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30 YEARS

2017-1988

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CHAPTERWISE SOLUTIONS

PHYSICS

STRUCTURED AS PER CLASS 11 & 12 NCERT BOOKS

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PHYSICS

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Contents

Syllabus*

UNIT 1: 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 2: 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 3: 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).

*For details, refer to latest prospectus

UNIT 4: 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 5: MOTION OF SYSTEM OF PARTICLES AND RIGID BODY

- Centre of mass of a two-particle system, momentum conservation and centre of mass motion. Centre of mass of a rigid body; centre of mass of uniform rod.
- Moment of a force, -torque, angular momentum, conservation of angular momentum with some examples.
- Equilibrium of rigid bodies, rigid body rotation and equation of rotational motion, comparison of linear and rotational motions; moment of inertia, radius of gyration. Values of M.I. for simple geometrical objects (no derivation). Statement of parallel and perpendicular axes theorems and their applications.

UNIT 6: 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 7: 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 8: THERMODYNAMICS

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- 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.

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- 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 12: 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.

UNIT 13: MAGNETIC EFFECTS OF CURRENT AND MAGNETISM

- Concept of magnetic field, Oersted's experiment. Biot-Savart law and its application to current carrying circular loop.
- Ampere's law and its applications to infinitely long straight wire, straight and toroidal solenoids. Force on a moving charge in uniform magnetic and electric fields. Cyclotron.
- Force on a current-carrying conductor in a uniform magnetic field. Force between two parallel current-carrying conductors-definition of ampere. Torque experienced by a current loop in a magnetic field; moving coil galvanometer-its current sensitivity and conversion to ammeter and voltmeter.

- Current loop as a magnetic dipole and its magnetic dipole moment. 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 14: 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 15: ELECTROMAGNETIC WAVES

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

UNIT 16: OPTICS

- Reflection of light, spherical mirrors, mirror formula. Refraction of light, total internal reflection and its applications, optical fibres, refraction at spherical surfaces, lenses, thin lens formula, lens-maker's formula. Magnification, power of a lens, combination of thin lenses in contact, combination of a lens and a mirror. Refraction and dispersion of light through a prism.
- Scattering of light- blue colour of the sky and reddish appearance of the sun at sunrise and sunset.
- 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. Polarization, plane polarized light; Brewster's law, uses of plane polarized light and Polaroids.

UNIT 17: 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 18: 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- alpha, beta and gamma 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 19: ELECTRONIC DEVICES

- Energy bands in solids (qualitative ideas only), conductors, insulators and semiconductors; semiconductor diode- *I-V* characteristics in forward and reverse bias, diode as a rectifier; *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.

Chapter 1 Units and Measurement

1. 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 the universal constant of gravitation and e is charge]
   (a) $c^2\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$ (b) $\frac{1}{c^2}\left[\frac{e^2}{G\,4\pi\varepsilon_0}\right]^{1/2}$
   (c) $\frac{1}{c}G\frac{e^2}{4\pi\varepsilon_0}$ (d) $\frac{1}{c^2}\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$
   (NEET 2017)

2. Planck's constant (h), speed of light in vacuum (c) and Newton's gravitational constant (G) are three fundamental constants. Which of the following combinations of these has the dimension of length ?
   (a) $\frac{\sqrt{hG}}{c^{3/2}}$ (b) $\frac{\sqrt{hG}}{c^{5/2}}$ (c) $\sqrt{\frac{hc}{G}}$ (d) $\sqrt{\frac{Gc}{h^{3/2}}}$
   (NEET-II 2016)

3. If dimensions of critical velocity v_c of a liquid flowing through a tube are expressed as $[\eta^x\rho^y r^z]$ where η, ρ 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
   (a) $-1, -1, -1$ (b) 1, 1, 1
   (c) $1, -1, -1$ (d) $-1, -1, 1$ *(2015)*

4. If energy (E), velocity (V) and time (T) are chosen as the fundamental quantities, the dimensional formula of surface tension will be
   (a) $[EV^{-2}T^{-2}]$ (b) $[E^{-2}V^{-1}T^{-3}]$
   (c) $[EV^{-2}T^{-1}]$ (d) $[EV^{-1}T^{-2}]$
   (2015 Cancelled)

5. If force (F), velocity (V) and time (T) are taken as fundamental units, then the dimensions of mass are
   (a) $[FVT^{-1}]$ (b) $[FVT^{-2}]$
   (c) $[FV^{-1}T^{-1}]$ (d) $[FV^{-1}T]$ *(2014)*

6. 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 as follows
   $$P = \frac{a^3b^2}{cd}$$
   % error in P is
   (a) 7% (b) 4% (c) 14% (d) 10%
   (NEET 2013)

7. The pair of quantities having same dimensions is
   (a) Impulse and Surface Tension
   (b) Angular momentum and Work
   (c) Work and Torque
   (d) Young's modulus and Energy
   (Karnataka NEET 2013)

8. The damping force on an oscillator is directly proportional to the velocity. The units of the constant of proportionality are
   (a) kg m s^{-1} (b) kg m s^{-2}
   (c) kg s^{-1} (d) kg s *(2012)*

9. The dimensions of $(\mu_0\varepsilon_0)^{-1/2}$ are
   (a) $[L^{1/2}T^{-1/2}]$ (b) $[L^{-1}T]$
   (c) $[LT^{-1}]$ (d) $[L^{1/2}T^{1/2}]$
   (Mains 2012, 2011)

10. The density of a material in CGS system of units is 4 g cm^{-3}. In a system of units in which unit of length is 10 cm and unit of mass is 100 g, the value of density of material will be
    (a) 0.04 (b) 0.4 (c) 40 (d) 400
    (Mains 2011)

11. The dimension of $\frac{1}{2}\varepsilon_0 E^2$, where ε_0 is permittivity of free space and E is electric field, is
    (a) ML^2T^{-2} (b) $ML^{-1}T^{-2}$
    (c) ML^2T^{-1} (d) MLT^{-1} *(2010)*

12. A student measures the distance traversed in free fall of a body, initially at rest, in a given time. He uses this data to estimate g, the acceleration due to gravity. If the maximum percentage errors in measurement of the distance and the time are e_1 and e_2 respectively, the percentage error in the estimation of g is
    (a) $e_2 - e_1$ (b) $e_1 + 2e_2$
    (c) $e_1 + e_2$ (d) $e_1 - 2e_2$
    (Mains 2010)

13. If the dimensions of a physical quantity are given by $M^aL^bT^c$, then the physical quantity will be
(a) velocity if $a = 1, b = 0, c = -1$
(b) acceleration if $a = 1, b = 1, c = -2$
(c) force if $a = 0, b = -1, c = -2$
(d) pressure if $a = 1, b = -1, c = -2$ *(2009)*

14. 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
(a) 8% (b) 2% (c) 4% (d) 6% *(2008)*

15. Which two of the following five physical parameters have the same dimensions ?
1. energy density 2. refractive index
3. dielectric constant 4. Young's modulus
5. magnetic field
(a) 1 and 4 (b) 1 and 5
(c) 2 and 4 (d) 3 and 5 *(2008)*

16. 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
(a) $[ML^2T^{-2}]$ (b) $[ML^2T^{-1}I^{-1}]$
(c) $[ML^2T^{-3}I^{-2}]$ (d) $[ML^2T^{-3}I^{-1}]$. *(2007)*

17. The velocity v of a particle at time t is given by $v = at + \frac{b}{t+c}$, where a, b and c are constants. The dimensions of a, b and c are
(a) $[L]$, $[LT]$ and $[LT^{-2}]$ (b) $[LT^{-2}]$, $[L]$ and $[T]$
(c) $[L^2]$, $[T]$ and $[LT^{-2}]$ (d) $[LT^{-2}]$, $[LT]$ and $[L]$. *(2006)*

18. The ratio of the dimensions of Planck's constant and that of moment of inertia is the dimensions of
(a) time (b) frequency
(c) angular momentum (d) velocity. *(2005)*

19. The dimensions of universal gravitational constant are
(a) $[M^{-1}L^3T^{-2}]$ (b) $[ML^2T^{-1}]$
(c) $[M^{-2}L^3T^{-2}]$ (d) $[M^{-2}L^2T^{-1}]$ *(2004, 1992)*

20. The unit of permittivity of free space, ε_0, is
(a) coulomb/newton-metre
(b) newton-metre^2/coulomb^2
(c) coulomb^2/newton-metre^2
(d) coulomb^2/(newton-metre)^2 *(2004)*

21. The dimensions of Planck's constant equals to that of
(a) energy (b) momentum
(c) angular momentum (d) power. *(2001)*

22. Which pair do not have equal dimensions ?
(a) Energy and torque (b) Force and impulse
(c) Angular momentum and Planck constant
(d) Elastic modulus and pressure. *(2000)*

23. The dimensional formula of magnetic flux is
(a) $[M^0L^{-2}T^{-2}A^{-2}]$ (b) $ML^0T^{-2}A^{-2}]$
(c) $[ML^2T^{-2}A^{-1}]$ (d) $[ML^2T^{-1}A^3]$ *(1999)*

24. An equation is given here $\left(P + \frac{a}{V^2}\right) = b\frac{\theta}{V}$ where P = Pressure, V = Volume and θ = Absolute temperature. If a and b are constants, the dimensions of a will be
(a) $[ML^{-5}T^{-1}]$ (b) $[ML^5T^1]$
(c) $[ML^5T^{-2}]$ (d) $[M^{-1}L^5T^2]$. *(1996)*

25. 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 lengths are 3% and 2% respectively, the maximum error in the measurement of density would be
(a) 12% (b) 14% (c) 7% (d) 9%. *(1996)*

26. The dimensions of impulse are equal to that of
(a) pressure (b) linear momentum
(c) force (d) angular momentum. *(1996)*

27. Which of the following dimensions will be the same as that of time?
(a) $\frac{L}{R}$ (b) $\frac{C}{L}$ (c) LC (d) $\frac{R}{L}$. *(1996)*

28. Which of the following is a dimensional constant?
(a) Relative density (b) Gravitational constant
(c) Refractive index (d) Poisson ratio. *(1995)*

29. The dimensions of RC is
(a) square of time (b) square of inverse time
(c) time (d) inverse time. *(1995)*

30. Percentage errors in the measurement of mass and speed are 2% and 3% respectively. The error in the estimate of kinetic energy obtained by measuring mass and speed will be
(a) 8% (b) 2% (c) 12% (d) 10%. *(1995)*

31. Which of the following has the dimensions of pressure?
(a) $[MLT^{-2}]$ (b) $[ML^{-1}T^{-2}]$
(c) $[ML^{-2}T^{-2}]$ (d) $[M^{-1}L^{-1}]$. *(1994, 90)*

32. 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 a distance x from the axis of the tube. The dimensions of h are
(a) $[M^0L^0T^0]$ (b) $[MLT^{-1}]$
(c) $[ML^2T^{-2}]$ (d) $[ML^{-1}T^{-1}]$ *(1993)*

