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# 34 YEARS' (1988-2021)

## Chapterwise Topicwise

# NEET Solved Papers

# PHYSICS

**Complete Collection of all Questions asked in last 34 years' in NEET & CBSE AIPMT**

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# PREFACE

Whenever a student decides to prepare for any examination his/her first and foremost curiosity is to know about the type of questions that are expected in the exam. This becomes more important in the context of competitive entrance examinations where there is neck-to-neck competition.

We feel great pleasure in presenting before you this book containing Error Free Chapterwise Topicwise Solutions of **CBSE AIPMT/NEET Physics** Questions from the years 1988 to 2021.

It has been our efforts to provide correct solutions to the best of our knowledge and opinion. Detailed explanatory discussions follow the answers. Discussions are not just sketchy–rather, have been drafted in a manner that the students will surely be able to answer some other related questions too ! Going through this book, the students would be able to have the complete idea of the questions being asked in the test.

We hope this chapterwise solved papers would be highly beneficial to the students. We would be grateful if any discrepancies or mistakes in the questions or answers are brought to our notice so that these could be rectified in subsequent editions.

**Publisher**

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# SYLLABUS

## CLASS 11th

### UNIT I Physical World and Measurement

Physics Scope and excitement, nature of physical laws Physics, technology and society.

Need for measurement Units of measurement, systems of units, SI units, fundamental and derived units. Length, mass and time measurements, accuracy and precision of measuring instruments, errors in measurement, significant figures. Dimensions of physical quantities, dimensional analysis and its applications.

### UNIT II Kinematics

Frame of reference, Motion in a straight line, Position-time graph, speed and velocity. Uniform and non-uniform motion, average speed and instantaneous velocity. Uniformly accelerated motion, velocity-time and position-time graphs, for uniformly accelerated motion (graphical treatment). Elementary concepts of differentiation and integration for describing motion. Scalar and vector quantities: Position and displacement vectors, general vectors, general vectors and notation, equality of vectors, multiplication of vectors by a real number, addition and subtraction of vectors. Relative velocity. Unit vectors. Resolution of a vector in a plane-rectangular components. Scalar and Vector products of Vectors. Motion in a plane. Cases of uniform velocity and uniform acceleration- projectile motion. Uniform circular motion.

### UNIT III Laws of Motion

Intuitive concept of force. Inertia, Newton's first law of motion; momentum and Newton's second law of motion, impulse, Newton's third law of motion. Law of conservation of linear momentum and its applications. Equilibrium of concurrent forces. Static and Kinetic friction, laws of friction, rolling friction, lubrication. Dynamics of uniform circular motion. Centripetal force, examples of circular motion (vehicle on level circular road, vehicle on banked road).

### UNIT IV Work, Energy and Power

Work done by a constant force and variable force, kinetic energy, work-energy theorem, power. Notion of potential energy, potential energy of a spring, conservative forces, conservation of mechanical energy (kinetic and potential energies), non-conservative forces, motion in a vertical circle, elastic and inelastic collisions in one and two dimensions.

### UNIT V Motion of System of Particles and Rigid Body

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### UNIT VI Gravitation

Kepler's laws of planetary motion. The universal law of gravitation.Acceleration due to gravity and its variation with altitude and depth. Gravitational potential energy, gravitational potential. Escape velocity, orbital velocity of a satellite. Geostationary satellites.

### UNIT VII Properties of Bulk Matter

Elastic behavior, Stress-strain relationship. Hooke's law, Young's modulus, bulk modulus, shear, modulus of rigidity, poisson's ratio; elastic energy. Viscosity, Stokes' law, terminal velocity, Reynold's number, streamline and turbulent flow. Critical velocity, Bernoulli's theorem and its applications. Surface energy and surface tension, angle of contact, excess of pressure, application of surface tension ideas to drops, bubbles and capillary rise. Heat, temperature, thermal expansion, thermal expansion of solids, liquids and gases. Anomalous expansion. Specific heat capacity, $C_P$, $C_V$- calorimetry; change of state – latent heat. Heat transfer- conduction and thermal conductivity, convection and radiation. Qualitative ideas of Black Body Radiation, Wein's displacement law and Green House effect. Newton's law of cooling and Stefan's law.

### UNIT VIII Thermodynamics

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### UNIT IX Behaviour of Perfect Gas and Kinetic Theory

Equation of state of a perfect gas, work done on compressing a gas. Kinetic theory of gases Assumptions, concept of pressure. Kinetic energy and temperature, degrees of freedom, law of equipartition of energy (statement only) and application to specific heat capacities of gases, concept of mean free path.

### UNIT X Oscillations and Waves

Periodic motion-period, frequency, displacement as a function of time. Periodic functions. Simple harmonic motion(SHM) and its equation, phase, oscillations of a spring-restoring force and force constant, energy in SHM–kinetic and potential energies, simple pendulum-derivation of expression for its time period, free, forced and damped oscillations (qualitative ideas only), resonance. Wave motion. Longitudinal and transverse waves, speed of wave motion. Displacement relation for a progressive wave. Principle of superposition of waves, reflection of waves, standing waves in strings and organ pipes, fundamental mode and harmonics. Beats, Doppler effect.

## CLASS 12th

### UNIT I Electrostatics

Electric charges and their conservation. Coulomb's law-force between two point charges, forces between multiple charges, superposition principle and continuous charge distribution. Electric field, electric field due to a point charge, electric field lines, electric dipole, electric field due to a dipole, torque on a dipole in a uniform electric field. Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straight wire, uniformly charged infinite plane sheet and uniformly charged thin spherical shell (field inside and outside).

Electric potential, potential difference, electric potential due to a point charge, a dipole and system of charges, equipotential surfaces, electrical potential energy of a system of two point charges and of electric diploes in an electrostatic field. Conductors and insulators, free charges and bound charges inside a conductor, Dielectrics and electric polarization, capacitors and capacitance, combination of capacitors in series and in parallel, capacitance of a parallel plate capacitor with and without dielectric medium between the plates, energy stored in a capacitor, Van de Graaff generator.

## UNIT II Current Electricity

Electric current, flow of electric charges in a metallic conductor, drift velocity and mobility and their relation with electric current, Ohm's law, electrical resistance,
V-I characteristics (linear and non-linear), electrical energy and power, electrical resistivity and conductivity. Carbon resistors, colour code for carbon resistors, series and parallel combinations of resistors, temperature dependence of resistance.

Internal resistance of a cell, potential difference and emf of a cell, combination of cells in series and in parallel. Kirchhoff's laws and simple applications. Wheatstone bridge, metre bridge. Potentiometer-principle and applications to measure potential difference, and for comparing emf of two cells, measurement of internal resistance of a cell.

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Magnetic dipole moment of a revolving electron. Magnetic field intensity due to a magnetic dipole (bar magnet) along its axis and perpendicular to its axis. Torque on a magnetic dipole (bar magnet) in a uniform magnetic field, bar magnet as an equivalent solenoid, magnetic field lines, Earth's magnetic field and magnetic elements. Para-, dia-and ferro-magnetic substances with examples. Electromagnetic and factors affecting their strengths. Permanent magnets.

## UNIT IV Electromagnetic Induction and Alternating Currents

**Electromagnetic induction** Faraday's law, induced emf and current, Lenz's Law, Eddy currents. Self and mutual inductance. Alternating currents, peak and rms value of alternating current/ voltage, reactance and impedance, LC oscillations (qualitative treatment only), LCR series circuit, resonance, power in AC circuits, wattles current. AC generator and transformer.

## UNIT V Electromagnetic Waves

Need for displacement current. Electromagnetic waves and their characteristics (qualitative ideas only). Transverse nature of electromagnetic waves. Electromagnetic spectrum (radiowaves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.

## UNIT VI Optics

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**Optical instruments** Human eye, image formation and accommodation, correction of eye defects (myopia and hypermetropia) using lenses. Microscopes and astronomical telescopes (reflecting and refracting) and their magnifying powers. Wave optics: Wavefront and Huygens' principle, reflection and refraction of plane wave at a plane surface using wavefronts. Proof of laws of reflection and refraction using Huygens' principle. Interference, Young's double hole experiment and expression for fringe width, coherent sources and sustained interference of light. Diffraction due to a single slit, width of central maximum. Resolving power of microscopes and astronomical telescopes. Polarisation, plane polarised light, Brewster's law, uses of plane polarised light and Polaroids.

## UNIT VII Dual Nature of Matter and Radiation

Photoelectric effect, Hertz and Lenard's observations, Einstein's photoelectric equation- particle nature of light. Matter waves- wave nature of particles, de-Broglie relation. Davisson-Germer experiment (experimental details should be omitted, only conclusion should be explained).

### UNIT VIII Atoms and Nuclei

Alpha- particle scattering experiments, Rutherford's model of atom, Bohr model, energy levels, hydrogen spectrum. Composition and size of nucleus, atomic masses, isotopes, isobars, isotones. Radioactivity- a, b and g particles/ rays and their properties decay law. Mass-energy relation, mass defect, binding energy per nucleon and its variation with mass number, nuclear fission and fusion.

### UNIT IX Electronic Devices

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I-V characteristics of LED, photodiode, solar cell and Zener diode, Zener diode as a voltage regulator. Junction transistor, transistor action, characteristics of a transistor, transistor as an amplifier (common emitter configuration) and oscillator. Logic gates (OR, AND, NOT, NAND and NOR). Transistor as a switch.

# 01

# Units and Measurements

## TOPIC 1
Units

**01** The angle of 1′ (minute of arc) in radian is nearly equal to **[NEET (Oct.) 2020]**

(a) $2.91 \times 10^{-4}$ rad (b) $4.85 \times 10^{-4}$ rad
(c) $4.80 \times 10^{-6}$ rad (d) $1.75 \times 10^{-2}$ rad

**Ans.** *(a)*

$$1 \text{ minute} = \frac{1}{60} \text{ degree } = \frac{1}{60} \times \frac{\pi}{180} \text{ rad}$$
$$= 2.91 \times 10^{-4} \text{ rad}$$

**02** The unit of thermal conductivity is : **[NEET (National) 2019]**

(a) $\text{J m}^{-1} \text{ K}^{-1}$
(b) $\text{W m K}^{-1}$
(c) $\text{W m}^{-1} \text{ K}^{-1}$
(d) $\text{J m K}^{-1}$

**Ans.** *(c)*

The rate of heat flow through a conductor of length $L$ and area of cross-section $A$ is given by

$$\frac{dQ}{dt} = KA\frac{\Delta T}{L} \text{ J/s or watt}$$

where, $K$ = coefficient of thermal conductivity and

$\Delta T$ = change in temperature

$$\Rightarrow \quad K = \frac{L}{A\Delta T}\frac{dQ}{dt}$$

$$\therefore \text{Unit of } K = \frac{\text{metre}}{(\text{metre})^2 \times \text{kelvin}} \times \text{watt}$$
$$= \text{Wm}^{-1}\text{K}^{-1}$$

**03** The unit of permittivity of free space, $\varepsilon_0$ is **[CBSE AIPMT 2004]**

(a) coulomb/newton-metre
(b) newton - metre$^2$ / coulomb$^2$
(c) coulomb$^2$ /newton -metre$^2$
(d) coulomb$^2$ / (newton - metre)$^2$

**Ans.** *(c)*

According to Coulomb's law, the electrostatic force

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

$q_1$ and $q_2$ = charges, $r$ = distance between charges

and $\varepsilon_0$ = permittivity of free space

$$\Rightarrow \quad \varepsilon_0 = \frac{1}{4\pi} \times \frac{q_1 q_2}{r^2 F}$$

Substituting the units for $q$, $r$ and $F$, we obtain unit of $\varepsilon_0$

$$= \frac{\text{coulomb} \times \text{coulomb}}{\text{newton-(metre)}^2}$$
$$= \frac{(\text{coulomb})^2}{\text{newton-(metre)}^2}$$

**04** The value of Planck's constant in SI unit is **[CBSE AIPMT 2002]**

(a) $6.63 \times 10^{-31}$ J-s
(b) $6.63 \times 10^{-30}$ kg - m / s
(c) $6.63 \times 10^{-32}$ kg - m$^2$
(d) $6.63 \times 10^{-34}$ J - s

**Ans.** *(d)*

The value of Planck's constant is $6.63 \times 10^{-34}$ and J-s is unit of the Planck's constant.

**05** In a particular system, the unit of length, mass and time are chosen to be 10 cm, 10 g and 0.1 s respectively. The unit of force in this system will be equivalent to **[CBSE AIPMT 1994]**

(a) 0.1 N (b) 1 N (c) 10 N (d) 100 N

**Ans.** *(a)*

$$\text{Force } F = [\text{MLT}^{-2}]$$
$$= (10 \text{ g})(10 \text{ cm})(0.1 \text{ s})^{-2}$$

Changing these units into MKS system

$$F = (10^{-2} \text{ kg})(10^{-1} \text{ m})(10^{-1} \text{ s})^{-2}$$
$$= 10^{-1} \text{ N} = 0.1 \text{ N}$$

## TOPIC 2
Errors in Measurement and Significant Figure

**06** A screw gauge gives the following readings when used to measure the diameter of a wire

Main scale reading : 0 mm

Circular scale reading : 52 divisions

Given that, 1 mm on main scale corresponds to 100 divisions on the circular scale. The diameter of the wire from the above data is

(a) 0.52 cm **[NEET 2021]**
(b) 0.026 cm
(c) 0.26 cm
(d) 0.052 cm

**Ans.** *(d)*

Given, the main scale reading, MSR = 0

The circular scale reading, CSR = 52 divisions

Now, we shall determine the least count of the screw gauge,

$$\text{LC} = \frac{p}{n}$$

Here, $p$ is the pitch of the screw, $n$ is the number of circular divisions in one complete revolution.

$$\text{LC} = \frac{1}{100} \text{ mm}$$

$\Rightarrow$ LC = 0.01 mm

$\Rightarrow$ LC = 0.001 cm

Thus, the least count of the screw gauge is 0.001 cm.

Therefore, diameter of the wire of screw gauge,

$$D = \text{MSR} + (\text{CSR} \times \text{LC})$$
$$\Rightarrow \quad D = 0 + (52 \times 0.001)$$
$$\Rightarrow \quad D = 0.052 \text{ cm}$$

**07** Time intervals measured by a clock give the following readings

1.25 s, 1.24 s, 1.27 s, 1.21 s and 1.28 s.

What is the percentage relative error of the observations?

**[NEET (Oct.) 2020]**

(a) 2% (b) 4% (c) 16% (d) 1.6%

**Ans.** *(d)*

Mean time interval

$$\bar{T} = \frac{1.25 + 1.24 + 1.27 + 1.21 + 1.28}{5}$$

$$\Rightarrow \quad = \frac{6.25}{5} = 1.25\text{ s}$$

Mean absolute error,

$$\Delta\bar{T} = \frac{|\Delta T_1| + |\Delta T_2| + |\Delta T_3| + |\Delta T_4| + |\Delta T_5|}{5}$$

$$\Rightarrow = \frac{|1.25-1.25| + |1.25-1.24| + |1.25-1.27| + |1.25-1.21| + |1.25-1.28|}{5}$$

$$\Rightarrow = \frac{0 + 0.01 + 0.02 + 0.04 + 0.03}{5}$$

$$= \frac{0.1}{5} = 0.02\text{ s}$$

$$\therefore \text{Percentage relative error} = \frac{\Delta\bar{T}}{\bar{T}} \times 100$$

$$= \frac{0.02}{1.25} \times 100 = 1.6\%$$

**08** A screw gauge has least count of 0.01 mm and there are 50 divisions in its circular scale.

The pitch of the screw gauge is

**[NEET (Sep.) 2020]**

(a) 0.25 mm (b) 0.5 mm
(c) 1.0 mm (d) 0.01 mm

**Ans.** *(b)*

Given, least count = 0.01 mm

Number of divisions on circular scale = 50

Pitch of the screw gauge = least count × number of divisions on circular scale

$$= 0.01 \times 50 = 0.5\text{ mm}$$

Hence, correct option is (b).

