statement(s) given above is/are correct?
(a) Only I *(b)* Only II
(c) Both I and II *(d)* Neither I nor II

10. Consider the following statements
Statement I The ships of iron and the boats of wood float in water but the nails iron sink.
Statement II The special by designed shape of the ship and the boat provides more force of buoyancy. So, the ships or boats floats. But the weight of the water displaced by the nails is less than the weight of nails that is why nails sink.

Which of the following statement(s) given above is/are correct?
(a) Only I *(b)* Only II
(c) Both I and II *(d)* Neither I nor II

11. Consider the following statements
1. Surface tension of liquid depends on length but not on the area like the elastic property.
2. SI unit of surface tension is N/m.
3. Surface tension is a scalar quantity because it has no specific direction for a given liquid.

Which of the statement(s) given above is/are correct?
(a) 1 and 2 *(b)* Only 3 *(c)* 2 and 3 *(d)* 1, 2 and 3

1. *(b)* **2.** *(c)* **3.** *(a)* **4.** *(d)* **5.** *(c)* **6.** *(a)* **7.** *(c)* **8.** *(c)* **9.** *(c)* **10.** *(c)* **11.** *(d)*

Chapter three
Oscillations and Waves

A wave motion is a process of transmission of disturbances created somewhere in an elastic medium in all directions around it and along with the directions around it and along with the disturbances energy transmit. Although the particles of the medium only vibrate or oscillate about their mean positions and do not leave their original respective positions.

Periodic Motion

- A motion which repeats itself identically after a fixed interval of time, is called a periodic motion.
  For example
  - Motion of arms of a clock, orbital motion of the earth around the sun, motion of a simple pendulum etc.

Oscillatory Motion

- A periodic motion taking place to and fro or back and forth about a fixed point, is called oscillatory motion or oscillation.
  For examples
  - Motion of a simple pendulum.
  - Motion of a loaded spring etc.
- If a particle oscillates with its own natural frequency without help of any external periodic force. The oscillation is then called **damped oscillation**.
- When a body oscillates with the help of an external periodic force with a frequency different from natural frequency of the body, then oscillation is called **forced oscillation**.

Simple Harmonic Motion (SHM)

- An oscillatory motion of constant amplitude and of single frequency under a restoring force whose magnitude is proportional to the displacement and always acts towards mean position, is called **Simple Harmonic Motion.**
  For example
  - Equation of SHM is given by $x = A\sin(\omega t + \delta)$, where $(\omega t + \delta)$ is known as **phase**.

Characteristics of SHM

- The motion of the particle should take place in a straight line to and fro about the mean position.
- The restoring force acting on the particle should always be proportional to the displacement of the particle towards the mean position.

Some Definitions Related to SHM

Time Period and Frequency

- Time taken by the particle to complete one oscillation, is known as time period (T).
- The number of oscillations completed by the particle in one second, is called frequency (ν).

  $$\text{Frequency } (\nu) = \frac{1}{\text{Time period } (T)}$$

  Its unit is second^{-1} or hertz.
- The product of frequency with a factor 2π, is called **angular frequency** (ω).
- Angular frequency

  $$(\omega) = 2\pi\nu = \frac{2\pi}{T}$$

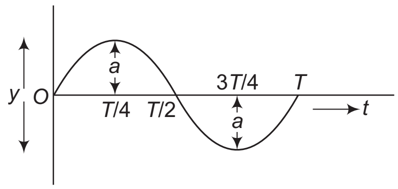
  Its unit is second^{-1} or hertz.

Displacement and Amplitude

- A physical quantity which changes uniformly with time and also mean position in a periodic motion, is called **displacement** (y).
- The maximum displacement in any direction from the mean position, is called **amplitude** (a).

Displacement in SHM at any instant is given by

$$y = a \sin \omega t \quad \text{or} \quad y = a \cos \omega t$$



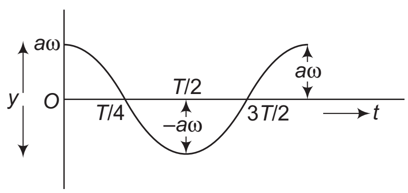
- **Velocity of a particle** executing SHM at any instant is given by $v = dy/dt = a\omega \cos \omega t$

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

  At mean position ($y = 0$), velocity is maximum.

  $$v_{max} = a\omega$$

  At extreme position ($y = a$), velocity is zero.



- **Acceleration of a particle** executing SHM at any instant is given by $\alpha = d^2y/dt^2$ A

  or $\quad \alpha = -\omega^2 y$
- At mean position ($y = 0$), the acceleration is zero and at extreme position ($y = a$), the acceleration is maximum. $\alpha_{max} = -a\omega^2$

  Time period in SHM is given by

  $$T = 2\pi \sqrt{\frac{\text{Displacement}}{\text{Acceleration}}}$$

Simple Pendulum

- A heavy point mass suspended from a rigid support by means of an elastic inextensible string, is called a simple pendulum.
- Time period of a simple pendulum is given by

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

  where, l = effective length of the pendulum

  g = acceleration due to gravity.
- The time period of a simple pendulum of infinite length is 84.6 min. The time period of a second's pendulum is 2 s. Its length on the earth is nearly 100 cm.
- Acceleration due to gravity decreases with altitude (height) and therefore time period of a pendulum clock will increase and clock becomes slow.
- If the bob of a simple pendulum is suspended from a metallic wire, then the length of the pendulum increases with increase in temperature and therefore its time period also increases. When a bob of simple pendulum of density (ρ) oscillates in a fluid of density ρ_0 ($\rho_0 < \rho$), then its time period gets increased.