33. The time dependence of a physical quantity p is given by $p = p_0$ exp $(-at^2)$, where a is a constant and t is the time. The constant a
(a) is dimensionless
(b) has dimensions $[T^{-2}]$
(c) has dimensions $[T^2]$
(d) has dimensions of p *(1993)*

34. P represents radiation pressure, c represents speed of light and S represents radiation energy striking per unit area per sec. The non zero integers x, y, z such that $P^xS^yc^z$ is dimensionless are
(a) $x = 1, y = 1, z = 1$ (b) $x = -1, y = 1, z = 1$
(c) $x = 1, y = -1, z = 1$ (d) $x = 1, y = 1, z = -1$ *(1992)*

35. A certain body weighs 22.42 g and has a measured volume of 4.7cc. The possible error in the measurement of mass and volume are 0.01 g and 0.1 cc. Then maximum error in the densiy will be
(a) 22% (b) 2% (c) 0.2% (d) 0.02%. *(1991)*

36. The dimensional formula of permeability of free space m_0 is
(a) $[MLT^{-2}A^{-2}]$ (b) $[M^0L^1T]$
(c) $[M^0L^2T^{-1}A^2]$ (d) none of these. *(1991)*

37. The frequency of vibration f of a mass m suspended from a spring of spring constant k is given by a relation $f = am^xk^y$, where a is a dimensionless constant. The values of x and y are
(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) $x = -\frac{1}{2}, y = \frac{1}{2}$. *(1990)*

38. According to Newton, the viscous force acting between liquid layers of area A and velocity gradient $\Delta v/\Delta Z$ is given by $F = -\eta A\frac{\Delta v}{\Delta Z}$, where h is constant called coefficient of viscosity. The dimensional formula of h is
(a) $[ML^{-2}T^{-2}]$ (b) $[M^0L^0T^0]$
(c) $[ML^2T^{-2}]$ (d) $[ML^{-1}T^{-1}]$. *(1990)*

39. If $x = at + bt^2$, where x is the distance travelled by the body in kilometers while t is the time in seconds, then the units of b is
(a) km/s (b) km s (c) km/s² (d) km s². *(1989)*

40. Of the following quantities, which one has dimensions different from the remaining three ?
(a) Energy per unit volume
(b) Force per unit area
(c) Product of voltage and charge per unit volume
(d) Angular momentum. *(1989)*

41. Dimensional formula of self inductance is
(a) $[MLT^{-2}A^{-2}]$ (b) $[ML^2T^{-1}A^{-2}]$
(c) $[ML^2T^{-2}A^{-2}]$ (d) $[ML^2T^{-2}A^{-1}]$. *(1989)*

42. The dimensional formula of torque is
(a) $[ML^2T^{-2}]$ (b) $[MLT^{-2}]$
(c) $[ML^{-1}T^{-2}]$ (d) $[ML^{-2}T^{-2}]$. *(1989)*

43. If C and R denote capacitance and resistance, the dimensional formula of CR is
(a) $[M^0L^0T^1]$ (b) $[M^0L^0T^0]$
(c) $[M^0L^0T^{-1}]$
(d) not expressible in terms of MLT. *(1988)*

44. The dimensional formula of angular momentum is
(a) $[ML^2T^{-2}]$ (b) $[ML^{-2}T^{-1}]$
(c) $[MLT^{-1}]$ (d) $[ML^2T^{-1}]$. *(1988)*

Answer Key

1.	(d)	**2.**	(a)	**3.**	(c)	**4.**	(a)	**5.**	(d)	**6.**	(c)	**7.**	(c)	**8.**	(c)	**9.**	(c)	**10.**	(c)
11.	(b)	**12.**	(b)	**13.**	(d)	**14.**	(d)	**15.**	(a)	**16.**	(c)	**17.**	(b)	**18.**	(b)	**19.**	(a)	**20.**	(c)
21.	(c)	**22.**	(b)	**23.**	(c)	**24.**	(c)	**25.**	(d)	**26.**	(b)	**27.**	(a)	**28.**	(b)	**29.**	(c)	**30.**	(a)
31.	(b)	**32.**	(d)	**33.**	(b)	**34.**	(c)	**35.**	(b)	**36.**	(a)	**37.**	(d)	**38.**	(d)	**39.**	(c)	**40.**	(d)
41.	(c)	**42.**	(a)	**43.**	(a)	**44.**	(d)												

EXPLANATIONS

1. **(d) :** Dimensions of

$$\frac{e^2}{4\pi\varepsilon_o} = [F \times d^2] = [ML^3T^{-2}]$$

Dimensions of $G = [M^{-1}L^3T^{-2}]$,
Dimensions of $c = [LT^{-1}]$

$$l \propto \left(\frac{e^2}{4\pi\varepsilon_o}\right)^p G^q c^r$$

$\therefore$ $[L^1] = [ML^3T^{-2}]^p [M^{-1}L^3T^{-2}]^q [LT^{-1}]^r$

On comparing both sides and solving, we get

$$p = \frac{1}{2}, \quad q = \frac{1}{2} \text{ and } r = -2$$

$$\therefore \; l = \frac{1}{c^2}\left[\frac{Ge^2}{4\pi\varepsilon_o}\right]^{1/2}$$

2. **(a) :** According to question,

$l \propto h^p c^q G^r$

$l = k h^p c^q G^r$ ...(i)

Writting dimensions of physical quantities on both sides,

$[M^0LT^0] = [ML^2T^{-1}]^p [LT^{-1}]^q [M^{-1}L^3T^{-2}]^r$

Applying the principle of homogeneity of dimensions, we get

$p - r = 0$ ...(ii)

$2p + q + 3r = 1$ ...(iii)

$-p - q - 2r = 0$ ...(iv)

Solving eqns. (ii), (iii) and (iv), we get

$$p = r = \frac{1}{2}, \; q = -\frac{3}{2}$$

From eqn. (i) $l = \dfrac{\sqrt{hG}}{c^{3/2}}$

3. **(c) :** $[v_c] = [\eta^x \rho^y r^z]$ (given) ... (i)

Writing the dimensions of various quantities in eqn. (i), we get

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

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

Applying the principle of homogeneity of dimensions, we get

$x + y = 0; -x - 3y + z = 1; \; -x = -1$

On solving, we get

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

4. **(a) :** Let $S = kE^aV^bT^c$

where k is a dimensionless constant.

Writing the dimensions on both sides, we get

$[M^1L^0T^{-2}] = [ML^2T^{-2}]^a [LT^{-1}]^b [T]^c$

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

Applying principle of homogeneity of dimensions, we get, $a = 1$ ...(i)

$2a + b = 0$ ...(ii)

$-2a - b + c = -2$ ...(iii)

Adding (ii) and (iii), we get

$c = -2$

From (ii), $b = -2a = -2$

$\therefore$ $S = kEV^{-2}T^{-2}$ or $[S] = [EV^{-2}T^{-2}]$

5. **(d) :** Let mass $m \propto F^aV^bT^c$

or $m = kF^aV^bT^c$ ...(i)

where k is a dimensionless constant and a, b and c are the exponents.

Writing dimensions on both sides, we get

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

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

Applying the principle of homogeneity of dimensions, we get

$a = 1$ ... (ii)

$a + b = 0$ ... (iii)

$-2a - b + c = 0$ ... (iv)

Solving eqns. (ii), (iii) and (iv), we get

$a = 1, b = -1, c = 1$

From eqn. (i), $[m] = [FV^{-1}T]$

6. **(c) :** As $P = \dfrac{a^3b^2}{cd}$

% error in P is

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

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

7. **(c) :** Impulse = Force × time

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

Surface tension $= \dfrac{\text{Force}}{\text{length}} = \dfrac{[MLT^{-2}]}{[L]} = [ML^0T^{-2}]$

Angular momentum

= Moment of inertia × angular velocity

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

Work = Force × distance = $[MLT^{-2}][L] = [ML^2T^{-2}]$

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

Torque = Force × distance = $[MLT^{-2}][L] = [ML^2T^{-2}]$

Young's modulus

$$= \frac{\text{Force / Area}}{\text{Change in length / original length}}$$

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

Hence, among the given pair of physical quantities work and torque have the same dimensions $[ML^2T^{-2}]$.

8. (c) : Damping force, $F \propto v$ or $F = kv$

where k is the constant of proportionality

$$\therefore \quad k = \frac{F}{v} = \frac{\text{N}}{\text{m s}^{-1}} = \frac{\text{kg m s}^{-2}}{\text{m s}^{-1}} = \text{kg s}^{-1}$$

9. (c) : The speed of the light in vacuum is

$$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = (\mu_0\varepsilon_0)^{-1/2}$$

$$\therefore \quad [(\mu_0\varepsilon_0)^{-1/2}] = [c] = [LT^{-1}]$$

10. (c) : As $n_1u_1 = n_2u_2$

$$4\frac{g}{\text{cm}^3} = n_2\frac{100g}{(10\text{ cm})^3} \Rightarrow n_2 = 40$$

11. (b) : Energy density of an electric field E is

$$u_E = \frac{1}{2}\varepsilon_0E^2$$

where ε_0 is permittivity of free space

$$u_E = \frac{\text{Energy}}{\text{Volume}} = \frac{ML^2T^{-2}}{L^3} = ML^{-1}T^{-2}$$

Hence, the dimension of $\frac{1}{2}\varepsilon_0E^2$ is $ML^{-1}T^{-2}$

12. (b) : From the relation

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

$$h = \frac{1}{2}gt^2 \Rightarrow g = \frac{2h}{t^2} \ (\because \text{ body initially at rest})$$

Taking natural logarithm on both sides, we get

$$\ln g = \ln h - 2\ln t$$

Differentiating, $\frac{\Delta g}{g} = \frac{\Delta h}{h} - 2\frac{\Delta t}{t}$

For maximum permissible error,

$$\text{or} \quad \left(\frac{\Delta g}{g}\times 100\right)_{\max} = \left(\frac{\Delta h}{h}\times 100\right) + 2\times\left(\frac{\Delta t}{t}\times 100\right)$$

According to problem

$$\frac{\Delta h}{h}\times 100 = e_1 \text{ and } \frac{\Delta t}{t}\times 100 = e_2$$

$$\text{Therefore, } \left(\frac{\Delta g}{g}\times 100\right)_{\max} = e_1 + 2e_2$$

13. (d) : Pressure, $P = \frac{\text{force}}{\text{area}} = \frac{\text{mass} \times \text{acceleration}}{\text{area}}$

$$\therefore \ [P] = \frac{M^1LT^{-2}}{L^2} = [M^1L^{-1}T^{-2}] = M^aL^bT^c.$$

$$\therefore \quad a = 1, b = -1, c = -2.$$

14. (d) : $V = \frac{4}{3}\pi R^3$; $\ln V = \ln\left(\frac{4}{3}\pi\right) + \ln R^3$

Differentiating, $\frac{dV}{V} = 3\frac{dR}{R}$

Error in the determination of the volume

$$= 3 \times 2\% = 6\%$$

15. (a) :

$$[\text{Energy density}] = \left[\frac{\text{Work done}}{\text{Volume}}\right] = \frac{MLT^{-2}\cdot L}{L^3} = [ML^{-1}T^{-2}]$$

$$[\text{Young's modulus}] = [Y] = \left[\frac{\text{Force}}{\text{Area}}\right]\times\frac{[l]}{[\Delta l]}$$

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

The dimensions of 1 and 4 are the same.