**09** Taking into account of the significant figures, what is the value of 9.99 m − 0.0099 m?

**[NEET (Sep.) 2020]**

(a) 9.98 m (b) 9.980 m
(c) 9.9 m (d) 9.9801 m

**Ans.** *(a)*

The difference between 9.99 m and 0.0099 m is

$$= 9.99 - 0.0099 = 9.9801\text{ m}$$

Taking significant figures into account, as both the values has two significant figures after decimal.

So, their difference will also have two significant figures after decimal, i.e. 9.98 m.

Hence, correct option is (a).

**10** The main scale of a vernier calliper has $n$ divisions/cm. $n$ divisions of the vernier scale coincide with $(n-1)$ divisions of main scale. The least count of the vernier callipers is **[NEET (Odisha) 2019]**

(a) $\frac{1}{(n+1)(n-1)}$ cm (b) $\frac{1}{n}$ cm

(c) $\frac{1}{n^2}$ cm (d) $\frac{1}{n(n+1)}$ cm

**Ans.** *(c)*

As it is given that $n$ divisions of vernier scale coincide with $(n-1)$ divisions of main scale i.e.

$$n(VSD) = (n-1)MSD$$

$$\Rightarrow \quad 1VSD = \frac{(n-1)}{n}MSD \quad \text{...(i)}$$

The least count is the difference between one main scale division ($MSD$) and one vernier scale division ($VSD$).

$$\therefore \text{Least Count } (LC) = 1MSD - 1VSD$$

$$= 1MSD - \frac{(n-1)}{n}MSD \text{ [From Eq. (i)]}$$

$$= \left(1 - \frac{(n-1)}{n}\right)MSD = \frac{1}{n}MSD$$

Here, $1MSD = \frac{1}{n}$ cm

$$\Rightarrow \quad LC = \frac{1}{n} \times \frac{1}{n}\text{ cm} = \frac{1}{n^2}\text{ cm}$$

**11** A student measured the diameter of a small steel ball using a screw gauge of least count 0.001 cm. The main scale reading is 5 mm and zero of circular scale division coincides with 25 divisions above the reference level. If screw gauge has a zero error of −0.004 cm, the correct diameter of the ball is

**[NEET 2018]**

(a) 0.053 cm (b) 0.525 cm
(c) 0.521 cm (d) 0.529 cm

**Ans.** *(d)*

Given, least count of screw gauge, LC = 0.001 cm

Main scale reading,

MSR = 5 mm = 0.5 cm

Number of coinciding divisions on the circular scale, i.e. Vernier scale reading, VSR = 25

Here, zero error = −0.004 cm

Final reading obtained from the screw gauge is given as

= MSR + VSR × LC − zero error

Final reading from the screw gauge

$$= 0.5 + 25 \times 0.001 - (-0.004)$$
$$= 0.5 + 0.025 + 0.004$$
$$= 0.5 + 0.029$$
$$= 0.529\text{ cm}$$

Thus, the diameter of the ball is 0.529 cm.

**12** In an experiment, four quantities $a, b, c$ and $d$ are measured with percentage error 1%, 2%, 3% and 4% respectively. Quantity $P$ is calculated $P = \frac{a^3 b^2}{cd}$%. Error in $P$ is

**[NEET 2013]**

(a) 14% (b) 10%
(c) 7% (d) 4%

**Ans.** *(a)*

As given, $P = \frac{a^3 b^2}{cd}$

$$\therefore \quad \frac{\Delta P}{P} \times 100$$

$$= \left(\frac{3\Delta a}{a} + \frac{2\Delta b}{b} + \frac{\Delta c}{c} + \frac{\Delta d}{d}\right) \times 100$$

$$= 3\frac{\Delta a}{a} \times 100 + 2\frac{\Delta b}{b} \times 100 + \frac{\Delta c}{c} \times 100 + \frac{\Delta d}{d} \times 100$$

$$= 3 \times 1 + 2 \times 2 + 3 + 4$$
$$= 3 + 4 + 3 + 4 = 14\%$$

**13** If the error in the measurement of radius of a sphere is 2%, then the error in the determination of volume of the sphere will be

**[CBSE AIPMT 2008]**

(a) 4% (b) 6%
(c) 8% (d) 2%

**Ans.** *(b)*

Volume of a sphere, $V = \frac{4}{3}\pi r^3$

$$\therefore \quad \frac{\Delta V}{V} \times 100 = \frac{3 \times \Delta r}{r} \times 100$$

Here $\frac{\Delta r}{r} \times 100 = 2\%$

$$\therefore \quad \frac{\Delta V}{V} \times 100 = 3 \times 2\% = 6\%$$

**14** The density of a cube is measured by measuring its mass and length of its sides. If the maximum error in the measurement of mass and length are 4% and 3% respectively, the maximum error in the measurement of density will be **[CBSE AIPMT 1996]**

(a) 7% (b) 9%
(c) 12% (d) 13%

**Ans.** *(d)*

As density $\rho = \frac{m}{V} = \frac{m}{l^3}$

$$\therefore \frac{\Delta\rho}{\rho} \times 100 = \pm\left(\frac{\Delta m}{m} + 3\frac{\Delta l}{l}\right) \times 100\%$$

$$= \pm(4 + 3 \times 3) = \pm 13\%$$

**15** The percentage errors in the measurement of mass and speed are 2% and 3% respectively. The error in kinetic energy obtained by measuring mass and speed, will be **[CBSE AIPMT 1995]**

(a) 12% (b) 10%
(c) 8% (d) 2%

**Ans.** *(c)*

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

$$\therefore \frac{\Delta K}{K} \times 100 = \frac{\Delta m}{m} \times 100 + 2 \times \frac{\Delta v}{v} \times 100$$

Here, $\frac{\Delta m}{m} \times 100 = 2\%$

$$\Rightarrow \frac{\Delta v}{v} \times 100 = 3\%$$

$$\therefore \frac{\Delta K}{K} \times 100 = 2\% + 2 \times 3\% = 8\%$$

**16** In a vernier callipers $N$ divisions of vernier scale coincide with $N-1$ divisions of main scale (in which length of one division is 1 mm). The least count of the instrument should be **[CBSE AIPMT 1994]**

(a) $N$ (b) $N-1$
(c) $\frac{1}{10N}$ (d) $\frac{1}{(N-1)}$

**Ans.** *(c)*

As given $N$ VSD $= (N-1)$ MSD

VSD = Vernier scale division

MSD = Main scale division

$$1\text{ VSD} = \left(\frac{N-1}{N}\right)\text{MSD}$$

LC = least count = 1 MSD − 1 VSD

$$\text{LC} = \left(1 - \frac{N-1}{N}\right)\text{MSD}$$

$$= \frac{1}{N}\text{MSD} = \frac{0.1}{N}\text{ cm} = \frac{1}{10N}\text{ cm}$$

**17** A certain body weighs 22.42 g and has a measured volume of 4.7 cc. The possible error in the measurement of mass and volume are 0.01 g and 0.1 cc. Then, maximum error in the density will be **[CBSE AIPMT 1991]**

(a) 22% (b) 2% (c) 0.2% (d) 0.02%

**Ans.** *(b)*

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\rho = \frac{m}{V}$$

$$\therefore \frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + \frac{\Delta V}{V}$$

Here, $\Delta m = 0.01, m = 22.42$

$\Delta V = 0.1, V = 4.7$

$$\therefore \frac{\Delta\rho}{\rho} = \left(\frac{0.01}{22.42} + \frac{0.1}{4.7}\right) \times 100 = 2\%$$

# TOPIC 3
## Dimensions

**18** If force $[F]$, acceleration $[a]$ and time $[T]$ are chosen as the fundamental physical quantities. Find the dimensions of energy. **[NEET 2021]**

(a) $[F][a][T]$ (b) $[F][a][T^2]$
(c) $[F][a][T^{-1}]$ (d) $[F][a^{-1}][T]$

**Ans.** *(b)*

Given, fundamental physical quantities are force $[F]$, acceleration $[a]$ and time $[T]$.

Now, we shall determine the dimensions of the energy.

Energy depends on force, acceleration and time as,

$$[E] = [F]^a[a]^b[T]^c$$

$$\Rightarrow [ML^2T^{-2}] = [MLT^{-2}]^a[LT^{-2}]^b[T]^c$$

$$\Rightarrow [ML^2T^{-2}] = [M]^a[L]^{a+b}[T]^{-2a-2b+c}$$

Comparing the powers of M, L and T on both sides, we get

$a = 1, a + b = 2$

and $-2a - 2b + c = -2$

$\Rightarrow 1 + b = 2 \Rightarrow b = 1,$

$\Rightarrow -2(1) - 2(1) + c = -2 \Rightarrow c = 2$

The dimensions of the energy are $[F^1][a]^1[T]^2$.

**19** If $E$ and $G$ respectively denote energy and gravitational constant. then $\frac{E}{G}$ has the dimensions of **[NEET 2021]**

(a) $[M^2][L^{-1}][T^0]$ (b) $[M][L^{-1}][T^{-1}]$
(c) $[M][L^0][T^0]$ (d) $[M^2][L^{-2}][T^{-1}]$

**Ans.** *(a)*

The dimensions of energy

$$[E] = [F] \cdot [d]$$

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

As we know that, the expression of gravitational force,

$$F = \frac{GM_1M_2}{r^2} \Rightarrow G = \frac{Fr^2}{M_1M_2}$$

$$\therefore [G] = \frac{[F][r^2]}{[M_1][M_2]} \Rightarrow [G] = \frac{[MLT^{-2}][L]^2}{[M][M]}$$

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

The dimensions of

$$\frac{E}{G} = \frac{[ML^2T^{-2}]}{[M^{-1}L^3T^{-2}]} \Rightarrow \left[\frac{E}{G}\right] = [M^2L^{-1}T^0]$$

**20** Dimensions of stress are **[NEET (Sep.) 2020]**

(a) $[ML^2T^{-2}]$ (b) $[ML^0T^{-2}]$
(c) $[ML^{-1}T^{-2}]$ (d) $[MLT^{-2}]$

**Ans.** *(c)*

$$\because \text{Stress} = \frac{\text{Force}}{\text{Area}}$$

$$\therefore \text{Dimensions of stress} = \frac{[MLT^{-2}]}{[L^2]}$$

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

Hence, correct option is (c).

**21** A physical quantity of the dimensions of length that can be formed out of $c$, $G$ and $\frac{e^2}{4\pi\varepsilon_0}$ is [$c$ is velocity of light, $G$ is universal constant of gravitation and $e$ is charge] **[NEET 2017]**

(a) $\frac{1}{c^2}\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$ (b) $c^2\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$
(c) $\frac{1}{c^2}\left[\frac{e^2}{G\,4\pi\varepsilon_0}\right]^{1/2}$ (d) $\frac{1}{c}G\frac{e^2}{4\pi\varepsilon_0}$

**Ans.** *(a)*

As force $F = \frac{e^2}{4\pi\varepsilon_0 r^2} \Rightarrow \frac{e^2}{4\pi\varepsilon_0} = r^2 \cdot F$

Putting dimensions of $r$ and $F$, we get,

$$\Rightarrow \left[\frac{e^2}{4\pi\varepsilon_0}\right] = [ML^3T^{-2}] \quad \text{...(i)}$$

Also, force, $F = \frac{Gm^2}{r^2}$

$\Rightarrow \quad [G] = \frac{[MLT^{-2}][L^2]}{[M^2]}$

$\Rightarrow \quad [G] = [M^{-1}L^3T^{-2}]$ ...(ii)

and $\left[\frac{1}{c^2}\right] = \frac{1}{[L^2T^{-2}]} = [L^{-2}T^2]$ ...(iii)

Now, checking optionwise,

$$= \frac{1}{c^2}\left(\frac{Ge^2}{4\pi\varepsilon_0}\right)^{1/2} = [L^{-2}T^2][L^6T^{-4}]^{1/2} = [L]$$

**22** If energy ($E$), velocity ($v$) and time ($T$) are chosen as the fundamental quantities, the dimensional formula of surface tension will be **[CBSE AIPMT 2015]**

(a) $[Ev^{-2}T^{-1}]$ (b) $[Ev^{-1}T^{-2}]$
(c) $[Ev^{-2}T^{-2}]$ (d) $[E^{-2}v^{-1}T^{-3}]$

**Ans.** *(c)*

We know that

Surface tension $(S) = \frac{\text{Force}[F]}{\text{Length}[L]}$

So, $[S] = \frac{[MLT^{-2}]}{[L]} = [ML^0T^{-2}]$

Energy $(E)$ = Force × displacement

$\Rightarrow \quad [E] = [ML^2T^{-2}]$

Velocity $(v) = \frac{\text{displacement}}{\text{time}}$

$\Rightarrow \quad [v] = [LT^{-1}]$

As, $S \propto E^a v^b T^c$

where, $a, b, c$ are constants.

From the principle of homogeneity,

$[LHS] = [RHS]$

$\Rightarrow \quad [ML^0T^{-2}] = [ML^2T^{-2}]^a [LT^{-1}]^b [T]^c$

$\Rightarrow \quad [ML^0T^{-2}] = [M^aL^{2a+b}T^{-2a-b+c}]$

Equating the power on both sides, we get

$a = 1, 2a + b = 0, b = -2$

$\Rightarrow \quad -2a - b + c = -2$

$\Rightarrow \quad c = (2a + b) - 2 = 0 - 2 = -2$

So $\quad [S] = [Ev^{-2}T^{-2}] = [Ev^{-2}T^{-2}]$

**23** If dimensions of critical velocity $v_c$ of a liquid flowing through a tube are expressed as $[\eta^x \rho^y r^z]$, where $\eta, \rho$ and $r$ are the coefficient of viscosity of liquid, density of liquid and radius of the tube respectively, then the values of $x$, $y$ and $z$ are given by **[CBSE AIPMT 2015]**

(a) 1, – 1, – 1 (b) – 1, – 1, 1
(c) – 1, – 1, – 1 (d) 1, 1, 1

**Ans.** *(a)*

**Key Concept** According to principle of homogeneity of dimension states that, a physical quantity equation will be dimensionally correct, if the dimensions of all the terms occurring on both sides of the equations are same.

Given critical velocity of liquid flowing through a tube are expressed as

$v_c \propto \eta^x \rho^y r^z$

Coefficient of viscosity of liquid,

$\eta = [ML^{-1}T^{-1}]$

Density of liquid, $\rho = [ML^{-3}]$

Radius of a tube $r = [L]$

Critical velocity of liquid $v_c = [ML^0T^{-1}]$

$\Rightarrow [M^0L^1T^{-1}] = [ML^{-1}T^{-1}]^x [ML^{-3}]^y [L]^z$

$[M^0L^1T^{-1}] = [M^{x+y}L^{-x-3y+z}T^{-x}]$

Comparing exponents of M, L and L, we get

$x + y = 0, -x - 3y + z = 1, -x = -1$

$\Rightarrow \quad z = -1, x = 1, y = -1$

**24** If force ($F$), velocity ($v$) and time ($T$) are taken as fundamental units, then the dimensions of mass are **[CBSE AIPMT 2014]**

(a) $[FvT^{-1}]$ (b) $[FvT^{-2}]$
(c) $[Fv^{-1}T^{-1}]$ (d) $[Fv^{-1}T]$

**Ans.** *(d)*

We know that

$F = ma$

$\Rightarrow \quad F = \frac{mv}{t} \quad \Rightarrow \quad m = \frac{Ft}{v}$

$[M] = \frac{[F][T]}{[v]} = [Fv^{-1}T]$

**25** The dimensions of $(\mu_0\varepsilon_0)^{-1/2}$ are **[CBSE AIPMT 2012]**

(a) $[L^{1/2}T^{-1/2}]$ (b) $[L^{-1}T]$
(c) $[LT^{-1}]$ (d) $[L^{1/2}T^{1/2}]$

**Ans.** *(c)*

$(\mu_0\varepsilon_0)^{-1/2}$ is the expression for velocity of light.