  Increased time period, $T' = T \sqrt{\frac{\rho}{\rho - \rho_0}}$
- Time period of oscillations of a loaded spring is given by

  $$T = 2\pi \sqrt{\frac{m}{k}}$$

  where, m = mass suspended with the spring

  k = force constant of the spring.

Energies in SHM

- **Potential energy of a particle of mass *m*** executing SHM is given by

  $$U = \frac{1}{2} m\omega^2 y^2 = \frac{1}{2} ky^2 \qquad [k = m\omega^2]$$

  where,

  m = mass of the particle,

  ω = angular velocity of oscillations,

  y = displacement.
- **Kinetic energy of a particle of mass *m*** executing SHM is given by

  $$K = \frac{1}{2} m\omega^2 (a^2 - y^2)$$
- **Total energy** $(E) = U + K$

  $$= \frac{1}{2} m\omega^2 a^2 = 2\pi^2 mn^2 a^2$$
- A girl is swinging over a swing. If she stands up over the swing, then the effective length of the swing decreases and therefore, the time period of oscillations decreases.
- A pendulum clock cannot be used in a space-ship.

Damped Harmonic Motion

- When there is friction or any other force acting within an oscillating system, the amplitudes of the oscillation decreases over time to this damping force. This is called damped harmonic motion.

Resonant Oscillations

- When a body oscillates with its own natural frequency (ν_0) with the help of an external periodic force also called forced harmonic motion. And if the frequency (ν) provided by the enternal agent is equal to the natural frequency of the body, the oscillations of the body are called resonant oscillations.

Wave

- A wave is a vibratory disturbance in a medium which carries energy from one point to another point without any actual movement of the medium.

Types of Waves

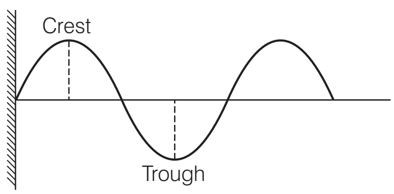
- Those waves which require a material medium for their propagation, are called **mechanical waves.**

  For examples
  - Sound waves, water waves etc.
- Those waves which do not require a material medium for their propagation, are called **electromagnetic waves.**

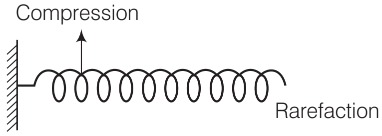
  For examples
  - Light waves, radio waves, X-rays etc.

Nature of Waves

- A wave in which the particles of the medium vibrate at right angles to the direction of propagation of wave, is called a **transverse wave.**
- These waves travel in the form of crests and troughs.



- In a transverse wave, the position of maximum displacement in the upward direction, is called **crest** and the position of maximum displacement in downward direction is called **trough**.
- A wave in which the particles of the medium vibrate in the same direction in which wave is propagating, is called a **longitudinal wave.**
- These waves travels in the form of compressions and rarefactions as shown below



- When a longitudinal wave propagates in a medium, the density and pressure becomes maximum at few points and minimum at other few points, these points are called **compressions** and **rarefactions.**
- Longitudinal waves can be produced in solid, liquid and gases. Transverse waves can be produced in solids and on the surface of a liquid but cannot be produced in the interior of a liquid or in a gas.

Definitions Related to Waves

- The distance between two nearest points in a wave which are in the same phase of vibration, is called the **wavelength** (λ).
- Time taken to complete one vibration, is called **time period** (T).
- The number of vibrations completed in one second, is called **frequency** of the wave.

  $$\text{Frequency } (\nu) = \frac{1}{\text{Time period } (T)}$$

  Its SI unit is hertz.

Superposition and Interference of Waves

- Two or more progressive waves can travel simultaneously in the medium without effecting the motion of one another. Therefore, resultant displacement of each particle of the medium at any instant is equal to vector sum of the displacements. This principle is called **principle of superposition**.
- On the other hand, when two waves of same frequency stand in the medium in the same direction, then the resultant intensity due to their superposition, at a point, is different from the sum of intensities of two waves. This phenomenon is called **interference**.

Sound

- Sound is a form of energy, which produces the sensation of hearing. Sound is produced by vibrating objects.
- Sound waves are mechanical longitudinal waves and require medium for their propagation. Sound waves cannot propagate through vacuum. If a sound wave propagates from one medium to another, then its speed and its wavelength changes but its frequency remains constant.
- *Sound waves are of three types*
  - The sound waves of frequency lies between 0 to 20 Hz, are called **infrasonic waves**.
  - The sound waves of frequency lies between 20 Hz to 20000 Hz, are called **audible waves**.
  - The sound waves of frequency greater than 20000 Hz, are called **ultrasonic waves.**

Speed of Sound

- The speed of sound is different in different media.

$$v = \sqrt{\frac{\gamma p}{d}} \qquad \text{(In gaseous medium)}$$

where, p is pressure, d is density, γ is ratio of specific heats.

$$v = \sqrt{\frac{Y}{d}} \qquad \text{(In solid)}$$

where, Y = Young's modulus.

$$v = \sqrt{\frac{\beta}{d}} \qquad \text{(In liquid)}$$

where, β = Bulk modulus.