16. (c) : According to Ohm's law,

$$V = RI \quad \text{or} \quad R = \frac{V}{I}$$

Dimensions of $V = \frac{W}{q} = \frac{[ML^2T^{-2}]}{[IT]}$

$$\therefore \quad R = \frac{[ML^2T^{-2}/IT]}{[I]} = [ML^2T^{-3}I^{-2}].$$

17. (b) : $v = at + \frac{b}{t+c}$

As c is added to t, $\therefore$ $[c] = [T]$

$$[at] = [LT^{-1}] \quad \text{or,} \quad [a] = \frac{[LT^{-1}]}{[T]} = [LT^{-2}]$$

$$\frac{[b]}{[T]} = [LT^{-1}] \quad \therefore [b] = [L].$$

18. (b) : $\frac{h}{I} = \frac{E\lambda}{c\times I} = \frac{[ML^2T^{-2}][L]}{[LT^{-1}]\times[ML^2]}$

$$\frac{h}{I} = [T^{-1}] = \text{frequency}.$$

19. (a) : Gravitational constant G

$$= \frac{\text{force}\times(\text{distance})^2}{\text{mass}\times\text{mass}}$$

$$\therefore \quad \text{Dimensions of } G = \frac{[MLT^{-2}][L^2]}{[M][M]} = [M^{-1}L^3T^{-2}]$$

20. (c) : Force between two charges

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{r^2} \Rightarrow \varepsilon_0 = \frac{1}{4\pi}\frac{q^2}{Fr^2} = \text{C}^2/\text{N-m}^2$$

21. **(c) :** Dimensions of Planck constant

$$h = \frac{\text{Energy}}{\text{Frequency}} = \frac{[ML^2T^{-2}]}{[T^{-1}]} = [ML^2T^{-1}]$$

Dimensions of angular momentum L

$= $ Moment of inertia $I \times$ Angular velocity ω

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

22. **(b) :** Dimensions of force $= [MLT^{-2}]$

Dimensions of impulse $= [MLT^{-1}]$.

23. **(c) :** Magnetic flux, $\phi = BA = \left(\frac{F}{Il}\right)A$

$$= \frac{[MLT^{-2}][L^2]}{[A][L]} = [ML^2T^{-2}A^{-1}].$$

24. **(c) :** Equation $\left(P + \frac{a}{V^2}\right) = b\,\frac{\theta}{V}$. Since $\frac{a}{V^2}$ is added to the pressure, therefore dimensions of $\frac{a}{V^2}$ and pressure (P) will be the same. And dimensions of $\frac{a}{V^2} = \frac{a}{[L^3]^2} = [ML^{-1}T^{-2}]$

or $a = [ML^5T^{-2}]$.

25. **(d) :** Maximum error in mass $\left(\frac{\Delta m}{m}\right) = 3\ \% = \frac{3}{100}$ and maximum error in length $\left(\frac{\Delta l}{l}\right) = 2\,\% = \frac{2}{100}$.

Maximum error in the measurement of density,

$$\frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + \left(3\times\frac{\Delta l}{l}\right) = \frac{3}{100} + \left(3\times\frac{2}{100}\right) = \frac{3}{100} + \frac{6}{100}$$

$$= \frac{9}{100} = 9\%.$$

26. **(b) :** Impulse = Force × Time.

Therefore dimensional formula of impulse = Dimensional formula of force × Dimensional formula of time $= [MLT^{-2}]\,[T] = [MLT^{-1}]$ and dimensional formula of linear momentum $[p] = MLT^{-1}$.

27. **(a)**

28. **(b) :** Relative density, refractive index and Poisson ratio all the three are ratios, therefore they are dimensionless constants.

29. **(c) :** Units of RC = ohm × ohm^{-1} × second = second. Therefore dimensions of RC = time.

30. **(a) :** Percentage error in mass $= 2\% = \frac{2}{100}$ and percentage error in speed $= 3\ \% = \frac{3}{100}$.

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

Therefore the error in measurement of kinetic energy

$$\frac{\Delta\,K.E.}{K.E.} = \frac{\Delta m}{m} + 2\times\frac{\Delta v}{v} = \frac{2}{100} + 2\times\frac{3}{100} = \frac{8}{100} = 8\ \%$$

31. **(b) :** Pressure $= \frac{\text{Force}}{\text{Area}}$. Therefore dimensions of pressure $= \frac{[MLT^{-2}]}{[L^2]} = ML^{-1}T^{-2}$.

32. **(d) :** Dimensions of $P = [ML^{-1}T^{-2}]$

Dimensions of $r = [L]$

Dimensions of $v = [LT^{-1}]$

Dimensions of $l = [L]$

$$\therefore \quad \text{Dimensions of } \eta = \frac{[P][r^2 - x^2]}{[4vl]} = \frac{[ML^{-1}T^{-2}][L^2]}{[LT^{-1}][L]}$$

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

33. **(b) :** Given : $p = p_0 e^{-\alpha t^2}$

αt^2 is a dimensionless

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

34. **(c) :** Let $k = P^x S^y c^z$ .....(i)

k is a dimensionless

Dimensions of $k = [M^0L^0T^0]$

$$\therefore \text{ Dimensions of } P = \frac{\text{Force}}{\text{Area}} = \frac{[MLT^{-2}]}{[L^2]} = [ML^{-1}T^{-2}]$$

$$\text{Dimensions of } S = \frac{\text{Energy}}{\text{Area}\times\text{time}} = \frac{[ML^2T^{-2}]}{[L^2][T]} = [MT^{-3}]$$

Dimensions of $c = [LT^{-1}]$

Substituting these dimensions in eqn (i), we get

$[M^0L^0T^0] = [ML^{-1}T^{-2}]^x\,[MT^{-3}]^y\,[LT^{-1}]^z$.

Applying the principle of homogeneity of dimensions, we get

$x + y = 0$ .....(ii)

$-x + z = 0$ .....(iii)

$-2x - 3y - z = 0$ .....(iv)

Solving (ii), (iii) and (iv), we get

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

35. **(b) :** Density $\rho = \frac{\text{mass } m}{\text{volume } V}$ .....(i)

Take logarithm to take base e on the both sides of eqn (i), we get

$\ln\rho = \ln m - \ln V$ .....(ii)

Differentiate eqn (ii), on both sides, we get

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

Errors are always added, Error in the density ρ will be

$$= \left[\frac{\Delta m}{m} + \frac{\Delta V}{V}\right]\times 100\%$$

$$= \left[\frac{0.01}{22.42} + \frac{0.1}{4.7}\right]\times 100\% = 2\ \%$$

36. (a) : Permeability of free space

$$\mu_0 = \frac{2\pi \times \text{force} \times \text{distance}}{\text{current} \times \text{current} \times \text{length}}$$

Dimensional formula of $\mu_0 = \frac{[MLT^{-2}][L]}{[A][A][L]} = [MLT^{-2}A^{-2}]$

37. (d) : $f = am^x k^y$ .....(i)

Dimensions of frequency $f = [M^0L^0T^{-1}]$
Dimensions of constant $a = [M^0L^0T^0]$
Dimensions of mass $m = [M]$
Dimensions of spring constant $k = [MT^{-2}]$
Putting these value in equation (i), we get

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

Applying principle of homogeneity of dimensions, we get

$x + y = 0$ .....(ii)

$-2y = -1$ .....(iii)

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

38. (d) : Dimensions of force $F = [MLT^{-2}]$

Dimensions of velocity gradient $\frac{\Delta v}{\Delta Z} = \frac{[LT^{-1}]}{[L]} = [T^{-1}]$

Dimensions of area $A = [L^2]$

Given $F = -\eta A \frac{\Delta v}{\Delta Z}$

Dimensional formula for coefficient of viscocity

$$\eta = \frac{F}{(A)\left(\frac{\Delta v}{\Delta Z}\right)} = \frac{[MLT^{-2}]}{[L^2][T^{-1}]} = [ML^{-1}T^{-1}]$$

39. (c) : Units of $b = \frac{x}{t^2} = \frac{\text{km}}{\text{s}^2}$

40. (d) : Dimensions of energy $E = [ML^2T^{-2}]$
Dimensions of volume $v = [L^3]$
Dimensions of force $F = [MLT^{-2}]$
Dimensions of area $A = [L^2]$
Dimensions of voltage $V = [ML^2T^{-3}A^{-1}]$
Dimensions of charge $q = [AT]$
Dimensions of angular momentum $L = [ML^2T^{-1}]$

$\therefore$ Dimensions of $\frac{E}{v} = \frac{[ML^2T^{-2}]}{[L^3]} = [ML^{-1}T^{-2}]$

Dimensions of $\frac{F}{A} = \frac{[MLT^{-2}]}{[L^2]} = [ML^{-1}T^{-2}]$

Dimensions of $\frac{Vq}{v} = \frac{[ML^2T^{-3}A^{-1}][AT]}{[L^3]} = [ML^{-1}T^{-2}]$

Dimensions of angular momentum is $[ML^2T^{-1}]$ while other three has dimensions $[ML^{-1}T^{-2}]$

41. (c) : Induced emf $|\varepsilon| = L\frac{dI}{dt}$

where L is the self inductance and $\frac{dI}{dt}$ is the rate of change of current.

$\therefore$ Dimensional formula of

$$L = \frac{|\varepsilon|}{\frac{dI}{dt}} = \frac{[ML^2T^{-3}A^{-1}]}{[AT^{-1}]} = [ML^2A^{-2}T^{-2}]$$

42. (a) : Torque (τ) = Force $\times$ distance
Dimensional formula for $(\tau) = [MLT^{-2}][L] = [ML^2T^{-2}]$

43. (a) : Capacitance $C = \frac{\text{charge}}{\text{Potential difference}}$

Dimensions of $C = \frac{[AT]}{[ML^2T^{-3}A^{-1}]} = [M^{-1}L^{-2}T^4A^2]$

Resistance $R = \frac{\text{Potential difference}}{\text{current}}$

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

Dimensional formula of CR

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

As the (CR) has dimensions of time and so is called time constant of CR circuit.

44. (d) : Angular momentum L
= Moment of inertia I $\times$ Angular velocity ω.
$\therefore$ Dimensional formula $L = [ML^2][T^{-1}] = [ML^2T^{-1}]$

Chapter 2 Motion in a Straight Line

1. 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

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

(c) $t_1 - t_2$ (d) $\frac{t_1 + t_2}{2}$

(NEET 2017)

2. 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?