As $\quad c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

So, dimension of $c = [LT^{-1}]$

**26** The dimensions of $\frac{1}{2}\varepsilon_0 E^2$, where $\varepsilon_0$ is permittivity of free space and $E$ is electric field, are **[CBSE AIPMT 2010]**

(a) $[ML^2T^{-2}]$ (b) $[ML^{-1}T^{-2}]$
(c) $[ML^2T^{-1}]$ (d) $[MLT^{-1}]$

**Ans.** *(b)*

As we know that,

Dimension of $\varepsilon_0 = [M^{-1}L^{-3}T^4A^2]$

Dimension of $E = [MLT^{-3}A^{-1}]$

So, dimension of

$\frac{1}{2}\varepsilon_0 E^2 = [M^{-1}L^{-3}T^4A^2] \times [MLT^{-3}A^{-1}]^2$

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

**27** If the dimensions of a physical quantity are given by $[M^a L^b T^c]$, then the physical quantity will be **[CBSE AIPMT 2009]**

(a) pressure if $a = 1, b = -1, c = -2$
(b) velocity if $a = 1, b = 0, c = -1$
(c) acceleration if $a = 1, b = 1, c = -2$
(d) force if $a = 0, b = -1, c = -2$

**Ans.** *(a)*

(i) Dimensions of velocity $= [M^0L^1T^{-1}]$
Here, $a = 0, b = 1, c = -1$

(ii) Dimensions of acceleration $= [M^0L^1T^{-2}]$
Here, $a = 0, b = 1, c = -2$

(iii) Dimensions of force $= [M^1L^1T^{-2}]$
Here, $a = 1, b = 1, T = -2$

(iv) Dimensions of pressure $= [M^1L^{-1}T^{-2}]$

$\therefore$ Here, $a = 1, b = -1, c = -2$

$\therefore$ The physical quantity is pressure.

**28** Which two of the following five physical parameters have the same dimensions? **[CBSE AIPMT 2008]**

(i) Energy density
(ii) Refractive index
(iii) Dielectric constant
(iv) Young's modulus
(v) Magnetic field

(a) (ii) and (iv) (b) (iii) and (v)
(c) (i) and (iv) (d) (i) and (v)

**Ans.** *(c)*

Energy density $= \frac{\text{Energy}}{\text{Volume}} \Rightarrow u = \frac{E}{V}$

Dimensions of $u = \frac{\text{Dimensions of } E}{\text{Dimensions of } V}$

$= \frac{[ML^2T^{-2}]}{[L^3]} = [ML^{-1}T^{-2}]$

Refractive index is a dimensionless quantity. Dielectric constant is a dimensionless quantity.

Young's modulus

$= \frac{\text{Longitudinal stress}}{\text{Longitudinal strain}} = \frac{F/A}{\Delta l/l} = [ML^{-1}T^{-2}]$

Magnetic field $= \frac{\text{Force}}{\text{Charge} \times \text{Velocity}} = \frac{F}{qv}$

$= \frac{[MLT^{-2}]}{[AT][LT^{-1}]} = [MT^{-2}A^{-1}]$

**29** Dimensions of resistance in an electrical circuit, in terms of dimension of mass $M$, of length $L$, of time $T$ and of current $I$, would be **[CBSE AIPMT 2007]**

(a) $[ML^2T^{-3}I^{-1}]$ (b) $[ML^2T^{-2}]$
(c) $[ML^2T^{-1}I^{-1}]$ (d) $[ML^2T^{-3}I^{-2}]$

**Ans.** *(d)*

According to Ohm's law, $V \propto I$

and $V = IR$

Resistance, $R = \dfrac{\text{Potential difference}}{\text{Current}}$

$= \dfrac{V}{i} = \dfrac{W}{qi}$

$\left(\because \text{Potential difference is equal to the work done per unit charge}\right)$

So, dimensions of $R$

$= \dfrac{\text{Dimensions of work}}{\text{Dimensions of charge} \times \text{Dimensions of current}}$

$= \dfrac{[ML^2T^{-2}]}{[IT][I]} = [ML^2T^{-3}I^{-2}]$

**30** The velocity $v$ of a particle at time $t$ is given by $v = at + \dfrac{b}{t+c}$, where $a, b$ and $c$ are constants. The dimensions of $a, b$ and $c$ are respectively **[CBSE AIPMT 2006]**

(a) $[LT^{-2}]$, $[L]$ and $[T]$
(b) $[L^2]$, $[T]$ and $[LT^2]$
(c) $[LT^2]$, $[LT]$ and $[L]$
(d) $[L]$, $[LT]$ and $[T^2]$

**Ans.** *(a)*

The given expression is

$v = at + \dfrac{b}{t+c}$

From principle of homogeneity

$[a][t] = [v]$

$[a] = \dfrac{[v]}{[t]} = \dfrac{[LT^{-1}]}{[T]} = [LT^{-2}]$

Similarly, $[c] = [t] = [T]$

Further, $\dfrac{[b]}{[t+c]} = [v]$

or $[b] = [v][t+c]$

or $[b] = [LT^{-1}][T] = [L]$

**31** The ratio of the dimensions of Planck's constant and that of the moment of inertia is the dimension of **[CBSE AIPMT 2005]**

(a) frequency
(b) velocity
(c) angular momentum
(d) time

**Ans.** *(a)*

Energy carried by photon is given by

$E = h\nu$

$\Rightarrow h = \text{Planck's constant} = \dfrac{E}{\nu}$

$\therefore [h] = \dfrac{[ML^2T^{-2}]}{[T^{-1}]} = [ML^2T^{-1}]$

and $I = \text{moment of inertia} = MR^2$

$\Rightarrow [I] = [ML^2]$

Hence, $\dfrac{[h]}{[I]} = \dfrac{[ML^2T^{-1}]}{[ML^2]} = [T^{-1}]$

$= \dfrac{1}{[T]}$ = dimension of frequency

**Alternative**

$\dfrac{h}{I} = \dfrac{E/\nu}{I}$

$= \dfrac{E \times T}{I} = \dfrac{(\text{kg-m}^2/\text{s}^2)\times \text{s}}{(\text{kg-m}^2)}$

$= \dfrac{1}{\text{s}} = \dfrac{1}{\text{time}}$ = frequency

Thus, dimensions of $\dfrac{h}{I}$ is same as that of frequency.

**32** The dimensions of universal gravitational constant are **[CBSE AIPMT 2004, 1992]**

(a) $[M^{-1}L^3T^{-2}]$ (b) $[ML^2T^{-1}]$
(c) $[M^{-2}L^3T^{-2}]$ (d) $[M^{-2}L^2T^{-1}]$

**Ans.** *(a)*

According to Newton's law of gravitation, the force of attraction between two masses $m_1$ and $m_2$ separated by a distance $r$ is,

$F = \dfrac{G\, m_1 m_2}{r^2} \Rightarrow G = \dfrac{Fr^2}{m_1 m_2}$

Substituting the dimensions for the quantities on the right hand side, we obtain

Dimensions of $G = \dfrac{[MLT^{-2}][L^2]}{[M]^2}$

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

**33** Planck's constant has the dimensions of **[CBSE AIPMT 2001]**

(a) linear momentum
(b) angular momentum
(c) energy
(d) power

**Ans.** *(b)*

$E = h\nu$

$\Rightarrow h = \text{Planck's constant} = \dfrac{\text{Energy }(E)}{\text{frequency }(\nu)}$

$\therefore [h] = \dfrac{E}{\nu} = \dfrac{[ML^2T^{-2}]}{[T^{-1}]} = [ML^2T^{-1}]$

(a) Linear momentum = Mass × velocity

or $p = m \times v = [M][LT^{-1}] = [MLT^{-1}]$

(b) Angular momentum

= Moment of inertia × angular velocity

or $L = I \times \omega = mr^2\omega$ $[\because I = mr^2]$

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

(c) Energy $[E] = [ML^2T^{-2}]$

(d) Power = Force × velocity

or $P = F \times v$

$\therefore [P] = [MLT^{-2}][LT^{-1}] = [ML^2T^{-3}]$

Hence, option (b) is correct.

**34** A pair of physical quantities having same dimensional formula is **[CBSE AIPMT 2000]**

(a) force and torque
(b) work and energy
(c) force and impulse
(d) linear momentum and angular momentum

**Ans.** *(b)*

(a) Force = Mass × acceleration

or $F = ma$

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

Torque = Moment of inertia × angular acceleration

or $\tau = I \times \alpha = [ML^2][T^{-2}] = [ML^2T^{-2}]$

(b) Work = Force × displacement

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

Energy $= \dfrac{1}{2} \times \text{mass} \times (\text{velocity})^2$

or $K = \dfrac{1}{2}mv^2 = [M][LT^{-1}]^2 = [ML^2T^{-2}]$

(c) Force as discussed above

$[F] = [MLT^{-2}]$

Impulse = Force × time-interval

$\therefore [I] = [MLT^{-2}][T] = [MLT^{-1}]$

(d) Linear momentum = Mass × velocity

or $p = mv$

$\therefore [p] = [M][LT^{-1}] = [MLT^{-1}]$

Angular momentum = Moment of inertia × angular velocity

or $[L] = [I] \times [\omega]$

$\therefore [L] = [ML^2][T^{-1}] = [ML^2T^{-1}]$

Hence, we observe that choice (b) is correct.

**35** The dimensional formula for magnetic flux is **[CBSE AIPMT 1999]**

(a) $[ML^2T^{-2}A^{-1}]$ (b) $[ML^3T^{-2}A^{-2}]$
(c) $[M^0L^{-2}T^2A^{-2}]$ (d) $[ML^2T^{-1}A^2]$

**Ans.** *(a)*

Mathematically, magnetic flux

$\phi = BA$ ...(i)

but magnetic force

$F = Bil$ or $B = \frac{F}{il}$

Putting the value of $B$ in Eq. (i), we have

$$\phi = \frac{F}{il} A$$

Thus, dimensions of $\phi = \frac{[MLT^{-2}][L^2]}{[AL]}$

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

**36** The force $F$ on a sphere of radius $r$ moving in a medium with velocity $v$ is given by $F = 6\pi\eta rv$. The dimensions of $\eta$ are **[CBSE AIPMT 1997]**

(a) $[ML^{-3}]$ (b) $[MLT^{-2}]$
(c) $[MT^{-1}]$ (d) $[ML^{-1}T^{-1}]$

**Ans.** *(d)*

Viscous force on a sphere of radius $r$ is

$$F = 6\pi\eta rv \Rightarrow \eta = \frac{F}{6\pi rv}$$

$$[\eta] = \frac{[F]}{[r][v]} = \frac{[MLT^{-2}]}{[L][LT^{-1}]} = [ML^{-1}T^{-1}]$$

**37** Which of the following will have the dimensions of time ? **[CBSE AIPMT 1996]**

(a) $LC$ (b) $\frac{R}{L}$ (c) $\frac{L}{R}$ (d) $\frac{C}{L}$

**Ans.** *(c)*

$\frac{L}{R}$ is time constant of $R$-$L$ circuit so, dimensions of $\frac{L}{R}$ is same as that of time.

Alternative

$$\frac{\text{Dimensions of } L}{\text{Dimensions of } R} = \frac{[ML^2T^{-2}A^{-2}]}{[ML^2T^{-3}A^{-2}]} = [T]$$

**38** An equation is given as $\left(p + \frac{a}{V^2}\right) = b\frac{\theta}{V}$, where $p$ = pressure, $V$ = volume and $\theta$ = absolute temperature. If $a$ and $b$ are constants, then dimensions of $a$ will be **[CBSE AIPMT 1996]**

(a) $[ML^5T^{-2}]$ (b) $[M^{-1}L^5T^2]$
(c) $[ML^{-5}T^{-1}]$ (d) $[ML^5T]$

**Ans.** *(a)*

From principle of homogeneity of dimensions.

Dimensions of $p$ = dimensions of $\frac{a}{V^2}$

$$p = \frac{a}{V^2} \Rightarrow a = pV^2$$

$$= [ML^{-1}T^{-2}][L^3]^2 = [ML^5T^{-2}]$$

**39** Which of the following is a dimensional constant ? **[CBSE AIPMT 1995]**

(a) Refractive index
(b) Poisson's ratio
(c) Relative density
(d) Gravitational constant

**Ans.** *(d)*

A quantity which has dimensions and also has a constant value is called dimensional constant.
Here, gravitational constant ($G$) is a dimensional constant.

**40** Turpentine oil is flowing through a tube of length $l$ and radius $r$. The pressure difference between the two ends of the tube is $p$. The viscosity of oil is given by

$$\eta = \frac{p(r^2 - x^2)}{4vl}$$

where, $v$ is the velocity of oil at distance $x$ from the axis of the tube. The dimensions of $\eta$ are **[CBSE AIPMT 1993]**

(a) $[M^0L^0T^0]$ (b) $[MLT^{-1}]$
(c) $[ML^2T^{-2}]$ (d) $[ML^{-1}T^{-1}]$

**Ans.** *(d)*

Pressure

$$(p) = \frac{\text{Force}}{\text{Area}} = \frac{[MLT^{-2}]}{[L^2]} = [ML^{-1}T^{-2}]$$

Velocity, $v = [LT^{-1}]$

From principle of homogeneity, the dimensions of $r^2$ and $x^2$ are same.

So, the dimensions of viscosity,

$$\eta = \frac{[ML^{-1}T^{-2}][L^2]}{[LT^{-1}][L]} = [ML^{-1}T^{-1}]$$

**41** The time dependence of physical quantity $p$ is given by $p = p_0 \exp(-\alpha t^2)$, where $\alpha$ is a constant and $t$ is the time. The constant $\alpha$ **[CBSE AIPMT 1992]**

(a) is dimensionless
(b) has dimensions $[T^{-2}]$
(c) has dimensions $[T^2]$
(d) has dimensions of $p$

**Ans.** *(b)*

$$p = p_0 \exp(-\alpha t^2)$$

As powers of exponential quantity is dimensionless, so $\alpha t^2$ is dimensionless.

or $\alpha t^2$ = dimensionless $= [M^0L^0T^0]$

$$\therefore \quad \alpha = \frac{1}{t^2} = \frac{1}{[T^2]} = [T^{-2}]$$

**42** If $p$ represents radiation pressure, $c$ represents speed of light and $S$ represents radiation energy striking unit area per sec. The non-zero integers $x, y, z$ such that $p^x S^y c^z$ is dimensionless are **[CBSE AIPMT 1992]**

(a) $x = 1, y = 1, z = 1$
(b) $x = -1, y = 1, z = 1$
(c) $x = 1, y = -1, z = 1$
(d) $x = 1, y = 1, z = -1$

**Ans.** *(c)*

Radiation pressure, $p = [ML^{-1}T^{-2}]$

Velocity of light, $c = [LT^{-1}]$

Energy striking unit area per second

$$S = \frac{[ML^2T^{-2}]}{[L^2T]} = [MT^{-3}]$$

Now, $p^x S^y c^z$ is dimensionless.

$\therefore [M^0L^0T^0] = p^x S^y c^z$

or $[M^0L^0T^0] = [M^1L^{-1}T^{-2}]^x [M^1T^{-3}]^y [L^1T^{-1}]^z$

or $[M^0L^0T^0] = [M]^{x+y} [L]^{-x+z} [T]^{-2x-3y-z}$

From principle of homogeneity of dimensions

$$x + y = 0 \quad \text{...(i)}$$
$$-x + z = 0 \quad \text{...(ii)}$$
$$-2x - 3y - z = 0 \quad \text{...(iii)}$$

Solving Eqs. (i), (ii) and (iii), we get

$$x = 1, \quad y = -1, \quad z = 1$$

**43** The dimensional formula for permeability of free space, $\mu_0$ is **[CBSE AIPMT 1991]**

(a) $[MLT^{-2}A^{-2}]$ (b) $[ML^{-1}T^2A^{-2}]$
(c) $[ML^{-1}T^{-2}A^2]$ (d) $[MLT^{-2}A^{-1}]$

**Ans.** *(a)*

From Biot-Savart law

$$dB = \frac{\mu_0}{4\pi} \frac{Idl \sin\theta}{r^2}$$

$Idl$ = current element

$r$ = displacement vector

$$\mu_0 = \frac{4\pi r^2 (dB)}{Idl \sin\theta} = \frac{[L^2][MT^{-2}A^{-1}]}{[A][L]}$$

$$= [MLT^{-2}A^{-2}]$$

**44** The frequency of vibration $f$ of a mass $m$ suspended from a spring of spring constant $k$ is given by a relation of the type $f = Cm^x k^y$, where $C$ is a dimensionless constant. The values of $x$ and $y$ are **[CBSE AIPMT 1990]**

(a) $x = \frac{1}{2}, y = \frac{1}{2}$ (b) $x = -\frac{1}{2}, y = -\frac{1}{2}$
(c) $x = \frac{1}{2}, y = -\frac{1}{2}$ (d) $x = -\frac{1}{2}, y = \frac{1}{2}$

**Ans.** *(d)*

As $f = Cm^x k^y$

$\therefore$ (Dimension of $f$) $= C$ (dimension of $m$)$^x$ $\times$(dimensions of $k$)$^y$

$$[T^{-1}] = C\ [M]^x\ [MT^{-2}]^y \quad ...(i)$$

$$\left(\text{where, } k = \frac{\text{force}}{\text{length}}\right)$$

Applying the principle of homogeneity of dimensions, we get

$$x + y = 0,\ -2y = -1 \text{ or } y = \frac{1}{2}$$

$$\therefore \qquad x = -\frac{1}{2}$$

**45** According to Newton, the viscous force acting between liquid layers of area $A$ and velocity gradient $\frac{\Delta v}{\Delta z}$ is given by $F = -\eta A \frac{dv}{dz}$, where $\eta$ is constant called **[CBSE AIPMT 1990]**

(a) $[ML^{-2}T^{-2}]$
(b) $[M^0L^0T^0]$
(c) $[ML^2T^{-2}]$
(d) $[ML^{-1}T^{-1}]$

**Ans.** *(d)*

As $F = -\eta A \frac{dv}{dz} \Rightarrow \eta = -\frac{F}{A\left(\frac{dv}{dz}\right)}$

As $F = [MLT^{-2}]$, $A = [L^2]$

$dv = [LT^{-1}]$, $dz = [L]$

$$\therefore \quad \eta = \frac{[MLT^{-2}][L]}{[L^2][LT^{-1}]} = [ML^{-1}T^{-1}]$$

**46** The dimensional formula of pressure is **[CBSE AIPMT 1990]**

(a) $[MLT^{-2}]$ (b) $[ML^{-1}T^2]$
(c) $[ML^{-1}T^{-2}]$ (d) $[MLT^{-2}]$

**Ans.** *(c)*

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{F}{A} = \frac{[MLT^{-2}]}{[L^2]}$$

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

**47** The dimensional formula of torque is **[CBSE AIPMT 1989]**

(a) $[ML^2T^{-2}]$ (b) $[MLT^{-2}]$
(c) $[ML^{-1}T^{-2}]$ (d) $[ML^{-2}T^{-2}]$

**Ans.** *(a)*

Torque $\tau = \mathbf{r} \times \mathbf{F}$

Dimensions of $\tau$ = dimension of $\mathbf{r}$ $\times$ dimension of $\mathbf{F}$

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

**48** If $x = at + bt^2$, where $x$ is the distance travelled by the body in kilometer while $t$ is the time in second, then the unit of $b$ is **[CBSE AIPMT 1989]**

(a) km/s (b) km-s (c) km/s$^2$ (d) km-s$^2$

**Ans.** *(c)*

Ans.As $x = at + bt^2$

According to the concept of dimensional analysis and principle of homogeneity

$\therefore$ unit of $x$ = unit of $bt^2$

$$\therefore \quad \text{unit of } b = \frac{\text{unit of } x}{\text{unit of } t^2} = \text{km /s}^2$$

**49** Dimensional formula of self-inductance is **[CBSE AIPMT 1989]**

(a) $[MLT^{-2}A^{-2}]$ (b) $[ML^2T^{-1}A^{-2}]$
(c) $[ML^2T^{-2}A^{-2}]$ (d) $[ML^2T^{-2}A^{-1}]$

**Ans.** *(c)*

As we know that emf induced in the inductors is given by

$$e = L\frac{di}{dt} \quad \Rightarrow L = \frac{edt}{di} = \frac{W}{q}\cdot\frac{dt}{di}$$

$$= \frac{[ML^2T^{-2}][T]}{[AT][A]} = [ML^2T^{-2}A^{-2}]$$

**50** Of the following quantities, which one has dimensions different from the remaining three? **[CBSE AIPMT 1989]**

(a) Energy per unit volume
(b) Force per unit area
(c) Product of voltage and charge per unit volume
(d) Angular momentum

**Ans.** *(d)*

Dimensions of energy per unit volume

$$= \frac{\text{Dimensions of energy}}{\text{Dimensions of volume}}$$

$$= \frac{[ML^2T^{-2}]}{[L^3]} = [ML^{-1}T^{-2}]$$

Dimensions of force per unit area

$$= \frac{\text{Dimensions of force}}{\text{Dimensions of area}} = \frac{[MLT^{-2}]}{[L^2]}$$

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

Voltage $\times$ Charge/ Volume

$$= \frac{\left(\frac{W}{q}\right)\times(it)}{l^3} = \frac{(W)}{(l^3)} = \frac{[ML^2T^{-2}]}{[L^3]}$$

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

Angular momentum

$$= (r)(p) = (r)(mv) = [L][M][LT^{-1}]$$

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

So, dimensions of angular momentum is different from other three.

**51** The dimensional formula for angular momentum is **[CBSE AIPMT 1988]**

(a) $[M^0L^2T^{-2}]$
(b) $[ML^2T^{-1}]$
(c) $[MLT^{-1}]$
(d) $[ML^2T^{-2}]$

**Ans.** *(b)*

Angular momentum

$$L = \mathbf{r} \times \mathbf{p} = \mathbf{r} \times mv$$

$\therefore$ Dimensional formula for angular momentum

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

**52** If $C$ and $R$ denote capacitance and resistance respectively, then the dimensional formula of $CR$ is **[CBSE AIPMT 1988]**

(a) $[M^0L^0T]$ (b) $[M^0L^0T^0]$
(c) $[M^0L^0T^{-1}]$
(d) Not expressible in terms of $[MLT]$

**Ans.** *(a)*

$$\because C = \frac{q}{V} = \frac{q}{\frac{W}{q}} = \frac{q^2}{W} = \frac{(it)^2}{F\cdot x} = \frac{[AT]^2}{[ML^2T^{-2}]}$$

$$= [M^{-1}L^{-2}T^4A^2] \quad \text{and} \quad R = \frac{V}{i} = \frac{W}{qi}$$

$$= \frac{F\cdot x}{i^2 t} = \frac{[ML^2T^{-2}]}{[AT][A]} = [ML^2T^{-3}A^{-2}]$$

$\therefore$ Dimensional formula of $CR$

$$= [M^{-1}L^{-2}T^4A^2][ML^2T^{-3}A^{-2}] = [M^0L^0T]$$

# 02

# Motion in a Straight Line

## TOPIC 1
### Terms Related to Motion

**01** A person travelling in a straight line moves with a constant velocity $v_1$ for certain distance 'x' and with a constant velocity $v_2$ for next equal distance. The average velocity $v$ is given by the relation **[NEET (Odisha) 2019]**

(a) $\frac{1}{v}=\frac{1}{v_1}+\frac{1}{v_2}$ (b) $\frac{2}{v}=\frac{1}{v_1}+\frac{1}{v_2}$

(c) $\frac{v}{2}=\frac{v_1+v_2}{2}$ (d) $v=\sqrt{v_1 v_2}$

**Ans.** *(b)*

For distance $x$, the person moves with constant velocity $v_1$ and for another $x$ distance, he moves with constant velocity of $v_2$, then

Total distance travelled, $D=x+x=2x$

Total time-taken, $T=t_1+t_2$

$$=\frac{x}{v_1}+\frac{x}{v_2} \qquad \left[\because t=\frac{\text{Distance}}{\text{Velocity}}\right]$$

The average velocity,

$$V_{av}=\frac{\text{total distance}}{\text{total time}}=\frac{D}{T}$$

$$v=\frac{2x}{\frac{x}{v_1}+\frac{x}{v_2}}=\frac{2}{\frac{1}{v_1}+\frac{1}{v_2}} \qquad [\because v_{av}=v]$$

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

**02** Preeti reached the metro station and found that the escalator was not working. She walked up the stationary escalator in time $t_1$. On other days, if she remains stationary on the moving escalator, then the escalator takes her up in time $t_2$. The time taken by her to walk up on the moving escalator will be **[NEET 2017]**

(a) $\frac{t_1+t_2}{2}$ (b) $\frac{t_1 t_2}{t_2-t_1}$

(c) $\frac{t_1 t_2}{t_2+t_1}$ (d) $t_1-t_2$

**Ans.** *(c)*

Speed of walking $=\frac{h}{t_1}=v_1$

Speed of escalator $=\frac{h}{t_2}=v_2$

Time taken when she walks over running escalator

$$\Rightarrow \quad t=\frac{h}{v_1+v_2}$$

$$\Rightarrow \quad \frac{1}{t}=\frac{v_1}{h}+\frac{v_2}{h}=\frac{1}{t_1}+\frac{1}{t_2}$$

$$\Rightarrow \quad t=\frac{t_1 t_2}{t_1+t_2}$$

**03** If the velocity of a particle is $v=At+Bt^2$, where $A$ and $B$ are constants, then the distance travelled by it between 1s and 2s is **[NEET 2016]**

(a) $3A+7B$ (b) $\frac{3}{2}A+\frac{7}{3}B$

(c) $\frac{A}{2}+\frac{B}{3}$ (d) $\frac{3}{2}A+4B3$

**Ans.** *(b)*

Velocity of the particle is given as

$$v=At+Bt^2$$

where $A$ and $B$ are constants.

$$\Rightarrow \quad \frac{dx}{dt}=At+Bt^2 \qquad \left[\because v=\frac{dx}{dt}\right]$$

$$\Rightarrow \quad dx=(At+Bt^2)\,dt$$

Integrating both sides, we get

$$\int_{x_1}^{x_2} dx=\int_1^2 (At+Bt^2)\,dt$$

$$\Rightarrow \quad \Delta x=x_2-x_1=A\int_1^2 t\,dt+B\int_1^2 t^2 dt$$

$$=A\left[\frac{t^2}{2}\right]_1^2+B\left[\frac{t^3}{3}\right]_1^2$$

$$=\frac{A}{2}(2^2-1^2)+\frac{B}{3}(2^3-1^3)$$

$\therefore$ Distance travelled between 1s and 2s is

$$\Delta x=\frac{A}{2}\times(3)+\frac{B}{3}(7)=\frac{3A}{2}+\frac{7B}{3}$$

**04** Two cars $P$ and $Q$ start from a point at the same time in a straight line and their positions are represented by $X_P(t)=at+bt^2$ and $X_Q(t)=ft-t^2$. At what time do the cars have the same velocity? **[NEET 2016]**

(a) $\frac{a-f}{1+b}$ (b) $\frac{a+f}{2(b-1)}$

(c) $\frac{a+f}{2(1+b)}$ (d) $\frac{f-a}{2(1+b)}$

**Ans.** *(d)*

Velocity of each car is given by

$$V_P=\frac{dx_P(t)}{dt}=a+2bt$$

and $$V_Q=\frac{dx_Q(t)}{dt}=f-2t$$

It is given that $V_P=V_Q$

$$\Rightarrow \quad a+2bt=f-2t$$

$$\Rightarrow \quad t=\frac{f-a}{2(b+1)}$$

**05** A particle of unit mass undergoes one-dimensional motion such that its velocity varies according to $v(x)=\beta x^{-2n}$ where, $\beta$ and $n$ are constants and $x$ is the position of the particle. The acceleration of the particle as a function of $x$, is given by **[CBSE AIPMT 2015]**

(a) $-2n\beta^2 x^{-2n-1}$ (b) $-2n\beta^2 x^{-4n-1}$
(c) $-2\beta^2 x^{-2n+1}$ (d) $-2n\beta^2 e^{-4n+1}$

**Ans.** *(b)*

Given, $v = \beta x^{-2n}$

$$a = \frac{dv}{dt} = \frac{dx}{dt} \cdot \frac{dv}{dx}$$

$$\Rightarrow \quad a = v\frac{dv}{dx} = (\beta x^{-2n})(-2n\beta x^{-2n-1})$$

$$\Rightarrow \quad a = -2n\beta^2 x^{-4n-1}$$

**06** The motion of a particle along a straight line is described by equation

$$x = 8 + 12t - t^3$$

where, $x$ is in metre and $t$ in sec. The retardation of the particle when its velocity becomes zero, is **[CBSE AIPMT 2012]**

(a) 24 $ms^{-2}$ (b) zero
(c) 6 $ms^{-2}$ (d) 12 $ms^{-2}$

**Ans.** *(d)*

***Concept*** Double differentiation of displacement equation gives acceleration and single differentiation gives velocity of the body.

Given, $x = 8 + 12t - t^3$

We know $v = \frac{dx}{dt}$

and acceleration $a = \frac{dv}{dt}$

So, $v = 12 - 3t^2$ and $a = -6t$

At $t = 2$ s

$v = 0$ and $a = -6 \times 2$

$a = -12 \text{ m/s}^2$

So, retardation of the particle $= 12 \text{ m/s}^2$.

**07** A body is moving with velocity 30 m/s towards East. After 10s, its velocity becomes 40 m/s towards North. The average acceleration of the body is **[CBSE AIPMT 2011]**

(a) $7 \text{ m/s}^2$ (b) $\sqrt{7} \text{ m/s}^2$
(c) $5 \text{ m/s}^2$ (d) $1 \text{ m/s}^2$

**Ans.** *(c)*

Average acceleration

$$a = \frac{\text{Change in velocity}}{\text{Total time}}$$

$$a = \frac{|\mathbf{v}_f - \mathbf{v}_i|}{\Delta t} = \frac{\sqrt{30^2 + 40^2}}{10}$$

$$= \frac{\sqrt{900 + 1600}}{10} = 5 \text{ ms}^{-2}$$

**08** A particle moves a distance $x$ in time $t$ according to the equation $x = (t + 5)^{-1}$. The acceleration of particle is proportional to **[CBSE AIPMT 2010]**

(a) $(\text{velocity})^{3/2}$ (b) $(\text{distance})^2$
(c) $(\text{distance})^{-2}$ (d) $(\text{velocity})^{2/3}$

**Ans.** *(a)*

Given, distance $x = (t + 5)^{-1}$ ...(i)

Differentiating Eq. (i) w.r.t. $t$, we get

$$\frac{dx}{dt} = (v) = \frac{-1}{(t+5)^2} \quad ...(ii)$$

Again, differentiating Eq. (ii) w.r.t. $t$, we get

$$\frac{d^2x}{dt^2} = (a) = \frac{2}{(t+5)^3} \quad ...(iii)$$

Comparing Eqs. (ii) and (iii), we get

$(a) \propto (v)^{3/2}$

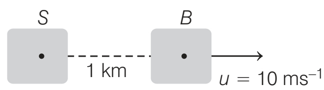
**09** A bus is moving with a speed of 10 $ms^{-1}$ on a straight road. A scooterist wishes to overtake the bus in 100 s. If the bus is at a distance of 1 km from the scooterist, with what speed should the scooterist chase the bus? **[CBSE AIPMT 2009]**

(a) 20 $ms^{-1}$ (b) 40 $ms^{-1}$
(c) 25 $ms^{-1}$ (d) 10 $ms^{-1}$

**Ans.** *(a)*

Let $v$ be the relative velocity of scooter ($s$) w.r.t. bus ($B$), then

$$v = v_S - v_B$$




$$\therefore \quad v_S = v + v_B \quad ...(i)$$

Relative velocity = Displacement / Time

$$= \frac{1000}{100} = 10 \text{ ms}^{-1}$$

Now, substituting the value of $v$ in Eq. (i), we get

$$v_S = 10 + 10 = 20 \text{ ms}^{-1}$$

**10** A particle moving along $x$-axis has acceleration $f$, at time $t$, given by $f = f_0\left(1 - \frac{t}{T}\right)$, where $f_0$ and $T$ are constants. The particle at $t = 0$ has zero velocity. In the time interval between $t = 0$ and the instant when $f = 0$, the particle's velocity ($v_x$) is **[CBSE AIPMT 2007]**

(a) $f_0 T$ (b) $\frac{1}{2} f_0 T^2$ (c) $f_0 T^2$ (d) $\frac{1}{2} f_0 T$

**Ans.** *(d)*

Acceleration

$$f = f_0\left(1 - \frac{t}{T}\right)$$

or $\quad f = \frac{dv}{dt} = f_0\left(1 - \frac{t}{T}\right) \qquad \left[\because f = \frac{dv}{dt}\right]$

or $\quad dv = f_0\left(1 - \frac{t}{T}\right)dt$ ...(i)

Integrating Eq. (i) on both sides,

$$\int dv = \int f_0\left(1 - \frac{t}{T}\right)dt$$

$$\therefore \quad v = f_0 t - \frac{f_0}{T} \cdot \frac{t^2}{2} + c \quad ...(ii)$$

where, $c$ is constant of integration.