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

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

(NEET-II 2016)

3. If the velocity of a particle is $v = At + Bt^2$, where A and B are constants, then the distance travelled by it between 1 s and 2 s is

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

(c) $\frac{3}{2}A + 4B$ (d) $3A + 7B$

(NEET-I 2016)

4. A particle of unit mass undergoes one-dimensional motion such that its velocity varies according to $v(x) = \beta x^{-2n}$, where β 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

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

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

(2015 Cancelled)

5. A stone falls freely under gravity. It covers distances h_1, h_2 and h_3 in the first 5 seconds, the next 5 seconds and the next 5 seconds respectively. The relation between h_1, h_2 and h_3 is

(a) $h_2 = 3h_1$ and $h_3 = 3h_2$

(b) $h_1 = h_2 = h_3$

(c) $h_1 = 2h_2 = 3h_3$

(d) $h_1 = \frac{h_2}{3} = \frac{h_3}{5}$ *(NEET 2013)*

6. The displacement 'x' (in meter) of a particle of mass 'm' (in kg) moving in one dimension under the action of a force, is related to time 't' (in sec) by $t = \sqrt{x} + 3$. The displacement of the particle when its velocity is zero, will be

(a) 4 m (b) 0 m (zero)

(c) 6 m (d) 2 m

(Karnataka NEET 2013)

7. 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 second. The retardation of the particle when its velocity becomes zero is

(a) 24 m s^{-2} (b) zero

(c) 6 m s^{-2} (d) 12 m s^{-2} (2012)

8. A boy standing at the top of a tower of 20 m height drops a stone. Assuming $g = 10$ m s^{-2}, the velocity with which it hits the ground is

(a) 10.0 m/s (b) 20.0 m/s

(c) 40.0 m/s (d) 5.0 m/s *(2011)*

9. A particle covers half of its total distance with speed v_1 and the rest half distance with speed v_2. Its average speed during the complete journey is

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

(c) $\frac{2v_1 v_2}{v_1 + v_2}$ (d) $\frac{v_1^2 v_2^2}{v_1^2 + v_2^2}$

(Mains 2011)

10. A particle moves a distance x in time t according to equation $x = (t + 5)^{-1}$. The acceleration of particle is proportional to

(a) $(\text{velocity})^{3/2}$ (b) $(\text{distance})^2$
(c) $(\text{distance})^{-2}$ (d) $(\text{velocity})^{2/3}$ *(2010)*

11. A ball is dropped from a high rise platform at $t = 0$ starting from rest. After 6 seconds 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 $g = 10\ m/s^2$)

(a) 75 m/s (b) 55 m/s
(c) 40 m/s (d) 60 m/s *(2010)*

12. A particle starts its motion from rest under the action of a constant force. If the distance covered in first 10 seconds is S_1 and that covered in the first 20 seconds is S_2, then

(a) $S_2 = 3S_1$ (b) $S_2 = 4S_1$
(c) $S_2 = S_1$ (d) $S_2 = 2S_1$ *(2009)*

13. 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?

(a) 40 m s^{-1} (b) 25 m s^{-1}
(c) 10 m s^{-1} (d) 20 m s^{-1} *(2009)*

14. A particle moves in a straight line with a constant acceleration. It changes its velocity from 10 ms^{-1} to 20 ms^{-1} while passing through a distance 135 m in t second. The value of t is

(a) 12 (b) 9
(c) 10 (d) 1.8 *(2008)*

15. The distance travelled by a particle starting from rest and moving with an acceleration $\frac{4}{3}$ m s^{-2}, in the third second is

(a) $\frac{10}{3}$ m (b) $\frac{19}{3}$ m
(c) 6 m (d) 4 m *(2008)*

16. 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

(a) $\frac{1}{2}f_0T^2$ (b) f_0T^2
(c) $\frac{1}{2}f_0T$ (d) f_0T. *(2007)*

17. A car moves from X to Y with a uniform speed v_u and returns to Y with a uniform speed v_d. The average speed for this round trip is

(a) $\sqrt{v_uv_d}$ (b) $\frac{v_dv_u}{v_d+v_u}$
(c) $\frac{v_u+v_d}{2}$ (d) $\frac{2v_dv_u}{v_d+v_u}$. *(2007)*

18. The position x of a particle with respect to time t along x-axis is given by $x = 9t^2 - t^3$ where x is in metres and t in seconds. What will be the position of this particle when it achieves maximum speed along the $+x$ direction?

(a) 54 m (b) 81 m
(c) 24 m (d) 32 m. *(2007)*

19. 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

(a) 4/5 (b) 5/4
(c) 12/5 (d) 5/12. *(2006)*

20. A car runs at a constant speed on a circular track of radius 100 m, taking 62.8 seconds for every circular lap. The average velocity and average speed for each circular lap respectively is

(a) 10 m/s, 0 (b) 0, 0
(c) 0, 10 m/s (d) 10 m/s, 10 m/s. *(2006)*

21. A particle moves along a straight line OX. At a time t (in seconds) the distance x (in metres) of the particle from O is given by $x = 40 + 12t - t^3$. How long would the particle travel before coming to rest?

(a) 16 m (b) 24 m
(c) 40 m (d) 56 m. *(2006)*

22. A ball is thrown vertically upward. It has a speed of 10 m/sec when it has reached one half of its maximum height. How high does the ball rise?
(Take $g = 10\ m/s^2$.)

(a) 10 m (b) 5 m
(c) 15 m (d) 20 m. *(2005)*

23. The displacement x of a particle varies with time t as $x = ae^{-\alpha t} + be^{\beta t}$, where a, b, α and β are positive constants. The velocity of the particle will
(a) be independent of β
(b) drop to zero when $\alpha = \beta$
(c) go on decreasing with time
(d) go on increasing with time. *(2005)*

24. A man throws balls with the same speed vertically upwards one after the other at an interval of 2 seconds. What should be the speed of the throw so that more than two balls are in the sky at any time ? (Given $g = 9.8$ m/s^2)
(a) more than 19.6 m/s (b) at least 9.8 m/s
(c) any speed less than 19.6 m/s
(d) only with speed 19.6 m/s. *(2003)*

25. If a ball is thrown vertically upwards with speed u, the distance covered during the last t seconds of its ascent is
(a) ut (b) $\frac{1}{2}gt^2$
(c) $ut - \frac{1}{2}gt^2$ (d) $(u + gt)\,t$. *(2003)*

26. A particle is thrown vertically upward. Its velocity at half of the height is 10 m/s, then the maximum height attained by it ($g = 10$ m/s^2)
(a) 8 m (b) 20 m
(c) 10 m (d) 16 m. *(2001)*

27. Motion of a particle is given by equation $s = (3t^3 + 7t^2 + 14t + 8)$ m. The value of acceleration of the particle at $t = 1$ sec is
(a) 10 m/s^2 (b) 32 m/s^2
(c) 23 m/s^2 (d) 16 m/s^2. *(2000)*

28. A car moving with a speed of 40 km/h can be stopped by applying brakes after at least 2 m. If the same car is moving with a speed of 80 km/h, what is the minimum stopping distance?
(a) 4 m (b) 6 m
(c) 8 m (d) 2 m. *(1998)*

29. A rubber ball is dropped from a height of 5 m on a plane. On bouncing it rises to 1.8 m. The ball loses its velocity on bouncing by a factor of
(a) $\frac{3}{5}$ (b) $\frac{2}{5}$ (c) $\frac{16}{25}$ (d) $\frac{9}{25}$. *(1998)*

30. The position x of a particle varies with time, (t) as $x = at^2 - bt^3$. The acceleration will be zero at time t is equal to
(a) $\frac{a}{3b}$ (b) zero (c) $\frac{2a}{3b}$ (d) $\frac{a}{b}$. *(1997)*

31. If a car at rest accelerates uniformly to a speed of 144 km/h in 20 sec, it covers a distance of
(a) 1440 cm (b) 2980 cm
(c) 20 m (d) 400 m. *(1997)*

32. A body dropped from a height h with initial velocity zero, strikes the ground with a velocity 3 m/s. Another body of same mass dropped from the same height h with an initial velocity of 4 m/s. The final velocity of second mass, with which it strikes the ground is
(a) 5 m/s (b) 12 m/s
(c) 3 m/s (d) 4 m/s. *(1996)*

33. The acceleration of a particle is increasing linearly with time t as bt. The particle starts from origin with an initial velocity v_0. The distance travelled by the particle in time t will be
(a) $v_0t + \frac{1}{3}bt^2$ (b) $v_0t + \frac{1}{2}bt^2$
(c) $v_0t + \frac{1}{6}bt^3$ (d) $v_0t + \frac{1}{3}bt^3$. *(1995)*

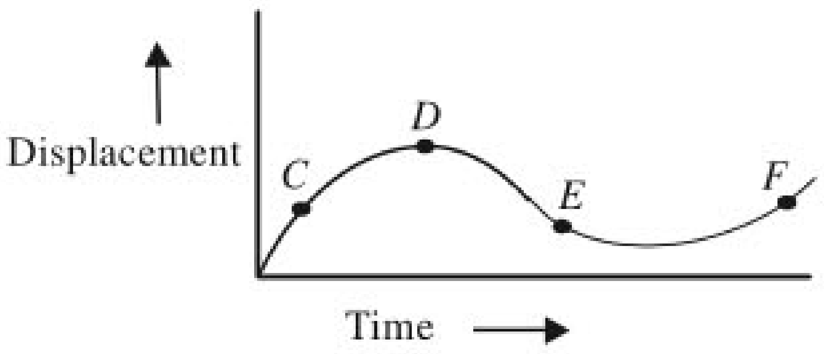
34. The water drop falls at regular intervals from a tap 5 m above the ground. The third drop is leaving the tap at instant the first drop touches the ground. How far above the ground is the second drop at that instant?
(a) 3.75 m (b) 4.00 m
(c) 1.25 m (d) 2.50 m. *(1995)*

35. A car accelerates from rest at a constant rate α for some time after which it decelerates at a constant rate β and comes to rest. If total time elapsed is t, then maximum velocity acquired by car will be
(a) $\frac{(\alpha^2 - \beta^2)t}{\alpha\beta}$ (b) $\frac{(\alpha^2 + \beta^2)t}{\alpha\beta}$
(c) $\frac{(\alpha + \beta)t}{\alpha\beta}$ (d) $\frac{\alpha\beta t}{\alpha + \beta}$. *(1994)*

36. A particle moves along a straight line such that its displacement at any time t is given by $s = (t^3 - 6t^2 + 3t + 4)$ metres. The velocity when the acceleration is zero is
(a) 3 m/s (b) 42 m/s
(c) -9 m/s (d) -15 m/s. *(1994)*