Now, when $t = 0$, $v = 0$.

So, from Eq. (ii), we get $c = 0$

$$\therefore \quad v = f_0 t - \frac{f_0}{T} \cdot \frac{t^2}{2} \quad ...(iii)$$

As, $\quad f = f_0\left(1 - \frac{t}{T}\right)$

When, $f = 0$,

$$0 = f_0\left(1 - \frac{t}{T}\right)$$

As, $f_0 \neq 0$, so, $1 - \frac{t}{T} = 0$

$\therefore \quad t = T$

Substituting, $t = T$ in Eq. (iii), we get

$$v_x = f_0 T - \frac{f_0}{T} \cdot \frac{T^2}{2} = f_0 T - \frac{f_0 T}{2} = \frac{1}{2} f_0 T$$

**11** A car moves from $X$ to $Y$ with a uniform speed $v_u$ and returns to $X$ with a uniform speed $v_d$. The average speed for this round trip is **[CBSE AIPMT 2007]**

(a) $\frac{2v_d v_u}{v_d + v_u}$ (b) $\sqrt{v_u v_d}$
(c) $\frac{v_d v_u}{v_d + v_u}$ (d) $\frac{v_u + v_d}{2}$

**Ans.** *(a)*

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

Let $t_1$ and $t_2$ be times taken by the car to go from $X$ to $Y$ and then from $Y$ to $X$ respectively.

Then, $\quad t_1 + t_2 = \frac{XY}{v_u} + \frac{XY}{v_d}$

$$= XY\left(\frac{v_u + v_d}{v_u v_d}\right)$$

Total distance travelled $= XY + XY = 2XY$
Therefore, average speed of the car for this round trip is

$$v_{av} = \frac{2XY}{XY\left(\frac{v_u + v_d}{v_u v_d}\right)} \quad \text{or} \quad v_{av} = \frac{2v_u v_d}{v_u + v_d}$$

**12** The position $x$ of a particle w.r.t. time $t$ along $x$-axis is given by $x = 9t^2 - t^3$, where $x$ is in metre and $t$ in sec. What will be the position of this particle when it achieves maximum speed along the $+x$ direction? **[CBSE AIPMT 2007]**

(a) 32 m (b) 54 m
(c) 81 m (d) 24 m

**Ans.** *(b)*

Given, the position $x$ of a particle w.r.t. time $t$ along $x$-axis

$$x = 9t^2 - t^3 \quad \text{...(i)}$$

Differentiating Eq. (i), w.r.t. time, we get speed, i.e.

$$v = \frac{dx}{dt} = \frac{d}{dt}(9t^2 - t^3)$$

or $$v = 18t - 3t^2 \quad \text{...(ii)}$$

Again differentiating Eq. (ii), with respect to time, we get acceleration, i.e.

$$a = \frac{dv}{dt} = \frac{d}{dt}(18t - 3t^2)$$

or $$a = 18 - 6t \quad \text{...(iii)}$$

Now, when speed of particle is maximum, its acceleration is zero, i.e.

$$a = 0$$

i.e. $18 - 6t = 0$ or $t = 3$ s

Putting in Eq. (i), we obtain position of particle at the time

$$x = 9(3)^2 - (3)^3 = 9(9) - 27$$
$$= 81 - 27 = 54 \text{ m}$$

**13** A particle moves along a straight line $OX$. At a time $t$ (in second), the distance $x$ (in metre) of the particle from $O$ is given by

$$x = 40 + 12t - t^3$$

How long would the particle travel before coming to rest? **[CBSE AIPMT 2006]**

(a) 24 m (b) 40 m (c) 56 m (d) 16 m

**Ans.** *(c)*

***Concept*** First $X$ by $X$ differentiating displacement equation we get velocity of the body, since body comes to rest so velocity becomes zero. Now by putting the value of time $t$ in displacement equation we get the distance travelled by the body when it comes to rest.

Distance travelled by the particle is

$$x = 40 + 12t - t^3$$

We know that, velocity is the rate of change of distance i.e. $v = \frac{dx}{dt}$.

$$\therefore \quad v = \frac{d}{dt}(40 + 12t - t^3)$$
$$= 0 + 12 - 3t^2$$

but final velocity $v = 0$

$$\therefore \quad 12 - 3t^2 = 0$$

or $$t^2 = \frac{12}{3} = 4$$

or $$t = 2 \text{ s}$$

Hence, distance travelled by the particle before coming to rest is given by

$$x = 40 + 12(2) - (2)^3$$
$$= 40 + 24 - 8$$
$$= 64 - 8 = 56 \text{ m}$$

**14.** The displacement $x$ of a particle varies with time $t$ as $x = ae^{-\alpha t} + be^{\beta t}$, where $a, b, \alpha$ and $\beta$ are positive constants. The velocity of the particle will **[CBSE AIPMT 2005]**

(a) decrease with time
(b) be independent of $\alpha$ and $\beta$
(c) drop to zero when $\alpha = \beta$
(d) increase with time

**Ans.** *(d)*

Given, $x = ae^{-\alpha t} + be^{\beta t}$

Velocity $v = \frac{dx}{dt} = -a\alpha e^{-\alpha t} + b\beta e^{\beta t}$

$$= A + B$$

where, $A = -a\alpha e^{-\alpha t}$

$B = b\beta e^{\beta t}$

The value of term $A = -a\alpha e^{-\alpha t}$ decreases and of term $B = b\beta e^{\beta t}$ increases with time. As a result, velocity goes on increasing with time.

**15.** A particle moves along a straight line such that its displacement at any time $t$ is given by $s = 3t^3 + 7t^2 + 14t + 5$. The acceleration of the particle at $t = 1$ s is **[CBSE AIPMT 2000]**

(a) 18 m/s$^2$
(b) 32 m/s$^2$
(c) 29 m/s$^2$
(d) 24 m/s$^2$

**Ans.** *(b)*

***Concept*** On double differentiation of displacement equation gives acceleration of body

i.e. $$a = \frac{d^2x}{dt^2}$$

The displacement of a particle along a straight line is

$$s = 3t^3 + 7t^2 + 14t + 5 \quad \text{...(i)}$$

Differentiating Eq. (i) w.r.t. time, which gives the velocity

$$v = \frac{ds}{dt} = \frac{d}{dt}(3t^3 + 7t^2 + 14t + 5)$$
$$= \frac{d}{dt}(3t^3) + \frac{d}{dt}(7t^2) + \frac{d}{dt}(14t) + \frac{d}{dt}(5)$$
$$v = 3\frac{d}{dt}(t^3) + 7\frac{d}{dt}(t^2) + 14\frac{d}{dt}(t) + 0 \quad \text{...(ii)}$$

(as differentiation of a constant is zero)

Now use $\frac{d}{dt}(x^n) = nx^{n-1}$

So, $$v = 3(3)t^{3-1} + 7(2)(t^{2-1}) + 14(t^{1-1})$$

$$\Rightarrow \quad v = 9t^2 + 14t + 14 \quad \text{....(iii)}$$
$$(\because t^0 = 1)$$

Again differentiating Eq. (iii) w.r.t. time, which gives the acceleration

$$a = \frac{dv}{dt} = \frac{d}{dt}(9t^2 + 14t + 14)$$
$$= 18t + 14 + 0 = 18t + 14$$

At $t = 1$ s,

$$a = 18(1) + 14 = 18 + 14 = 32 \text{ m/s}^2$$

**16.** The position $x$ of a particle varies with time $t$, as $x = at^2 - bt^3$. The acceleration of the particle will be zero at time $t$ equals to **[CBSE AIPMT 1997]**

(a) zero (b) $\frac{a}{3b}$
(c) $\frac{2a}{3b}$ (d) $\frac{a}{b}$

**Ans.** *(b)*

Acceleration, $a = \frac{dv}{dt} = \frac{d^2x}{dt^2}$,

Velocity $v = \frac{dx}{dt}$.

The given equation is

$$x = at^2 - bt^3$$

Velocity, $v = \frac{dx}{dt} = 2at - 3bt^2$

Acceleration $a = \frac{dv}{dt} = 2a - 6bt$

but $a = 0$ (given)

$$\therefore 2a - 6bt = 0 \text{ or } 6bt = 2a \text{ or } t = \frac{2a}{6b} = \frac{a}{3b}$$

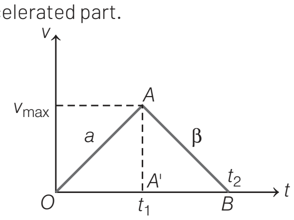
**17.** A car accelerates from rest at a constant rate $\alpha$ for some time, after which it decelerates at a constant rate $\beta$ and comes to rest. If the total time elapsed is $t$, then the maximum velocity acquired by the car is **[CBSE AIPMT 1994]**

(a) $\left(\frac{\alpha^2+\beta^2}{\alpha\beta}\right)t$ (b) $\left(\frac{\alpha^2-\beta^2}{\alpha\beta}\right)t$

(c) $\frac{(\alpha+\beta)\,t}{\alpha\beta}$ (d) $\left(\frac{\alpha\beta\,t}{\alpha+\beta}\right)$

**Ans.** *(d)*

This situation is plotted on $(v\text{-}t)$ graph. In $(v\text{-}t)$ graph, $OA$ represents the accelerated part and $AB$ represents the decelerated part.




Let $t_1$ and $t_2$ be the times for part $OA$ and $AB$ respectively.

At point $A$ velocity is maximum and let it be $v_{\max}$.

$\therefore \quad v_{\max} = \alpha t_1 = \beta t_2$

But $\quad t = t_1 + t_2 = \frac{v_{\max}}{\alpha} + \frac{v_{\max}}{\beta}$

$$= v_{\max}\left(\frac{1}{\alpha}+\frac{1}{\beta}\right) = v_{\max}\left(\frac{\alpha+\beta}{\alpha\beta}\right)$$

or $\quad v_{\max} = t\left(\frac{\alpha\beta}{\alpha+\beta}\right)$

**Alternative**

This problem can also be solved by checking the dimensions on both sides. On checking the dimensions we note that the dimensions of option (d) match with that of velocity.

**18.** A particle moves along a straight line such that its displacement at any time $t$ is given by $s = (t^3 - 6t^2 + 3t + 4)$ m

The velocity when the acceleration is zero, is **[CBSE AIPMT 1994]**

(a) $3\,\text{ms}^{-1}$ (b) $-12\,\text{ms}^{-1}$

(c) $42\,\text{ms}^{-1}$ (d) $-9\,\text{ms}^{-1}$

**Ans.** *(d)*

Given, $s = t^3 - 6t^2 + 3t + 4$

$\therefore$ Velocity $v = \frac{ds}{dt} = 3t^2 - 12t + 3 \quad$ ...(i)

Acceleration $a$ is given by

$$a = \frac{dv}{dt}$$

$\therefore \quad a = 6t - 12 \quad$ ...(ii)

For $a = 0$, we have $0 = 6t - 12$

or $\quad t = 2$ s

Hence, at $t = 2$ s the velocity will be

$$v = 3\times 2^2 - 12\times 2 + 3 = -9\,\text{ms}^{-1}$$

**19.** A train of 150 m length is going towards North direction at a speed of 10 m/s. A parrot flies at the speed of 5 m/s towards South direction parallel to the railways track. The time taken by the parrot to cross the train is **[CBSE AIPMT 1992]**

(a) 12 s (b) 8 s (c) 15 s (d) 10 s

**Ans.** *(d)*

*Concept* Velocity of A w.r.t. B is given by $v_{AB} = v_A - v_B$.

Relative velocity of the parrot w.r.t. the train

$$= [10 - (-5)]\,\text{ms}^{-1} = 15\,\text{ms}^{-1}.$$

Time taken by the parrot to cross the train

$$= \frac{150}{15} = 10 \text{ s}$$

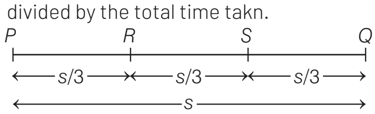
**20.** A bus travelling the first one-third distance at a speed of 10 km/h, the next one-third at 20 km/h and the last one-third at 60 km/h. The average speed of the bus is **[CBSE AIPMT 1991]**

(a) 9 km/h (b) 16 km/h

(c) 18 km/h (d) 48 km/h

**Ans.** *(c)*

*Concept* Average speed can be calculated as the total distance travelled divided by the total time takn.




Let $t_1, t_2, t_3$ be times taken in covering distances $PR$, $RS$ and $SQ$ respectively.

$\therefore \quad t_1 = \frac{(s/3)}{10}, \quad t_2 = \frac{(s/3)}{20}$

and $\quad t_3 = \frac{(s/3)}{60}$

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

$$= \frac{s}{t_1 + t_2 + t_3}$$

$$= \frac{s}{\frac{(s/3)}{10} + \frac{(s/3)}{20} + \frac{(s/3)}{60}}$$

$$= \frac{s}{(s/18)} = 18 \text{ km/h}$$

**21.** A car moves a distance of 200 m. It covers the first-half of the distance at speed 40 km/h and the second-half of distance at speed $v$ km/h. The average speed is 48 km/h. Find the value of $v$. **[CBSE AIPMT 1991]**

(a) 56 km/h (b) 60 km/h

(c) 50 km/h (d) 48 km/h

**Ans.** *(b)*

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

Let $t_1, t_2$ be time taken during first-half and second-half respectively.

So, $\quad t_1 = \frac{100}{40}$ s

and $\quad t_2 = \frac{100}{v}$ s

So, according to average speed formula

$$48 = \frac{200}{\left(\frac{100}{40}\right) + \left(\frac{100}{v}\right)}$$

or $\quad \frac{1}{40} + \frac{1}{v} = \frac{2}{48} = \frac{1}{24}$

or $\quad \frac{1}{v} = \frac{2}{120} = \frac{1}{60}$

$\Rightarrow \quad v = 60$ km/h

**22.** A car covers the first-half of the distance between two places at 40 km/h and other half at 60 km/h. The average speed of the car is **[CBSE AIPMT 1990]**

(a) 40 km/h (b) 48 km/h

(c) 50 km/h (d) 60 km/h

**Ans.** *(b)*

Let the distance between two places be $d$ and $t_1$ is time taken by car to travel first-half length, $t_2$ is time taken by car to travel second-half length. Time taken by car to travel first-half length,

$$t_1 = \frac{\left(\frac{d}{2}\right)}{40} = \frac{d}{80}$$

Time taken by car to travel second-half length,

$$t_2 = \frac{\left(\frac{d}{2}\right)}{60} = \frac{d}{120}$$

$\therefore$ Total time $= t_1 + t_2$

$$= \frac{d}{80} + \frac{d}{120}$$

$$= d\left(\frac{1}{80} + \frac{1}{120}\right) = \frac{d}{48}$$

$\therefore$ Average speed

$$= \frac{d}{t_1 + t_2} = \frac{d}{\left(\frac{d}{48}\right)} = 48 \text{ km/h}$$

**Alternative**

$$v_{av} = \frac{2v_1v_2}{v_1 + v_2} = \frac{2 \times 40 \times 60}{40 + 60} = 48 \text{ km/h}$$

# TOPIC 2

## Kinematics Equations of Uniformly Accelerated Motion

**23.** A car starts from rest and accelerates at $5 \text{ m/s}^2$. At $t = 4$s, a ball is dropped out of a window by a person sitting in the car. What is the velocity and acceleration of the ball at $t = 6$ s? (Take, $g = 10 \text{ m/s}^2$) **[NEET 2021]**

(a) 20 m/s, 5 m/s$^2$
(b) 20 m/s, 0
(c) $20\sqrt{2}$ m/s, 0
(d) $20\sqrt{2}$ m/s, 10 m/s$^2$

**Ans.** *(d)*

Given, the initial velocity of a car, $u = 0$

The acceleration of a car, $a = 5 \text{ m/s}^2$

At $t = 4$ s, $v = u + at$

$\Rightarrow v = 0 + (5)4 \Rightarrow v = 20$ m/s

Thus, the final velocity of car at $t = 4$ s is 20 m/s.

At $t = 4$ s, the ball is dropped out of a window by a person sitting in the car.

The velocity of the ball in the $x$-direction,

$v_x = 20$ m/s (due to the car)

Therefore, in the $y$-direction, the acceleration is equal to the acceleration due to gravity,

$$a_y = g = 10 \text{ m/s}^2$$

The velocity of the ball in the $y$-direction,

$$v_y = u + a_y t \Rightarrow v_y = 0 + 10 \times 2$$

$$\Rightarrow v_y = 20 \text{ m/s}$$

Thus, the velocity of the ball in $y$-direction is 20 m/s.

The net velocity at $t = 6$s,

$$v = \sqrt{v_x^2 + v_y^2} \Rightarrow v = \sqrt{(20)^2 + (20)^2}$$

$$\Rightarrow v = 20\sqrt{2} \text{ m/s}$$

Thus, the velocity of the ball at $t = 6$ s is $20\sqrt{2}$ m/s.

and there is no acceleration in the $x$-direction, $a_x = 0 \text{ ms}^{-2}$

In $y$-direction, $a_y = 10 \text{ ms}^{-2}$

Now, we shall determine the net acceleration

at $t = 6$ s, $a = \sqrt{a_x^2 + a_y^2}$

$$\Rightarrow a = \sqrt{(0) + (10)^2} \Rightarrow a = 10 \text{ ms}^{-2}$$

**24.** A small block slides down on a smooth inclined plane, starting from rest at time $t = 0$. Let $s_n$ be the distance travelled by the block in the interval $t = n - 1$ to $t = n$. Then, the ratio $\frac{s_n}{s_{n+1}}$ is **[NEET 2021]**

(a) $\frac{2n-1}{2n}$ (b) $\frac{2n-1}{2n+1}$ (c) $\frac{2n+1}{2n-1}$ (d) $\frac{2n}{2n-1}$

**Ans.** *(b)*

Distance covered $n$th seconds is $s_n$.

Distance covers in $(n+1)$ th seconds is $s_{n+1}$.

Initial velocity of small block, $u = 0$

Distance cover in $n$th seconds,

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

$$\Rightarrow s_n = 0 + \frac{a}{2}(2n - 1)$$

$$\Rightarrow s_n = \frac{a}{2}(2n - 1) \quad \text{...(i)}$$

Distance cover in $(n+1)$th seconds,

$$s_{n+1} = u + \frac{a}{2}[2(n+1) - 1]$$

$$\Rightarrow s_{n+1} = 0 + \frac{a}{2}(2n + 2 - 1)$$

$$\Rightarrow s_{n+1} = \frac{a}{2}(2n + 1) \quad \text{...(ii)}$$

On dividing Eq. (i) by Eq. (ii), we get

$$\frac{s_n}{s_{n+1}} = \frac{\frac{a}{2}(2n-1)}{\frac{a}{2}(2n+1)}$$

$$\Rightarrow \frac{s_n}{s_{n+1}} = \frac{(2n-1)}{(2n+1)}$$

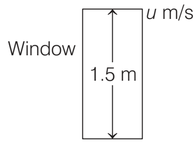
**25.** A person sitting in the ground floor of a building notices through the window of height 1.5 m, a ball dropped from the roof of the building crosses the window in 0.1 s. What is the velocity of the ball when it is at the topmost point of the window? ($g = 10 \text{ m/s}^2$) **[NEET (Oct.) 2020]**

(a) 15.5 m/s (b) 14.5 m/s
(c) 4.5 m/s (d) 20 m/s

**Ans.** *(b)*

According to question, time taken by the ball to cross the window,

$$t = 0.1 \text{ s}$$
$$h = 1.5 \text{ m}$$




If $u$ be the velocity at the top most point of the window, then from equation of motion,

$$h = ut + \frac{1}{2}gt^2$$

$$\Rightarrow 1.5 = u \times 0.1 + \frac{1}{2} \times 10 \times (0.1)^2$$

$$\Rightarrow 1.5 = 0.1u + 0.05$$

$$\Rightarrow u = \frac{1.5 - 0.05}{0.1} = \frac{1.45}{0.1} = 14.5 \text{ m/s}$$

**26.** A ball is thrown vertically downward with a velocity of 20 m/s from the top of a tower. It hits the ground after some time with a velocity of 80 m/s. The height of the tower is ($g = 10 \text{ m/s}^2$) **[NEET (Sep.) 2020]**

(a) 340 m
(b) 320 m
(c) 300 m
(d) 360 m

**Ans.** *(c)*

Given, $u = 20$ m/s, $v = 80$ m/s and $h = ?$

From kinematic equation of motion,

$$v^2 = u^2 + 2gh$$

$$\Rightarrow h = \frac{v^2 - u^2}{2g}$$

$$= \frac{(80)^2 - (20)^2}{2 \times 10} \quad (\because \text{given, } g = 10 \text{ m/s}^2)$$

$$= 300 \text{ m}$$

Hence, correct option is (c).

**27.** A person standing on the floor of an elevator drops a coin. The coin reaches the floor in time $t_1$ if the elevator is at rest and in time $t_2$ if the elevator is moving uniformly. The which of the following option is correct? **[NEET (Odisha) 2019]**

(a) $t_1 < t_2$ or $t_1 > t_2$ depending upon whether the lift is going up or down
(b) $t_1 < t_2$
(c) $t_1 > t_2$
(d) $t_1 = t_2$

**Ans.** *(d)*

Let $h$ be the height through which the coin is dropped. Then, according to the equation of motion, it is given as

$$h = ut + \frac{1}{2}gt^2 \Rightarrow t = \sqrt{\frac{2h}{g}} \quad [\because u = 0]$$

$$\Rightarrow t \propto \frac{1}{\sqrt{g}}$$

As the elevator is moving uniformly i.e. its velocity is constant, so the acceleration is zero.

$\therefore$ Relative acceleration of the lift when it is either moving upward or downward is given as, $g' = g \pm a = g \pm 0 = g$

Hence, the time for the coin to reach the floor will remains same i.e. $t_1 = t_2$.

**28.** A toy car with charge $q$ moves on a frictionless horizontal plane surface under the influence of a uniform electric field $\mathbf{E}$. Due to the force $q\mathbf{E}$, its velocity increases from 0 to 6 m/s in one second duration. At that instant, the direction of the field is reversed. The car continues to move for two more seconds under the influence of this field. The average velocity and the average speed of the toy car between 0 to 3 seconds are respectively **[NEET 2018]**

(a) 1 m/s, 3.5 m/s
(b) 1 m/s, 3 m/s
(c) 2 m/s, 4 m/s
(d) 1.5 m/s, 3 m/s

**Ans.** *(b)*

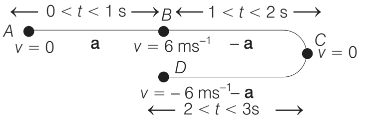
According to the question,

For the time duration $0 < t < 1$ s,

the velocity increase from 0 to 6 $ms^{-1}$

As the direction of field has been reversed for, $1 < t < 2$ s: the velocity firstly decreases from 6 $ms^{-1}$ to 0.

Then, for $2 < t < 3$ s; as the field strength is same; the magnitude of acceleration would be same, but velocity increases from 0 to $-6ms^{-1}$.




Acceleration of the car

$$|a| = \left|\frac{v-u}{t}\right| = \frac{6-0}{1} = 6ms^{-2}$$

The displacement of the particle is given as

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

For $t = 0$ to $t = 1$ s,

$u = 0, a = +6 m/s^2$

$$\Rightarrow s_1 = 0 + \frac{1}{2} \times 6 \times (1)^2 = 3 \text{ m}$$

For $t = 1$ s to $t = 2$ s,

$u = 6\,ms^{-1}, a = -6\,ms^{-2}$

$$\Rightarrow s_2 = 6 \times 1 - \frac{1}{2} \times 6 \times (1)^2 = 6 - 3 = 3\text{m}$$

For $t = 2$ s to $t = 3$ s,

$u = 0, a = -6ms^{-1}$

$$\Rightarrow s_3 = 0 - \frac{1}{2} \times 6 \times (1)^2 = -3\text{m}$$

$\therefore$ Net displacement, $s = s_1 + s_2 + s_3$
$= 3\text{m} + 3\text{m} - 3\text{m} = 3\text{m}$

Hence, average velocity

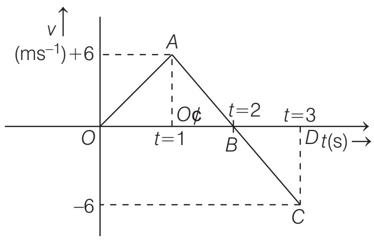
$$= \frac{\text{Net displacement}}{\text{Total time}} = \frac{3}{3} = 1\text{m s}^{-1}$$

Total distance travelled, $d = 9$m

$$\text{Hence, average speed} = \frac{\text{Total distance}}{\text{Total time}} = \frac{9}{3} = 3 \text{ m s}^{-1}$$

**Alternative Method**

Given condition can be represented through graph also as shown below.




$\therefore$ Displacement in three seconds

= Area under the graph

= Area of $\Delta OAO'$ + Area of $\Delta AO'B$ – Area of $\Delta BCD$

$$= \frac{1}{2} \times 1 \times 6 + \frac{1}{2} \times 1 \times 6 - \frac{1}{2} \times 6 \times 1 = 3\text{m}$$

$$\therefore \text{Average velocity} = \frac{3}{3} = 1\text{ms}^{-1}.$$

Total distance travelled, $d = 9$m

$$\therefore \text{Average speed} = \frac{9}{3} = 3\text{ms}^{-1}$$

**29.** A stone falls freely under gravity. It covers distances $h_1, h_2$ and $h_3$ in the first 5s, the next 5s and the next 5s respectively. The relation between $h_1, h_2$ and $h_3$ is **[NEET 2013]**

(a) $h_1 = 2h_2 = 3h_3$
(b) $h_1 = \frac{h_2}{3} = \frac{h_3}{5}$
(c) $h_2 = 3h_1$ and $h_3 = 3h_2$
(d) $h_1 = h_2 = h_3$

**Ans.** *(b)*

For free fall from a height, $u = 0$

$\therefore$ Distance covered by stone in first 5 s,

$$h_1 = 0 + \frac{1}{2}g(5)^2 = \frac{25}{2}g \quad \text{...(i)}$$

$\therefore$ Distance covered in first 10 s,

$$s_2 = 0 + \frac{1}{2}g(10)^2 = \frac{100}{2}g$$

$\therefore$ Distance covered in second 5 s

$$h_2 = s_2 - h_1 = \frac{100}{2}g - \frac{25}{2}g = \frac{72}{2}g \quad \text{...(ii)}$$

Distance covered in first 15 s,

$$s_3 = 0 + \frac{1}{2}g(15)^2 = \frac{225}{2}g$$

$\therefore$ Distance covered in last 5 s,

$$h_3 = s_3 - s_2 = \frac{225}{2}g - \frac{100}{2}g = \frac{125}{2}g \quad \text{...(iii)}$$

From Eqs. (i), (ii) and (iii), we get

$$h_1 : h_2 : h_3 = \frac{25}{2}g : \frac{75}{2}g : \frac{125}{2}g = 1:3:5$$

$$\Rightarrow \quad h_1 = \frac{h_2}{3} = \frac{h_3}{5}$$

**30.** A boy standing at the top of a tower of 20 m height drops a stone. Assuming, $g = 10\,\mathbf{ms}^{-2}$, the velocity with which it hits the ground is **[CBSE AIPMT 2011]**

(a) 20 m/s (b) 40 m/s
(c) 5 m/s (d) 10 m/s

**Ans.** *(a)*

Given, $g = 10 \text{ m/s}^2$ and $h = 20$ m

We have $v = \sqrt{2gh} = \sqrt{2 \times 10 \times 20}$

$= \sqrt{400} = 20 \text{ m/s}$

**31.** A ball is dropped from a high rise platform at $t = 0$ starting from rest. After 6 s, another ball is thrown downwards from the same platform with a speed $v$. The two balls meet at $t = 18$ s. What is the value of $v$?
(Take $g = 10 ms^{-2}$) **[CBSE AIPMT 2010]**

(a) 74 $ms^{-1}$
(b) 55 $ms^{-1}$
(c) 40 $ms^{-1}$
(d) 60 $ms^{-1}$

**Ans.** *(a)*

For first ball, $u = 0$

$\therefore \quad s_1 = \frac{1}{2} g t_1^2 = \frac{1}{2} \times g\,(18)^2$

For second ball, initial velocity $= v$

$\therefore \quad s_2 = v t_2 + \frac{1}{2} g t^2$

$t_2 = 18 - 6 = 12\,\text{s}$

$\Rightarrow \quad s_2 = v \times 12 + \frac{1}{2} g\,(12)^2$

Here, $s_1 = s_2$

$\frac{1}{2} g (18)^2 = 12 v + \frac{1}{2} g\,(12)^2$

$\Rightarrow \quad v = 74\ \text{ms}^{-1}$

**32.** A particle starts its motion from rest under the action of a constant force. If the distance covered in first 10 s is $s_1$ and that covered in the first 20 s is $s_2$, then **[CBSE AIPMT 2009]**

(a) $s_2 = 2\,s_1$ (b) $s_2 = 3\,s_1$
(c) $s_2 = 4\,s_1$ (d) $s_2 = s_1$

**Ans.** *(c)*

Since, the body starts from rest $u = 0$

$\therefore \quad s = \frac{1}{2} a t^2$

Now, $s_1 = \frac{1}{2} a\,(10)^2$ ...(i)

and $s_2 = \frac{1}{2} a\,(20)^2$ ...(ii)

Dividing Eq. (i) and Eq. (ii), we get

$$\frac{s_1}{s_2} = \frac{(10)^2}{(20)^2}$$

$\Rightarrow \quad s_2 = 4 s_1$

**33.** A particle moves in a straight line with a constant acceleration. It changes its velocity from $10\ \text{ms}^{-1}$ to $20\ \text{ms}^{-1}$ while passing through a distance 135 m in $t$ sec. The value of $t$ is **[CBSE AIPMT 2008]**

(a) 10 (b) 1.8
(c) 12 (d) 9

**Ans.** *(d)*

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

$(20)^2 - (10)^2 = 2 \times a \times 135$

$\Rightarrow \quad \frac{300}{270} = a = \frac{10}{9}$

Now, using $v - u = at$

$20 - 10 = \frac{10}{9} \times t$

$\Rightarrow \quad t = 9\,\text{s}$

**34.** The distance travelled by a particle starting from rest and moving with an acceleration $\frac{4}{3}\ \text{ms}^{-2}$, in the third-second is **[CBSE AIPMT 2008]**

(a) 6 m (b) 4 m
(c) $\frac{10}{3}$ m (d) $\frac{19}{3}$ m

**Ans.** *(c)*

Distance travelled in $n^{\text{th}}$ second is given by

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

Here, $u = 0,\ a = \frac{4}{3}$

$\therefore \quad s_3 = 0 + \frac{1}{2} \times \frac{4}{3} \times (6 - 1) = \frac{10}{3}\ \text{m}$

**35.** Two bodies $A$ (of mass 1 kg) and $B$ (of mass 3 kg) are dropped from heights of 16 m and 25 m, respectively. The ratio of the time taken by them to reach the ground is **[CBSE AIPMT 2006]**

(a) $-5/4$ (b) $12/5$
(c) $5/12$ (d) $4/5$

**Ans.** *(d)*

For free fall from a height, $u = 0$ (initial velocity).