37. The velocity of train increases uniformly from 20 km/h to 60 km/h in 4 hours. The distance travelled by the train during this period is
(a) 160 km (b) 180 km
(c) 100 km (d) 120 km. *(1994)*

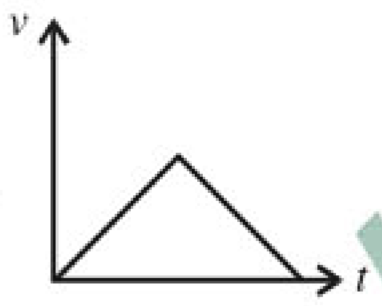
38. The displacement-time graph of a moving particle is shown below. The instantaneous velocity of the particle is negative at the point

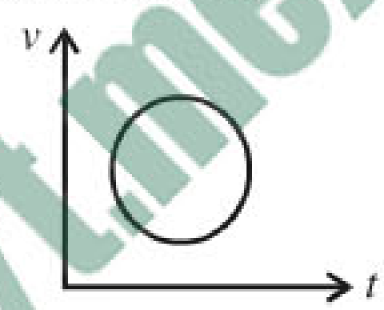


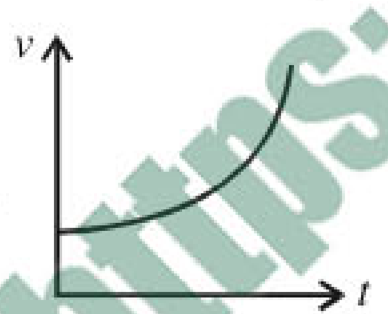
(a) E (b) F (c) C (d) D
(1994)

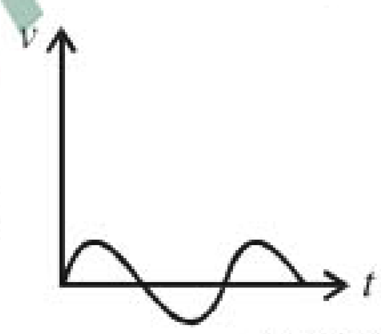
39. A body starts from rest, what is the ratio of the distance travelled by the during the 4th and 3rd second ?
(a) $\frac{7}{5}$ (b) $\frac{5}{7}$
(c) $\frac{7}{3}$ (d) $\frac{3}{7}$. *(1993)*

40. Which of the following curve does not represent motion in one dimension ?

(a) 

(b) 

(c) 

(d) 

(1992)

41. 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 m/s^2)
(a) 60 m (b) 45 m
(c) 80 m (d) 50 m.
(1992)

42. 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. The average speed is 48 km/h. The value of v is
(a) 56 km/h (b) 60 km/h
(c) 50 km/h (d) 48 km/h.
(1991)

43. A bus travelling the first one-third distance at a speed of 10 km/h, the next one-third at 20 km/h and at last one-third at 60 km/h. The average speed of the bus is
(a) 9 km/h (b) 16 km/h
(c) 18 km/h (d) 48 km/h.
(1991)

44. A car covers the first half of the distance between two places at 40 km/h and another half at 60 km/h. The average speed of the car is
(a) 40 km/h (b) 48 km/h
(c) 50 km/h (d) 60 km/h.
(1990)

45. What will be the ratio of the distance moved by a freely falling body from rest in 4th and 5th seconds of journey ?
(a) 4 : 5 (b) 7 : 9
(c) 16 : 25 (d) 1 : 1.
(1989)

46. 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
(a) 33.3 km/h (b) $20\sqrt{2}$ km/h
(c) $25\sqrt{2}$ km/h (d) 35 km/h.
(1988)

Answer Key

1. (b)	**2.** (d)	**3.** (a)	**4.** (d)	**5.** (d)	**6.** (b)	**7.** (d)	**8.** (b)	**9.** (c)	**10.** (a)
11. (a)	**12.** (b)	**13.** (d)	**14.** (b)	**15.** (a)	**16.** (c)	**17.** (d)	**18.** (a)	**19.** (a)	**20.** (c)
21. (a)	**22.** (a)	**23.** (d)	**24.** (a)	**25.** (b)	**26.** (c)	**27.** (b)	**28.** (c)	**29.** (a)	**30.** (a)
31. (d)	**32.** (a)	**33.** (c)	**34.** (a)	**35.** (d)	**36.** (c)	**37.** (a)	**38.** (a)	**39.** (a)	**40.** (b)
41. (b)	**42.** (b)	**43.** (c)	**44.** (b)	**45.** (b)	**46.** (c)				

EXPLANATIONS

1. **(b) :** Let v_1 is the velocity of Preeti on stationary escalator and d is the distance travelled by her

$\therefore \quad v_1 = \dfrac{d}{t_1}$

Again, let v_2 is the velocity of escalator

$\therefore \quad v_2 = \dfrac{d}{t_2}$

$\therefore$ Net velocity of Preeti on moving escalator with respect to the ground

$$v = v_1 + v_2 = \frac{d}{t_1} + \frac{d}{t_2} = d\left(\frac{t_1 + t_2}{t_1 t_2}\right)$$

The time taken by her to walk up on the moving escalator will be

$$t = \frac{d}{v} = \frac{d}{d\left(\frac{t_1 + t_2}{t_1 t_2}\right)} = \frac{t_1 t_2}{t_1 + t_2}$$

2. **(d) :** Position of the car P at any time t, is

$x_P(t) = at + bt^2$

$$v_P(t) = \frac{dx_P(t)}{dt} = a + 2bt \quad \text{...(i)}$$

Similarly, for car Q,

$x_Q(t) = ft - t^2$

$$v_Q(t) = \frac{dx_Q(t)}{dt} = f - 2t \quad \text{...(ii)}$$

$\because \quad v_P(t) = v_Q(t)$ (Given)

$\therefore \quad a + 2bt = f - 2t$ or, $2t(b + 1) = f - a$

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

3. **(a) :** Velocity of the particle is $v = At + Bt^2$

$\dfrac{ds}{dt} = At + Bt^2$, $\int ds = \int (At + Bt^2)dt$

$\therefore \quad s = \dfrac{At^2}{2} + B\dfrac{t^3}{3} + C$

$s(t = 1\text{ s}) = \dfrac{A}{2} + \dfrac{B}{3} + C$, $s(t = 2\text{ s}) = 2A + \dfrac{8}{3}B + C$

Required distance = $s(t = 2\text{ s}) - s(t = 1\text{ s})$

$$= \left(2A + \frac{8}{3}B + C\right) - \left(\frac{A}{2} + \frac{B}{3} + C\right) = \frac{3}{2}A + \frac{7}{3}B$$

4. **(d) :** According to question, velocity of unit mass varies as

$$v(x) = \beta x^{-2n} \quad \text{...(i)}$$

$$\frac{dv}{dx} = -2n\beta x^{-2n-1} \quad \text{...(ii)}$$

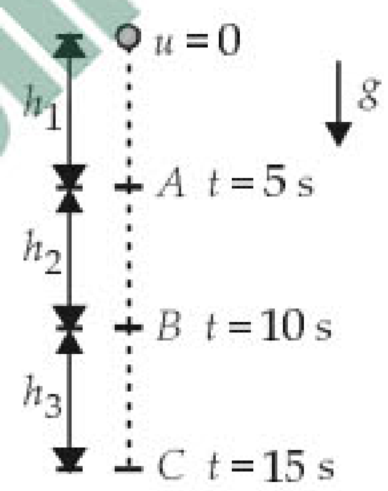
Acceleration of the particle is given by

$$a = \frac{dv}{dt} = \frac{dv}{dx} \times \frac{dx}{dt} = \frac{dv}{dx} \times v$$

Using equation (i) and (ii), we get

$$a = (-2n\beta x^{-2n-1}) \times (\beta x^{-2n}) = -2n\beta^2 x^{-4n-1}$$

5. **(d) :** Distance covered by the stone in first 5 seconds



(*i.e.* $t = 5$ s) is

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

Distance travelled by the stone in next 5 seconds

(*i.e.* $t = 10$ s) is

$$h_1 + h_2 = \frac{1}{2}g(10)^2 = \frac{100}{2}g \quad \text{...(ii)}$$

Distance travelled by the stone in next 5 seconds (*i.e.* $t = 15$ s) is

$$h_1 + h_2 + h_3 = \frac{1}{2}g(15)^2 = \frac{225}{2}g \quad \text{...(iii)}$$

Subtract (i) from (ii), we get

$$(h_1 + h_2) - h_1 = \frac{100}{2}g - \frac{25}{2}g = \frac{75}{2}g$$

$$h_2 = \frac{75}{2}g = 3h_1 \quad \text{...(iv)}$$

Subtract (ii) from (iii), we get

$$(h_1 + h_2 + h_3) - (h_2 + h_1) = \frac{225}{2}g - \frac{100}{2}g$$

$$h_3 = \frac{125}{2}g = 5h_1 \quad \text{...(v)}$$

From (i), (iv) and (v), we get

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

6. **(b) :** Given : $t = \sqrt{x} + 3$ or $\sqrt{x} = t - 3$

Squaring both sides, we get

$x = (t - 3)^2$

Velocity, $v = \dfrac{dx}{dt} = \dfrac{d}{dt}(t - 3)^2 = 2(t - 3)$

Velocity of the particle becomes zero, when

$2(t - 3) = 0$ or $t = 3$ s

At $t = 3$ s,

$x = (3 - 3)^2 = 0$ m

7. (d) : Given : $x = 8 + 12t - t^3$

Velocity, $v = \frac{dx}{dt} = 12 - 3t^2$

When $v = 0$, $12 - 3t^2 = 0$ or $t = 2$ s

$$a = \frac{dv}{dt} = -6t$$

$$a|_{t=2\,s} = -12 \text{ m s}^{-2}$$

Retardation = 12 m s^{-2}

8. (b) : Here, $u = 0$, $g = 10$ m s^{-2}, $h = 20$ m

Let v be the velocity with which the stone hits the ground.

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

or $v = \sqrt{2gh} = \sqrt{2\times10\times20} = 20$ m/s $(\because\ u = 0)$

9. (c) : Let S be the total distance travelled by the particle.

Let t_1 be the time taken by the particle to cover first half of the distance. Then

$$t_1 = \frac{S/2}{v_1} = \frac{S}{2v_1}$$

Let t_2 be the time taken by the particle to cover remaining half of the distance. Then

$$t_2 = \frac{S/2}{v_2} = \frac{S}{2v_2}$$

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

$$= \frac{S}{t_1 + t_2} = \frac{S}{\frac{S}{2v_1} + \frac{S}{2v_2}} = \frac{2v_1v_2}{v_1 + v_2}$$

10. (a) : Distance, $x = (t + 5)^{-1}$ ...(i)

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

Acceleration

$$a = \frac{dv}{dt} = \frac{d}{dt}[-(t+5)^{-2}] = 2(t+5)^{-3} \quad \text{...(iii)}$$

From equation (ii), we get

$$v^{3/2} = -(t+5)^{-3} \quad \text{...(iv)}$$

Substituting this in equation (iii) we get

Acceleration, $a = -2v^{3/2}$ or $a \propto (\text{velocity})^{3/2}$

From equation (i), we get

$$x^3 = (t+5)^{-3}$$

Substituting this in equation (iii), we get

Acceleration, $a = 2x^3$ or $a \propto (\text{distance})^3$

Hence option (a) is correct.

11. (a) : Let the two balls meet after t s at distance x from the platform.

For the first ball

$$u = 0,\ t = 18 \text{ s},\ g = 10 \text{ m/s}^2$$

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

$$\therefore\quad x = \frac{1}{2}\times10\times18^2 \quad \text{...(i)}$$

For the second ball

$$u = v,\ t = 12 \text{ s},\ g = 10 \text{ m/s}^2$$

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

$$\therefore\quad x = v\times12 + \frac{1}{2}\times10\times12^2 \quad \text{...(ii)}$$

From equations (i) and (ii), we get

$$\frac{1}{2}\times10\times18^2 = 12v + \frac{1}{2}\times10\times(12)^2$$

or $12v = \frac{1}{2}\times10\times[(18)^2 - (12)^2]$

$$= \frac{1}{2}\times10\times[(18+12)(18-12)]$$

$$12v = \frac{1}{2}\times10\times30\times6$$

or $v = \frac{1\times10\times30\times6}{2\times12} = 75$ m/s

12. (b) : Given $u = 0$.

Distance travelled in 10 s, $S_1 = \frac{1}{2}a\cdot10^2 = 50a$

Distance travelled in 20 s, $S_2 = \frac{1}{2}a\cdot20^2 = 200a$

$\therefore$ $S_2 = 4S_1$.

13. (d) : Let v_s be the velocity of the scooter, the distance between the scooter and the bus = 1000 m,

The velocity of the bus = 10 ms^{-1}

Time taken to overtake = 100 s

Relative velocity of the scooter with respect to the bus = $(v_s - 10)$

$$\therefore\quad \frac{1000}{(v_s - 10)} = 100 \text{ s} \Rightarrow v_s = 20 \text{ ms}^{-1}.$$

14. (b) : $v^2 - u^2 = 2as$

Given $v = 20$ ms^{-1}, $u = 10$ ms^{-1}, $s = 135$ m

$$\therefore\quad a = \frac{400-100}{2\times135} = \frac{300}{270} = \frac{10}{9} \text{ m/s}^2$$

$$v = u + at \Rightarrow t = \frac{v-u}{a} = \frac{10 \text{ m/s}}{\frac{10}{9}\text{ m/s}^2} = 9 \text{ s}$$

15. (a) : Distance travelled in the 3rd second

= Distance travelled in 3 s

– distance travelled in 2 s.

As, $u = 0$,

$$S_{(3^{rd}\,s)} = \frac{1}{2}a\cdot 3^2 - \frac{1}{2}a\cdot 2^2 = \frac{1}{2}\cdot a\cdot 5$$

Given $a = \frac{4}{3}\,\text{ms}^{-2}$; $\therefore$ $S_{(3^{rd}\,s)} = \frac{1}{2}\times\frac{4}{3}\times 5 = \frac{10}{3}$ m

16. (c) : Given : At time $t = 0$, velocity, $v = 0$.

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

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

Since f_0 is a constant,

$\therefore \quad 1-\frac{t}{T} = 0 \quad$ or $\quad t = T$.

Also, acceleration $f = \frac{dv}{dt}$

$$\therefore \int_0^{v_x} dv = \int_{t=0}^{t=T} f\,dt = \int_0^T f_0\left(1-\frac{t}{T}\right)dt$$

$$\therefore \quad v_x = \left[f_0 t - \frac{f_0 t^2}{2T}\right]_0^T = f_0 T - \frac{f_0 T^2}{2T} = \frac{1}{2}f_0 T.$$

17. (d) : Average speed $= \frac{\text{total distance travelled}}{\text{total time taken}}$

$$= \frac{s+s}{t_1+t_2} = \frac{2s}{\frac{s}{v_u}+\frac{s}{v_d}} = \frac{2v_u v_d}{v_d+v_u}.$$

18. (a) : Given : $x = 9t^2 - t^3$ ...(i)

Speed $\quad v = \frac{dx}{dt} = \frac{d}{dt}(9t^2 - t^3) = 18t - 3t^2.$

For maximum speed, $\frac{dv}{dt} = 0 \Rightarrow 18 - 6t = 0$

$\therefore \quad t = 3$ s.

$\therefore$ $x_{max} = 81$ m $- 27$ m $= 54$ m. (From $x = 9t^2 - t^3$)

19. (a) : Time taken by a body fall from a height h to reach the ground is $t = \sqrt{\frac{2h}{g}}$.

$$\therefore \quad \frac{t_A}{t_B} = \frac{\sqrt{\frac{2h_A}{g}}}{\sqrt{\frac{2h_B}{g}}} = \sqrt{\frac{h_A}{h_B}} = \sqrt{\frac{16}{25}} = \frac{4}{5}.$$

20. (c) : Distance travelled in one rotation (lap) = $2\pi r$

$\therefore$ Average speed $= \frac{\text{distance}}{\text{time}} = \frac{2\pi r}{t}$

$$= \frac{2\times 3.14\times 100}{62.8} = 10\ \text{m s}^{-1}$$

Net displacement in one lap = 0

Average velocity $= \frac{\text{net displacement}}{\text{time}} = \frac{0}{t} = 0.$

21. (a) : $x = 40 + 12t - t^3$

$\therefore$ Velocity $v = \frac{dx}{dt} = 12 - 3t^2$

When particle come to rest, $dx/dt = v = 0$

$\therefore$ $12 - 3t^2 = 0 \Rightarrow 3t^2 = 12 \Rightarrow t = 2$ sec.

Distance travelled by the particle before coming to rest

$$\int_0^s ds = \int_0^2 v\,dt \qquad s = \int_0^2 (12-3t^2)dt = 12t - \frac{3t^3}{3}\Big|_0^2$$

$s = 12 \times 2 - 8 = 24 - 8 = 16$ m.

22. (a) : $v^2 = u^2 - 2gh$

After reaching maximum height velocity becomes zero.

$$0 = (10)^2 - 2\times 10\times\frac{h}{2} \quad \therefore\ h = \frac{200}{20} = 10\ \text{m}.$$

23. (d) : $x = ae^{-\alpha t} + be^{\beta t}$

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

$v = -a\alpha e^{-\alpha t} + b\beta e^{\beta t}$

For certain value of t, velocity will increases.

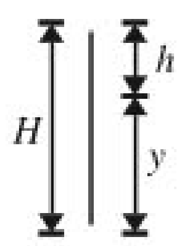
24. (a) : Interval of ball thrown = 2 sec

If we want that minimum three (more than two) balls remain in air then time of flight of first ball must be greater than 4 sec.

$T > 4$ sec or $\frac{2u}{g} > 4\,\text{sec} \Rightarrow u > 19.6$ m/s.

25. (b) : Let total height = H

Time of ascent = T



So, $\quad H = uT - \frac{1}{2}gT^2$

Distance covered by ball in time $(T - t)$ sec.

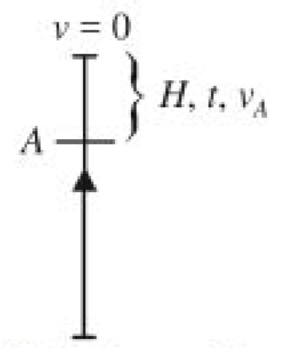
$$y = u(T-t) - \frac{1}{2}g(T-t)^2$$

So distance covered by ball in last t sec.

$$h = H - y = \left[uT - \frac{1}{2}gT^2\right] - \left[u(T-t) - \frac{1}{2}g(T-t)^2\right]$$

By solving and putting $T = \frac{u}{g}$ we will get

$$h = \frac{1}{2}gt^2.$$



Aliter :

Time to reach the topmost position, $T = u/g$

Velocity at the top, $v = 0$

Let's consider a point A distance H below the highest point. Let it takes t seconds for the ball to reach the top from A. So we have to calculate H.

Let's find the velocity at point A. Now the time taken to reach A is $(T - t)$.

$\therefore$ $v_A = u - g(T - t) = u - gT - gt = u - u - gt = -gt$.

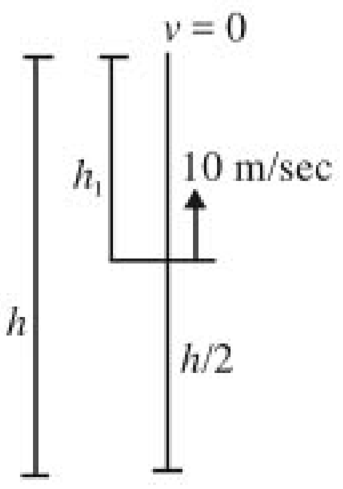
Now consider its journey from A to the top.

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

$$\Rightarrow \quad 0 = v_A^2 - 2gH \Rightarrow H = \frac{(-gt)^2}{2g} = \frac{1}{2}gt^2.$$

26. (c) : For half height,

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



For total height,

$0 = u^2 - 2gh$ ...(ii)

From (i) and (ii)

$\Rightarrow \quad 10^2 = \frac{2gh}{2} \Rightarrow h = 10$ m.

27. (b) : $\frac{ds}{dt} = 9t^2 + 14t + 14$

$\Rightarrow \quad \frac{d^2s}{dt^2} = 18t + 14 = a$

$a_{t=1} = 18 \times 1 + 14 = 32$ m/s^2

28. (c) : 1st case $v^2 - u^2 = 2as$

$0 - \left(\frac{100}{9}\right)^2 = 2 \times a \times 2$ [$\because$ 40 km/h = 100/9 m/s]

$a = -\frac{10^4}{81 \times 4}$ m/s

2nd case : $0 - \left(\frac{200}{9}\right)^2 = 2 \times \left(-\frac{10^4}{81 \times 4}\right) \times s$

[80 km/h = 200/9 m/s]

or $\quad s = 8$ m.

29. (a) : Initial energy equation

$mgh = \frac{1}{2}mv^2$ i.e. $10 \times 5 = \frac{1}{2}v_1^2 \Rightarrow v_1 = 10$ ...(i)

After one bounce, $10 \times 1.8 = \frac{1}{2}v_2^2 \Rightarrow v_2 = 6$ ...(ii)

Loss in velocity on bouncing $\frac{6}{10} = \frac{3}{5}$ a factor.

30. (a) : Distance $(x) = at^2 - bt^3$.

Therefore velocity $(v) = \frac{dx}{dt} = \frac{d}{dt}\left(at^2 - bt^3\right)$

$= 2at - 3bt^2$ and

acceleration $= \frac{dv}{dt} = \frac{d}{dt}\left(2at - 3bt^2\right) = 2a - 6bt = 0$

or $\quad t = \frac{2a}{6b} = \frac{a}{3b}$.