From second equation of motion

$$h = ut + \frac{1}{2} g t^2$$

or $h = 0 + \frac{1}{2} g t^2$

$\therefore \quad \frac{h_1}{h_2} = \left(\frac{t_1}{t_2}\right)^2$

Given, $h_1 = 16\,\text{m}, h_2 = 25\,\text{m}$

$\therefore \quad \frac{t_1}{t_2} = \sqrt{\frac{h_1}{h_2}} = \sqrt{\frac{16}{25}} = \frac{4}{5}$

**36.** A man throws balls with the same speed vertically upwards one after the other at an interval of 2 s. What should be the speed of the throw so that more than two balls are in the sky at any time? (Take $g = 9.8\,\text{m/s}^2$) **[CBSE AIPMT 2003]**

(a) Any speed less than 19.6 m/s
(b) Only with speed 19.6 m/s
(c) More than 19.6 m/s
(d) At least 9.8 m/s

**Ans.** *(c)*

From equation of motion time taken by ball to reach maximum height $v = u - gt$

At maximum height, final speed is zero i.e. $v = 0$

So, $u = gt$ or $t = \frac{u}{g}$

In 2 s, $u = 2 \times 9.8 = 19.6\ \text{m/s}$

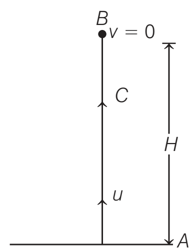
If man throws the ball with velocity of 19.6 m/s then after 2 s it will reach the maximum height. When he throws 2nd ball, 1st is at top. When he throws third ball, 1st will come to ground and 2nd will be at the top. Therefore, only 2 balls are in air. If he wants to keep more than 2 balls in air he should throw the ball with a speed greater than 19.6 m/s.

**37.** If a ball is thrown vertically upwards with speed $u$, the distance covered during the last $t$ sec of its ascent is **[CBSE AIPMT 2003]**

(a) $ut - \frac{1}{2} g t^2$ (b) $(u + gt)\,t$
(c) $ut$ (d) $\frac{1}{2} g t^2$

**Ans.** *(d)*

Let the ball takes $T$ second to reach maximum height $H$. $v = u - gT$




put $v = 0$
(at height $H$)

$\therefore \quad u = gT$

or $T = \frac{u}{g}$ ...(i)

Velocity attained by the ball in $(T - t)$ s is,

$$v' = u - g\,(T - t) = u - gT + gt$$
$$= u - g\frac{u}{g} + gt = u - u + gt$$

$v' = gt$ ...(ii)

Hence, distance travelled in last $t$ sec of its ascent

$$CB = v't - \frac{1}{2} g t^2 = (gt)\,t - \frac{1}{2} g t^2$$

$= g t^2 - \frac{1}{2} g t^2$ [From Eq. (ii)]

$= \frac{1}{2} g t^2$

**38.** A stone is thrown vertically upwards. When stone is at a height half of its maximum height, its speed is 10 m/s, then the maximum height attained by the stone is $(g = 10\,\mathbf{m/s^2})$ **[CBSE AIPMT 2001]**

(a) 8 m (b) 10 m
(c) 15 m (d) 20 m

**Ans.** *(b)*

Let $u$ be the initial velocity and $H$ be the maximum height attained.

At height $h = \frac{H}{2}$, we have $v = v_1 = 10$ m/s

From third equation of motion,

$$v_1^2 = u^2 - 2gh$$

$\left(\begin{array}{l}\text{Negative sign indicates that velocity and}\\ \text{acceleration are in opposite direction}\end{array}\right)$

or $\quad (10)^2 = u^2 - 2g\frac{H}{2}$ ...(i)

At height $H$, $\quad v_2 = 0$

$v_2^2 = u^2 - 2gH$ or $0 = u^2 - 2gH$ ...(ii)

Subtract Eq. (ii) from Eq. (i), we get

$$(10)^2 = 2g\frac{H}{2} \quad \text{or} \quad H = \frac{(10)^2}{g}$$

or $\quad H = \frac{(10)^2}{10} = 10$ m

**Alternative**

Maximum height attained by the stone

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

When, $\quad H = \frac{H}{2}, u = 10$ m / s

$$\frac{H}{2} = \frac{(10)^2}{2g} \quad \text{or}\ H = \frac{100}{10} = 10\ \text{m}$$

**39.** A car moving with a speed of 40 km/h can be stopped after 2 m by applying brakes. If the same car is moving with a speed of 80 km/h, what is the minimum stopping distance? **[CBSE AIPMT 1998]**

(a) 8 m (b) 2 m
(c) 4 m (d) 6 m

**Ans.** *(a)*

According to conservation of energy, the kinetic energy of car = work done in stopping the car

i.e. $\quad \frac{1}{2}mv^2 = Fs$

where, $F$ is the retarding force and $s$ is the stopping distance.

For same retarding force,

$$s \propto v^2$$

$$\therefore \quad \frac{s_2}{s_1} = \left(\frac{v_2}{v_1}\right)^2 = \left(\frac{80}{40}\right)^2 = 4$$

$$\therefore \quad s_2 = 4s_1 = 4 \times 2 = 8\ \text{m}$$

**Alternative**

Initial speed of car $u = 40$ km / h

$$= 40 \times \frac{5}{18}\ \text{m / s} = \frac{100}{9}\ \text{m / s}$$

From 3rd equation of motion,

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

$$\Rightarrow \quad 0 = \left(\frac{100}{9}\right)^2 - 2 \times a \times 2$$

$$4a = \frac{100 \times 100}{81}$$

$$\Rightarrow \quad a = \frac{2500}{81}\ \text{m / s}^2$$

Final speed of car = 80 km/h

$$= 80 \times \frac{5}{18} = \frac{200}{9}\ \text{m/s}$$

Suppose car stops for a distance $s'$. Then

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

$$0 = \left(\frac{200}{9}\right)^2 - 2 \times \frac{2500}{81}s'$$

$$\Rightarrow \quad s' = \frac{200 \times 200 \times 81}{9 \times 9 \times 2 \times 2500} = 8\ \text{m}$$

**40.** If a car at rest, accelerates uniformly to a speed of 144 **km/h** in 20s, it covers a distance of **[CBSE AIPMT 1997]**

(a) 2880 m (b) 1440 m
(c) 400 m (d) 20 m

**Ans.** *(c)*

**Concept** First of all find acceleration from the given values and then using equation of motion calculate distance travelled.

Given,

Initial velocity $u = 0$, time $t = 20$s

Final velocity $v = 144$ km/h $= 40$ m/s

From 1st equation of motion,

$$v = u + at$$

$$\Rightarrow \quad a = \frac{v - u}{t} = \frac{40 - 0}{20} = 2\ \text{m/s}^2$$

Now, from 2nd equation of motion,

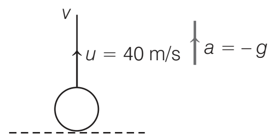
distance covered, $s = ut + \frac{1}{2}at^2$

$$= 0 + \frac{1}{2} \times 2 \times (20)^2 = 400\ \text{m}$$

**41.** If a ball is thrown vertically upwards with a velocity of 40 **m/s**, then velocity of the ball after 2s will be $(g = 10\ \text{m / s}^2)$ **[CBSE AIPMT 1996]**

(a) 15 m/s (b) 20 m/s
(c) 25 m/s (d) 28 m/s

**Ans.** *(b)*




Here, initial velocity of ball $u = 40$ m/s

Acceleration of ball $a = -g$ m/s$^2$

$= -10$ m/s$^2$

Time = 2 s

From first equation of motion,

$$v = u + at = 40 - 10 \times 2$$

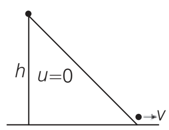
$$\Rightarrow \quad v = 20\ \text{m/s}$$

**42.** Three different objects of masses $m_1$, $m_2$ and $m_3$ are allowed to fall from rest and from the same point $O$ along three different frictionless paths. The speeds of the three objects on reaching the ground will be in the ratio of **[CBSE AIPMT 1995]**

(a) $m_1 : m_2 : m_3$
(b) $m_1 : 2m_2 : 3m_3$
(c) 1:1:1
(d) $\frac{1}{m_1} : \frac{1}{m_2} : \frac{1}{m_3}$

**Ans.** *(c)*

When an object falls freely under gravity, then its speed depends only on its height of fall and is independent of the mass of the object. As all objects are falling through the same height, therefore their speeds on reaching the ground will be in the ratio of 1 : 1 : 1.




**Alternative**

The vertical displacement for all the three is same and paths are frictionless. So, by conservation of mechanical energy,

$$\frac{1}{2}mv^2 = mgl$$

$$\Rightarrow \quad v = \sqrt{2gl}$$

So, $v_1 : v_2 : v_3 = 1 : 1 : 1$

**43.** The water drops fall at regular intervals from a tap 5 m above the ground. The third drop is leaving the tap at an instant when the first drop touches the ground. How far above the ground is the second drop at that instant ? (Take $g = 10 \text{m/s}^2$) **[CBSE AIPMT 1995]**

(a) 1.25 m
(b) 2.50 m
(c) 3.75 m
(d) 5.00 m

**Ans.** *(c)*

Let $t$ be the time interval of two drops. For third drop to fall

$$5 = \frac{1}{2} g (2t)^2 \qquad [\text{As } u = 0]$$

or $$\frac{1}{2} gt^2 = \frac{5}{4} \qquad \text{...(i)}$$

Let $x$ be the distance through which second drop falls for time $t$, then

$$x = \frac{1}{2} gt^2 = \frac{5}{4} \text{m} \qquad [\text{from Eq. (i)}]$$

Thus, height of second drop from ground

$$= 5 - \frac{5}{4} = \frac{15}{4} = 3.75 \text{m}$$

**44.** A body is thrown vertically upwards from the ground. It reaches a maximum height of 20 m in 5 s. After what time it will reach the ground from its maximum height position ? **[CBSE AIPMT 1995]**

(a) 2.5 s (b) 5 s
(c) 10 s (d) 25 s

**Ans.** *(b)*

Time taken by the body to reach the ground from some height is the same as taken to reach that height. Hence, time to reach the ground from its maximum height is 5 s.

**45.** A stone released with zero velocity from the top of a tower, reaches the ground in 4 s. The height of the tower is $(g = 10 \,\mathbf{m/s^2})$ **[CBSE AIPMT 1995]**

(a) 20 m (b) 40 m
(c) 80 m (d) 160 m

**Ans.** *(c)*

Initial velocity of stone $u = 0$
Time to reach at ground $t = 4$ s
Acceleration $a = + g = 10 \text{ m/s}^2$

$$\left(\begin{array}{l}\text{As motion of body is along}\\ \text{the acceleration due to gravity.}\end{array}\right)$$

$\therefore$ Height of tower

$$h = ut + \frac{1}{2} gt^2 = (0 \times 4) + \frac{1}{2} \times 10 \times 4^2$$
$$= 80 \text{ m}$$

**46.** A body starts from rest, what is the ratio of the distance travelled by the body during the 4th and 3rd s? **[CBSE AIPMT 1993]**

(a) $\frac{7}{5}$ (b) $\frac{5}{7}$ (c) $\frac{7}{3}$ (d) $\frac{3}{7}$

**Ans.** *(a)*

Distance travelled by the body in $n$th second is given by

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

Here, $u = 0$

$\therefore$ For $4^{\text{th}}$ s, $s_4 = \frac{a}{2}(2 \times 4 - 1)$

and For $3^{\text{th}}$ s, $s_3 = \frac{a}{2}(2 \times 3 - 1)$

Hence, $$\frac{s_4}{s_3} = \frac{(2 \times 4 - 1)}{(2 \times 3 - 1)} = \frac{7}{5}$$

**47.** A body dropped from top of a tower fall through 40 m during the last two seconds of its fall. The height of tower is $(g = 10 \,\mathbf{m/s^2})$ **[CBSE AIPMT 1991]**

(a) 60 m (b) 45 m
(c) 80 m (d) 50 m

**Ans.** *(b)*

Let the body falls through the height of tower in $t$ seconds.

From $s_n = u + \frac{a}{2}(2n - 1)$, we have

Total distance travelled in last 2 s of fall is

$$s = s_t + s_{(t-1)}$$
$$= \left[0 + \frac{g}{2}(2t - 1)\right] + \left[0 + \frac{g}{2}(2(t-1) - 1)\right]$$
$$= \frac{g}{2}(2t - 1) + \frac{g}{2}(2t - 3)$$
$$= \frac{g}{2}(4t - 4) = \frac{10}{2} \times 4(t - 1)$$

or $40 = 20(t - 1)$ or $t = 2 + 1 = 3$ s

Distance travelled in $t$ sec is

$$s = ut + \frac{1}{2} at^2$$
$$= 0 + \frac{1}{2} \times 10 \times 3^2 = 45 \text{ m}$$

**48.** What will be the ratio of the distance moved by a freely falling body from rest in 4th and 5th second of journey? **[CBSE AIPMT 1989]**

(a) 4 : 5 (b) 7 : 9
(c) 16 : 25 (d) 1 : 1

**Ans.** *(b)*

As distance travelled in $n^{\text{th}}$ sec is given by

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

Here, $u = 0$, acceleration due to gravity

$$a = 9.8 \text{ m/s}^2$$

$\therefore$ For $4^{\text{th}}$ s, $s_4 = \frac{1}{2} \times 9.8 (2 \times 4 - 1)$

and for $5^{\text{th}}$ s, $s_5 = \frac{1}{2} \times 9.8 (2 \times 5 - 1)$

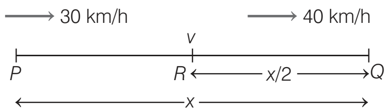
$$\therefore \qquad \frac{s_4}{s_5} = \frac{7}{9}$$

**49.** A car is moving along a straight road with a uniform acceleration. It passes through two points $P$ and $Q$ separated by a distance with velocity 30 km/h and 40 km/h respectively. The velocity of the car midway between $P$ and $Q$ is **[CBSE AIPMT 1988]**

(a) 33.3 km/h (b) $20\sqrt{2}$ km/h
(c) $25\sqrt{2}$ km/h (d) 0.35 km/h

**Ans.** *(c)*

Let $x$ be the total distance between points $P$ and $Q$ and $v$ be the velocity of car while passing a certain middle point of $PQ$. If $a$ is the acceleration of the car, then




For part $PQ$,

$$40^2 - 30^2 = 2ax$$

or $$a = \frac{350}{x} \qquad \text{...(i)}$$

For part $RQ$,

$$40^2 - v^2 = \frac{2ax}{2} \qquad \text{...(ii)}$$

Putting value of $a$ from Eq. (i) in Eq. (ii), we have

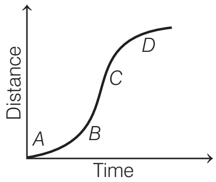
$$40^2 - v^2 = 2\left(\frac{350}{x}\right)\frac{x}{2}$$

or $$40^2 - v^2 = 350 \quad \text{or}$$
$$v^2 = 1250$$

$\Rightarrow$ $$v = 25\sqrt{2} \text{ km/h}$$

## TOPIC 3
### Graphs in Motion

**50.** A particle shows distance-time curve as given in this figure. The maximum instantaneous velocity of the particle is around the point **[CBSE AIPMT 2008]**



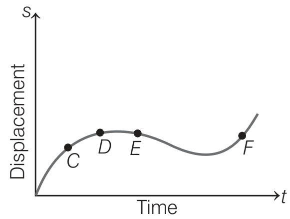

(a) $B$ (b) $C$
(c) $D$ (d) $A$

**Ans.** *(b)*

Maximum velocity point means, the point at which $\frac{dx}{dt}$ i.e. the slope of the graph is maximum.

At point $C$, slope is maximum.