31. (d) : Initial velocity $u = 0$,

Final velocity = 144 km/h = 40 m/s and time = 20 sec.

Using $v = u + at \Rightarrow a = v/t = 2$ m/s^2

Again, $s = ut + \frac{1}{2}at^2 = \frac{1}{2} \times 2 \times (20)^2 = 400$ m.

32. (a) : Initial velocity of first body $(u_1) = 0$; Final velocity $(v_1) = 3$ m/s and initial velocity of second body $(u_2) = 4$ m/s.

height $(h) = \frac{v_1^2}{2g} = \frac{(3)^2}{2 \times 9.8} = 0.46$ m.

Therefore velocity of the second body,

$v_2 = \sqrt{u_2^2 + 2gh} = \sqrt{(4)^2 + 2 \times 9.8 \times 0.46} = 5$ m/s.

33. (c) : Acceleration µ bt. *i.e.*, $\frac{d^2x}{dt^2} = a \propto bt$

Integrating, $\frac{dx}{dt} = \frac{bt^2}{2} + C$

Initially, $t = 0$, $dx/dt = v_0$

Therefore, $\frac{dx}{dt} = \frac{bt^2}{2} + v_0$

Integrating again, $x = \frac{bt^3}{6} + v_0 t + C$

When $t = 0, x = 0 \Rightarrow C = 0$.

i.e., distance travelled by the particle in time t

$= v_0 t + \frac{bt^3}{6}$.

34. (a) : Height of tap = 5 m. For the first drop,

$5 = ut + \frac{1}{2}gt^2 = \frac{1}{2} \times 10t^2 = 5t^2$ or $t^2 = 1$

or $t = 1$ sec. It means that the third drop leaves after one second of the first drop, or each drop leaves after every 0.5 sec. Distance covered by the second drop in 0.5 sec

$= \frac{1}{2}gt^2 = \frac{1}{2} \times 10 \times (0.5)^2 = 1.25$ m.

Therefore distance of the second drop above the ground = 5 – 1.25 = 3.75 m.

35. (d) : Initial velocity $(u) = 0$; Acceleration in the first phase = α; Deceleration in the second phase = β and total time = t.

When car is accelerating then

final velocity $(v) = u + \alpha t = 0 + \alpha t_1$

or $t_1 = \frac{v}{\alpha}$ and when car is decelerating,

then final velocity $0 = v - \beta t$ or $t_2 = \frac{v}{\beta}$.

Therefore total time $(t) = t_1 + t_2 = \frac{v}{\alpha} + \frac{v}{\beta}$

$t = v\left(\frac{1}{\alpha} + \frac{1}{\beta}\right) = v\left(\frac{\beta + \alpha}{\alpha\beta}\right)$ or $v = \frac{\alpha\beta t}{\alpha + \beta}$.

36. (c) : Displacement $(s) = t^3 - 6t^2 + 3t + 4$ metres.

velocity $(v) = \frac{ds}{dt} = 3t^2 - 12t + 3$

acceleration $(a) = \frac{dv}{dt} = 6t - 12$.

When $a = 0$, we get $t = 2$ seconds.

Therefore velocity when the acceleration is zero (v) $= 3 \times (2)^2 - (12 \times 2) + 3 = -9$ m/s.

37. (a) : Initial velocity (u) = 20 km/h; Final velocity (v) = 60 km/h and time (t) = 4 hours.

velocity (v) $= 60 = u + at = 20 + (a \times 4)$

$$\text{or,} \quad a = \frac{60-20}{4} = 10 \text{ km/h}^2.$$

Therefore distance travelled in 4 hours is s

$$s = ut + \frac{1}{2}at^2 = (20 \times 4) + \frac{1}{2} \times 10 \times (4)^2 = 160 \text{ km}.$$

38. (a) : The velocity (v) $= \dfrac{ds}{dt}$.

Therefore, instantaneous velocity at point E is negative.

39. (a) : Distance covered in n^{th} second is given by

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

Here, $u = 0$

$$\therefore \quad s_4 = 0 + \frac{a}{2}(2 \times 4 - 1) = \frac{7a}{2}$$

$$s_3 = 0 + \frac{a}{2}(2 \times 3 - 1) = \frac{5a}{2} \qquad \therefore \frac{s_4}{s_3} = \frac{7}{5}$$

40. (b) : In one dimensional motion, the body can have at a time one value of velocity but not two values of velocities.

41. (b) : Let h be height of the tower and t is the time taken by the body to reach the ground.

Here, $u = 0$, $a = g$

$$\therefore \quad h = ut + \frac{1}{2}gt^2 \text{ or } h = 0 \times t + \frac{1}{2}gt^2$$

$$\text{or} \quad h = \frac{1}{2}gt^2 \qquad \text{.....(i)}$$

Distance covered in last two seconds is

$$40 = \frac{1}{2}gt^2 - \frac{1}{2}g(t-2)^2 \quad (\text{Here, } u = 0)$$

$$\text{or} \quad 40 = \frac{1}{2}gt^2 - \frac{1}{2}g(t^2 + 4 - 4t)$$

or $40 = (2t - 2)g$ or $t = 3$ s

From eqn (i), we get $h = \frac{1}{2} \times 10 \times (3)^2$ or $h = 45$ m

42. (b) : Total distance travelled = 200 m

$$\text{Total time taken} = \frac{100}{40} + \frac{100}{v}$$

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

$$48 = \frac{200}{\left(\frac{100}{40} + \frac{100}{v}\right)} \quad \text{or} \quad 48 = \frac{2}{\left(\frac{1}{40} + \frac{1}{v}\right)}$$

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

$$\text{or} \quad \frac{1}{v} = \frac{1}{24} - \frac{1}{40} = \frac{5-3}{120} = \frac{1}{60}$$

or $v = 60$ km/hr

43. (c) : Total distance travelled = s

$$\text{Total time taken} = \frac{s/3}{10} + \frac{s/3}{20} + \frac{s/3}{60}$$

$$= \frac{s}{30} + \frac{s}{60} + \frac{s}{180} = \frac{10s}{180} = \frac{s}{18}$$

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

$$= \frac{s}{s/18} = 18 \text{ km/hr.}$$

44. (b) : Total distance covered = s

$$\text{Total time taken} = \frac{s/2}{40} + \frac{s/3}{60} = \frac{5s}{240} = \frac{s}{48}$$

$$\therefore \text{Average speed} = \frac{\text{total distance covered}}{\text{total time taken}}$$

$$= \frac{s}{\left(\frac{s}{48}\right)} = 48 \text{ km/hr}$$

45. (b) : Distance covered in n^{th} second is given by

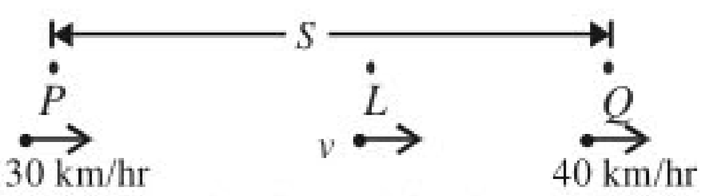
$$s_n = u + \frac{a}{2}(2n-1)$$

Given : $u = 0$, $a = g$

$$\therefore \quad s_4 = \frac{g}{2}(2 \times 4 - 1) = \frac{7g}{2}$$

$$s_5 = \frac{g}{2}(2 \times 5 - 1) = \frac{9g}{2} \qquad \therefore \frac{s_4}{s_5} = \frac{7}{9}$$

46. (c) :



Let $PQ = s$ and L is the midpoint of PQ and v be velocity f the car at point L.

Using third equation of motion, we get

$(40)^2 - (30)^2 = 2as$

$$\text{or} \quad a = \frac{(40)^2 - (30)^2}{2s} = \frac{350}{s} \qquad \text{.....(i)}$$

$$\text{Also,} \quad v^2 - (30)^2 = 2a\frac{s}{2}$$

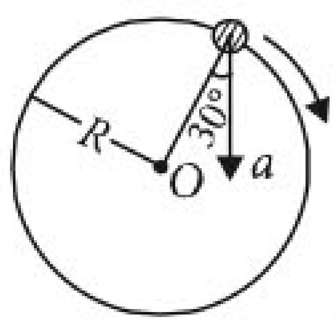
$$\text{or} \quad v^2 - (30)^2 = 2 \times \frac{350}{s} \times \frac{s}{2} \qquad [\text{Using (i)}]$$

$$\text{or} \quad v = 25\sqrt{2} \text{ km/hr}$$

Chapter 3 Motion in a Plane

1. The x and y coordinates of the particle at any time are $x = 5t - 2t^2$ and $y = 10t$ respectively, where x and y are in metres and t in seconds. The acceleration of the particle at $t = 2$ s is
(a) 5 m s^{-2} (b) -4 m s^{-2}
(c) -8 m s^{-2} (d) 0 *(NEET 2017)*

2. In the given figure, $a = 15$ m s^{-2} represents the total acceleration of a particle moving in the clockwise direction in a circle of radius $R = 2.5$ m at a given instant of time. The speed of the particle is



(a) 4.5 m s^{-1} (b) 5.0 m s^{-1}
(c) 5.7 m s^{-1} (d) 6.2 m s^{-1}
(NEET-II 2016)

3. 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
(a) 45° (b) 180°
(c) 0° (d) 90° *(NEET-I 2016)*

4. A particle moves so that its position vector is given by $\vec{r} = \cos\omega t\,\hat{x} + \sin\omega t\,\hat{y}$, where ω is a constant.
Which of the following is true?
(a) Velocity is perpendicular to $\vec{r}$ and acceleration is directed towards the origin.
(b) Velocity is perpendicular to $\vec{r}$ and acceleration is directed away from the origin.
(c) Velocity and acceleration both are perpendicular to $\vec{r}$
(d) Velocity and acceleration both are parallel to $\vec{r}$ *(NEET-I 2016)*

5. If vectors $\vec{A} = \cos\omega t\,\hat{i} + \sin\omega t\,\hat{j}$ and $\vec{B} = \cos\frac{\omega t}{2}\hat{i} + \sin\frac{\omega t}{2}\hat{j}$ are functions of time, then the value of t at which they are orthogonal to each other is
(a) $t = \frac{\pi}{\omega}$ (b) $t = 0$
(c) $t = \frac{\pi}{4\omega}$ (d) $t = \frac{\pi}{2\omega}$ *(2015)*

6. The position vector of a particle $\vec{R}$ as a function of time is given by $\vec{R} = 4\sin(2\pi t)\hat{i} + 4\cos(2\pi t)\hat{j}$ Where R is in meters, t is in seconds and $\hat{i}$ and $\hat{j}$ denote unit vectors along x-and y-directions, respectively. Which one of the following statements is wrong for the motion of particle?
(a) Magnitude of the velocity of particle is 8 meter/second.
(b) Path of the particle is a circle of radius 4 meter.
(c) Acceleration vector is along $-\vec{R}$.
(d) Magnitude of acceleration vector is $\frac{v^2}{R}$, where v is the velocity of particle. *(2015)*