**51.** The displacement-time graph of moving particle is shown below.



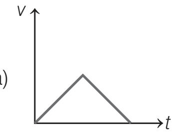

The instantaneous velocity of the particle is negative at the point **[CBSE AIPMT 1994]**

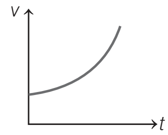
(a) $D$
(b) $F$
(c) $C$
(d) $E$

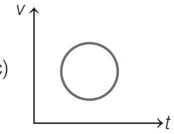
**Ans.** *(d)*

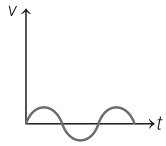
Instantaneous velocity is the slope of displacement-time graph. At point $E$, the slope is negative so instantaneous velocity of the particle is negative. At points $C$ and $F$, the slope is positive and at $D$, the slope is zero.

**52.** Which of the following curves does not represent motion in one dimension? **[CBSE AIPMT 1992]**

(a)



(b)



(c)



(d)



**Ans.** *(c)*

In option (c), particle have two velocities at a particular instant of time, which is impossible.

# 03

# Motion in a Plane

## TOPIC 1
### Vectors

**01** If the magnitude of sum of two vectors is equal to the magnitude of difference of the two vectors, the angle between these vectors is **[NEET 2016, CBSE AIPMT 1991]**

(a) $90^\circ$ (b) $45^\circ$
(c) $180^\circ$ (d) $0^\circ$

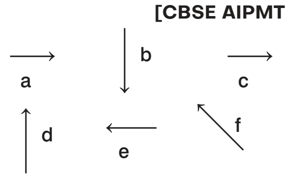
**Ans.** *(a)*
Suppose two vectors are $\mathbf{P}$ and $\mathbf{Q}$.
It is given that
$$|\mathbf{P}+\mathbf{Q}| = |\mathbf{P}-\mathbf{Q}|$$
Let angle between $\mathbf{P}$ and $\mathbf{Q}$ is $\phi$.
$\therefore$
$$P^2 + Q^2 + 2PQ\cos\phi = P^2 + Q^2 - 2PQ\cos\phi$$
$$\Rightarrow \quad 4PQ\cos\phi = 0$$
$$\Rightarrow \quad \cos\phi = 0 \quad [\because P, Q \neq 0]$$
$$\Rightarrow \quad \phi = \frac{\pi}{2} = 90^\circ$$

**02** If vectors $\mathbf{A} = \cos\omega t\,\hat{\mathbf{i}} + \sin\omega t\,\hat{\mathbf{j}}$ and $\mathbf{B} = \cos\frac{\omega t}{2}\,\hat{\mathbf{i}} + \sin\frac{\omega t}{2}\,\hat{\mathbf{j}}$ are functions of time, then the value of $t$ at which they are orthogonal to each other, is **[CBSE AIPMT 2015]**

(a) $t = \frac{\pi}{4\omega}$ (b) $t = \frac{\pi}{2\omega}$
(c) $t = \frac{\pi}{\omega}$ (d) $t = 0$

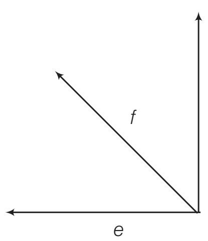
**Ans.** *(c)*
For perpendicular vector, we have
$$\mathbf{A}\cdot\mathbf{B} = 0$$
$$[\cos\omega t\,\hat{\mathbf{i}} + \sin\omega t\,\hat{\mathbf{j}}]\left[\cos\frac{\omega t}{2}\,\hat{\mathbf{i}} + \frac{\sin\omega t}{2}\,\hat{\mathbf{j}}\right] = 0$$
$$\Rightarrow \quad \cos\omega t\cos\frac{\omega t}{2} + \sin\omega t\sin\frac{\omega t}{2} = 0$$
$[\because \cos(A-B) = \cos A\cos B + \sin A\sin B]$
$$\Rightarrow \quad \cos\left(\omega t - \frac{\omega t}{2}\right) = 0 \Rightarrow \cos\frac{\omega t}{2} = 0$$
$$\Rightarrow \quad \frac{\omega}{2} = \frac{\pi}{2} \Rightarrow t = \frac{\pi}{\omega}$$
Thus, time taken by vectors which are orthogonal to each other is $\frac{\pi}{\omega}$.

**03** Six vectors **a** to **f** have the magnitudes and directions indicated in the figure. Which of the following statements is true? **[CBSE AIPMT 2010]**




(a) $\mathbf{b}+\mathbf{c}=\mathbf{f}$ (b) $\mathbf{d}+\mathbf{c}=\mathbf{f}$
(c) $\mathbf{d}+\mathbf{e}=\mathbf{f}$ (d) $\mathbf{b}+\mathbf{e}=\mathbf{f}$

**Ans.** *(c)*
If two non-zero vectors are represented by the two adjacent sides of a parallelogram, then the resultant is given by the diagonal of the parallelogram passing through the point of intersection of the two vectors
$$\therefore \quad \mathbf{d}+\mathbf{e}=\mathbf{f}$$




**04** $A$ and $B$ are two vectors and $\theta$ is the angle between them. If $|A\times B| = \sqrt{3}(A\cdot B)$, then the value of $\theta$ is **[CBSE AIPMT 2007]**

(a) $60^\circ$ (b) $45^\circ$ (c) $30^\circ$ (d) $90^\circ$

**Ans.** *(a)*
Given, $|\mathbf{A}\times\mathbf{B}| = \sqrt{3}(\mathbf{A}\cdot\mathbf{B})$
$$\Rightarrow \quad AB\sin\theta = \sqrt{3}\,AB\cos\theta$$
$$\Rightarrow \quad \tan\theta = \sqrt{3}$$
$$\therefore \quad \theta = 60^\circ$$

**05** If a vector $2\hat{\mathbf{i}} + 3\hat{\mathbf{j}} + 8\hat{\mathbf{k}}$ is perpendicular to the vector $4\hat{\mathbf{j}} - 4\hat{\mathbf{i}} + \alpha\hat{\mathbf{k}}$, then the value of $\alpha$ is **[CBSE AIPMT 2005]**

(a) $-1$ (b) $\frac{1}{2}$ (c) $-\frac{1}{2}$ (d) 1

**Ans.** *(c)*
Concept If two vectors are perpendicular to each other than their dot product is always equal to zero.
Let, $\mathbf{a} = 2\hat{\mathbf{i}} + 3\hat{\mathbf{j}} + 8\hat{\mathbf{k}}$
$\mathbf{b} = 4\hat{\mathbf{j}} - 4\hat{\mathbf{i}} + \alpha\hat{\mathbf{k}} = -4\hat{\mathbf{i}} + 4\hat{\mathbf{j}} + \alpha\hat{\mathbf{k}}$
According to the above hypothesis
$$\mathbf{a}\perp\mathbf{b}$$
$$\Rightarrow \quad \mathbf{a}\cdot\mathbf{b} = 0$$
$$\Rightarrow (2\hat{\mathbf{i}} + 3\hat{\mathbf{j}} + 8\hat{\mathbf{k}})\cdot(-4\hat{\mathbf{i}} + 4\hat{\mathbf{j}} + \alpha\hat{\mathbf{k}}) = 0$$
$$\Rightarrow \quad -8 + 12 + 8\alpha = 0$$
$$\Rightarrow \quad 8\alpha = -4$$
$$\therefore \quad \alpha = -\frac{4}{8} = -\frac{1}{2}$$

**06** If $|\mathbf{A}\times\mathbf{B}| = \sqrt{3}\,\mathbf{A}\cdot\mathbf{B}$, then the value of $|\mathbf{A}+\mathbf{B}|$ is **[CBSE AIPMT 2004]**

(a) $(A^2 + B^2 + AB)^{1/2}$
(b) $\left(A^2 + B^2 + \frac{AB}{\sqrt{3}}\right)^{1/2}$
(c) $A + B$
(d) $(A^2 + B^2 + \sqrt{3}\,AB)^{1/2}$

**Ans.** *(a)*
Given, $|\mathbf{A}\times\mathbf{B}| = \sqrt{3}\,\mathbf{A}\cdot\mathbf{B}$ ...(i)
but $|\mathbf{A}\times\mathbf{B}| = |\mathbf{A}||\mathbf{B}|\sin\theta = AB\sin\theta$

and $\mathbf{A}\cdot\mathbf{B} = |\mathbf{A}||\mathbf{B}|\cos\theta = AB\cos\theta$

Substituting these values in Eq. (i), we get

$$AB\sin\theta = \sqrt{3}\,AB\cos\theta$$

or $\tan\theta = \sqrt{3}$

$\therefore$ $\theta = 60°$

The addition of vectors **A** and **B** can be given by the law of parallelogram.

$$\therefore\quad |\mathbf{A}+\mathbf{B}| = \sqrt{A^2 + B^2 + 2AB\cos 60°}$$

$$= \sqrt{A^2 + B^2 + 2AB \times \frac{1}{2}}$$

$$= (A^2 + B^2 + AB)^{1/2}$$

**07** The vector sum of two forces is perpendicular to their vector differences. In that case, the forces **[CBSE AIPMT 2003]**

(a) are not equal to each other in magnitude
(b) cannot be predicted
(c) are equal to each other
(d) are equal to each other in magnitude

**Ans.** *(d)*

Let **A** and **B** be two forces. The sum of the two forces.

$$\mathbf{F}_1 = \mathbf{A}+\mathbf{B} \quad \text{...(i)}$$

The difference of the two forces,

$$\mathbf{F}_2 = \mathbf{A}-\mathbf{B} \quad \text{...(ii)}$$

Since, sum of the two forces is perpendicular to their differences as given, so

$$\mathbf{F}_1\cdot\mathbf{F}_2 = 0$$

or $(\mathbf{A}+\mathbf{B})\cdot(\mathbf{A}-\mathbf{B}) = 0$

or $A^2 - \mathbf{A}\cdot\mathbf{B} + \mathbf{B}\cdot\mathbf{A} - B^2 = 0$

or $A^2 = B^2$ or $|\mathbf{A}| = |\mathbf{B}|$

Thus, the forces are equal to each other in magnitude.

**08** If a unit vector is represented by $0.5\hat{\mathbf{i}} + 0.8\hat{\mathbf{j}} + c\hat{\mathbf{k}}$, then the value of $c$ is **[CBSE AIPMT 1999]**

(a) 1 (b) $\sqrt{0.11}$ (c) $\sqrt{0.01}$ (d) 0.39

**Ans.** *(b)*

*Concept* Unit vector can be found by dividing a vector with its magnitude i.e.

$$\mathbf{A} = \frac{\mathbf{A}}{|\mathbf{B}|}$$

Let we represent the unit vector by $\hat{n}$.

We also know that the modulus of unit vector is 1 i.e., $|\hat{n}| = 1$

$\therefore$ $|\hat{n}| = |0.5\hat{\mathbf{i}} + 0.8\hat{\mathbf{j}} + c\hat{\mathbf{k}}| = 1$

or $\sqrt{(0.5)^2 + (0.8)^2 + c^2} = 1$

or $0.25 + 0.64 + c^2 = 1$

or $0.89 + c^2 = 1$

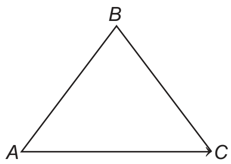
or $c^2 = 1 - 0.89 = 0.11 \Rightarrow c = \sqrt{0.11}$

**09** Which of the following is not a vector quantity? **[CBSE AIPMT 1995]**

(a) Speed (b) Velocity
(c) Torque (d) Displacement

**Ans.** *(a)*

Speed is a scalar quantity. It gives no idea about the direction of motion of the object. Velocity is a vector quantity, as it has both magnitude and direction. Displacement is a vector as it possesses both magnitude and direction. When an object goes on the path $ABC$(in figure), then the displacement of the object is **AC**. The arrow head at $C$ shows that the object is displaced from $A$ to $C$.




Torque is turning effect of force which is a vector quantity.

**10** The angle between the two vectors $\mathbf{A} = 3\hat{\mathbf{i}} + 4\hat{\mathbf{j}} + 5\hat{\mathbf{k}}$ and $\mathbf{B} = 3\hat{\mathbf{i}} + 4\hat{\mathbf{j}} - 5\hat{\mathbf{k}}$ will be **[CBSE AIPMT 1994]**

(a) 0° (b) 45° (c) 90° (d) 180°

**Ans.** *(c)*

Angle between two vectors is given as from dot product $\mathbf{A}\cdot\mathbf{B} = |\mathbf{A}||\mathbf{B}|\cos\theta$

$$\cos\theta = \frac{\mathbf{A}\cdot\mathbf{B}}{AB}$$

Here, $\mathbf{A} = 3\hat{i} + 4\hat{j} + 5\hat{k}$

$\mathbf{B} = 3\hat{i} + 4\hat{j} - 5\hat{k}$

$\therefore$ $A = \sqrt{(3)^2 + (4)^2 + (5)^2} = \sqrt{50}$

$B = \sqrt{(3)^2 + (4)^2 + (-5)^2} = \sqrt{50}$

and $\mathbf{A}\cdot\mathbf{B} = (3\hat{i} + 4\hat{j} + 5\hat{k})\cdot(3\hat{i} + 4\hat{j} - 5\hat{k})$

$= 9 + 16 - 25 = 0$

$$\therefore\quad \cos\theta = \frac{0}{\sqrt{50}\cdot\sqrt{50}} = 0$$

$\Rightarrow$ $\theta = 90°$

**11** The resultant of $\mathbf{A}\times 0$ will be equal to **[CBSE AIPMT 1992]**

(a) zero (b) $A$
(c) zero vector (d) unit vector

**Ans.** *(c)*

From the properties of vector product, the cross product of any vector with zero is a null vector or zero vector.

**12** The angle between **A** and **B** is $\theta$. The value of the triple product $\mathbf{A}\cdot(\mathbf{B}\times\mathbf{A})$ is **[CBSE AIPMT 1989]**

(a) $A^2B$ (b) zero
(c) $A^2B\sin\theta$ (d) $A^2B\cos\theta$

**Ans.** *(b)*

In scalar triple product of vectors, the positions of dot and cross can be interchanged, i.e.

$$\mathbf{A}\cdot(\mathbf{B}\times\mathbf{A}) = (\mathbf{A}\times\mathbf{B})\cdot\mathbf{A} = (\mathrm{A}\times\mathrm{A})\cdot\mathrm{B}$$

but $\mathbf{A}\times\mathbf{A} = 0$

$\therefore$ $\mathbf{A}\cdot(\mathbf{B}\times\mathbf{A}) = 0$

**Alternative**

$\mathbf{A}\cdot(\mathbf{B}\times\mathbf{A})$

Let $\mathbf{A}\times\mathbf{B} = \mathbf{C}$

The direction of **C** is $\perp$ to **A** and **B** from cross product formula

So, $\mathbf{A}\cdot\mathbf{C} = 0$

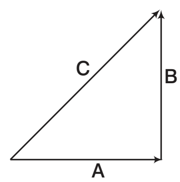
( since, **A** and **C** are $\perp$ to each other)

**13** The magnitudes of vectors **A**, **B** and **C** are 3, 4 and 5 units respectively. If $\mathbf{A}+\mathbf{B} = \mathbf{C}$, the angle between **A** and **B** is **[CBSE AIPMT 1988]**

(a) $\frac{\pi}{2}$ (b) $\cos^{-1}(0.6)$
(c) $\tan^{-1}\left(\frac{7}{5}\right)$ (d) $\frac{\pi}{4}$

**Ans.** *(a)*

In figure shown, $\mathbf{A}+\mathbf{B} = \mathbf{C}$




Also, $|\mathbf{A}| = 3$, $|\mathbf{B}| = 4$, $|\mathbf{C}| = 5$

As $\mathbf{A}+\mathbf{B} = \mathbf{C}$

So, $5^2 = 3^2 + 4^2 + 2\cdot 4\cdot 3\cos\theta$

$\cos\theta = 0 \Rightarrow \theta = \frac{\pi}{2}$

$\Rightarrow$ **A** is perpendicular to **B**.

# TOPIC 2

## Motion in a Plane and Projectile Motion

**14** Two bullets are fired horizontally and simultaneously towards each other from roof tops of two buildings 100 m apart and of same height of 200 m with the same velocity of 25 m/s. When and where will the two bullets collides. $(g = 10\text{ m/s}^2)$ **[NEET (Odisha) 2019]**

(a) After 2s at a height 180 m