7. A ship A is moving Westwards with a speed of 10 km h^{-1} and a ship B 100 km South of A, is moving Northwards with a speed of 10 km h^{-1}. The time after which the distance between them becomes shortest, is
(a) $5\sqrt{2}$ h (b) $10\sqrt{2}$ h
(c) 0 h (d) 5 h
(2015 Cancelled)

8. A projectile is fired from the surface of the earth with a velocity of 5 m s^{-1} and angle θ with the horizontal. Another projectile fired from another planet with a velocity of 3 m s^{-1} at the same angle follows a trajectory which is identical with the trajectory of the projectile fired from the earth. The value of the acceleration due to gravity on the planet is (in m s^{-2}) is
(Given $g = 9.8$ m s^{-2})
(a) 3.5 (b) 5.9 (c) 16.3 (d) 110.8
(2014)

9. A particle is moving such that its position coordinates (x, y) are (2 m, 3 m) at time $t = 0$, (6 m, 7 m) at time $t = 2$ s and (13 m, 14 m) at time $t = 5$ s. Average velocity vector $(\vec{v}_{av})$ from $t = 0$ to $t = 5$ s is

(a) $\frac{1}{5}(13\hat{i}+14\hat{j})$ (b) $\frac{7}{3}(\hat{i}+\hat{j})$

(c) $2(\hat{i}+\hat{j})$ (d) $\frac{11}{5}(\hat{i}+\hat{j})$ *(2014)*

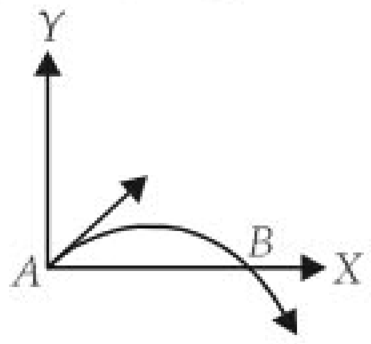
10. The velocity of a projectile at the initial point A is $(2\hat{i}+3\hat{j})$ m/s. It's velocity (in m/s) at point B is

(a) $2\hat{i}-3\hat{j}$

(b) $2\hat{i}+3\hat{j}$

(c) $-2\hat{i}-3\hat{j}$

(d) $-2\hat{i}+3\hat{j}$ *(NEET 2013)*



11. Vectors $\vec{A}$, $\vec{B}$ and $\vec{C}$ are such that $\vec{A}\cdot\vec{B}=0$ and $\vec{A}\cdot\vec{C}=0$. Then the vector parallel to $\vec{A}$ is

(a) $\vec{A}\times\vec{B}$ (b) $\vec{B}+\vec{C}$

(c) $\vec{B}\times\vec{C}$ (d) $\vec{B}$ and $\vec{C}$ *(Karnataka NEET 2013)*

12. The horizontal range and the maximum height of a projectile are equal. The angle of projection of the projectile is

(a) $\theta = \tan^{-1}\left(\frac{1}{4}\right)$ (b) $\theta = \tan^{-1}(4)$

(c) $\theta = \tan^{-1}(2)$ (d) $\theta = 45°$ *(2012)*

13. A particle has initial velocity $(2\vec{i}+3\vec{j})$ and acceleration $(0.3\vec{i}+0.2\vec{j})$. The magnitude of velocity after 10 seconds will be

(a) $9\sqrt{2}$ units (b) $5\sqrt{2}$ units

(c) 5 units (d) 9 units *(2012)*

14. A particle moves in a circle of radius 5 cm with constant speed and time period 0.2π s. The acceleration of the particle is

(a) 15 m/s^2 (b) 25 m/s^2

(c) 36 m/s^2 (d) 5 m/s^2 *(2011)*

15. A missile is fired for maximum range with an initial velocity of 20 m/s. If g = 10 m/s^2, the range of the missile is

(a) 40 m (b) 50 m

(c) 60 m (d) 20 m *(2011)*

16. A body is moving with velocity 30 m/s towards east. After 10 seconds its velocity becomes 40 m/s towards north. The average acceleration of the body is

(a) 1 m/s^2 (b) 7 m/s^2

(c) $\sqrt{7}$ m/s^2 (d) 5 m/s^2 *(2011)*

17. A projectile is fired at an angle of 45° with the horizontal. Elevation angle of the projectile at its highest point as seen from the point of projection, is

(a) 45° (b) 60°

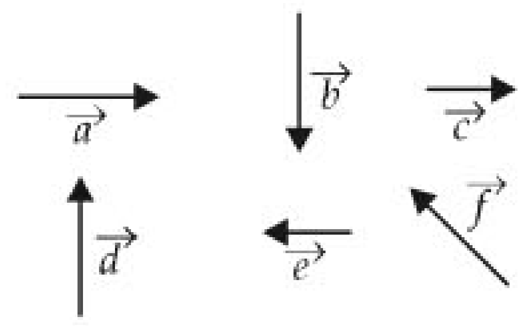
(c) $\tan^{-1}\left(\frac{1}{2}\right)$ (d) $\tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$ *(Mains 2011)*

18. A particle has initial velocity $(3\hat{i}+4\hat{j})$ and has acceleration $(0.4\hat{i}+0.3\hat{j})$. Its speed after 10 s is

(a) 7 units (b) $7\sqrt{2}$ units

(c) 8.5 units (d) 10 units *(2010)*

19. Six vectors, $\vec{a}$ through $\vec{f}$ have the magnitudes and directions indicated in the figure. Which of the following statements is true?



(a) $\vec{b}+\vec{c}=\vec{f}$ (b) $\vec{d}+\vec{c}=\vec{f}$

(c) $\vec{d}+\vec{e}=\vec{f}$ (d) $\vec{b}+\vec{e}=\vec{f}$ *(2010)*

20. The speed of a projectile at its maximum height is half of its initial speed. The angle of projection is

(a) 60° (b) 15° (c) 30° (d) 45° *(Mains 2010)*

21. A particle moves in x-y plane according to rule $x = a\sin\omega t$ and $y = a\cos\omega t$. The particle follows

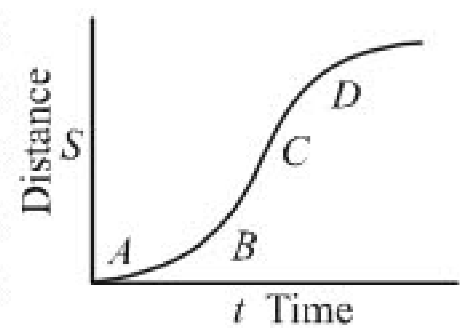
(a) an elliptical path

(b) a circular path

(c) a parabolic path

(d) a straight line path inclined equally to x and y-axes *(Mains 2010)*

22. A particle shows distance - time curve as given in this figure. The maximum instantaneous velocity of the particle is around the point



(a) D (b) A

(c) B (d) C *(2008)*

23. A particle of mass m is projected with velocity v making an angle of 45° with the horizontal.

When the particle lands on the level ground the magnitude of the change in its momentum will be
(a) $mv\sqrt{2}$ (b) zero
(c) $2mv$ (d) $mv/\sqrt{2}$ *(2008)*

24. $\vec{A}$ and $\vec{B}$ are two vectors and θ is the angle between them, if $|\vec{A}\times\vec{B}| = \sqrt{3}(\vec{A}\cdot\vec{B})$, the value of θ is
(a) 45° (b) 30°
(c) 90° (d) 60°. *(2007)*

25. A particle starting from the origin (0, 0) moves in a straight line in the (x, y) plane. Its coordinates at a later time are $(\sqrt{3}, 3)$. The path of the particle makes with the x-axis an angle of
(a) 45° (b) 60°
(c) 0° (d) 30°. *(2007)*

26. For angles of projection of a projectile at angle (45° − θ) and (45° + θ), the horizontal range described by the projectile are in the ratio of
(a) 2 : 1 (b) 1 : 1
(c) 2 : 3 (d) 1 : 2. *(2006)*

27. The vectors $\vec{A}$ and $\vec{B}$ are such that $|\vec{A}+\vec{B}| = |\vec{A}-\vec{B}|$. The angle between the two vectors is
(a) 45° (b) 90° (c) 60° (d) 75°. *(2006, 1996, 1991)*

28. Two boys are standing at the ends A and B of a ground where $AB = a$. The boy at B starts running in a direction perpendicular to AB with velocity v_1. The boy at A starts running simultaneously with velocity v and catches the other in a time t, where t is
(a) $\dfrac{a}{\sqrt{v^2+v_1^2}}$ (b) $\dfrac{a}{v+v_1}$
(c) $\dfrac{a}{v-v_1}$ (d) $\sqrt{\dfrac{a^2}{v^2-v_1^2}}$. *(2005)*

29. A stone tied to the end of a string of 1 m long is whirled in a horizontal circle with a constant speed. If the stone makes 22 revolutions in 44 seconds, what is the magnitude and direction of acceleration of the stone?
(a) π^2 m s^{-2} and direction along the radius towards the centre
(b) π^2 m s^{-2} and direction along the radius away from the centre
(c) π^2 m s^{-2} and direction along the tangent to the circle
(d) $\pi^2/4$ ms^{-2} and direction along the radius towards the centre. *(2005)*

30. If the angle between the vectors $\vec{A}$ and $\vec{B}$ is θ, the value of the product $(\vec{B}\times\vec{A})\cdot\vec{A}$ is equal to
(a) $BA^2\sin\theta$ (b) $BA^2\cos\theta$
(c) $BA^2\sin\theta\cos\theta$ (d) zero. *(2005, 1989)*

31. If a vector $2\hat{i}+3\hat{j}+8\hat{k}$ is perpendicular to the vector $4\hat{j}-4\hat{i}+\alpha\hat{k}$, then the value of α is
(a) 1/2 (b) −1/2
(c) 1 (d) −1. *(2005)*

32. If $|\vec{A}\times\vec{B}| = \sqrt{3}\vec{A}\cdot\vec{B}$ then the value of $|\vec{A}+\vec{B}|$ is
(a) $(A^2+B^2+AB)^{1/2}$
(b) $\left(A^2+B^2+\dfrac{AB}{\sqrt{3}}\right)^{1/2}$
(c) $A+B$
(d) $\left(A^2+B^2+\sqrt{3}AB\right)^{1/2}$. *(2004)*

33. The vector sum of two forces is perpendicular to their vector differences. In that case, the forces
(a) are equal to each other
(b) are equal to each other in magnitude
(c) are not equal to each other in magnitude
(d) cannot be predicted. *(2003)*

34. A particle moves along a circle of radius $\left(\dfrac{20}{\pi}\right)$ m with constant tangential acceleration. If the velocity of the particle is 80 m/s at the end of the second revolution after motion has begun, the tangential acceleration is
(a) 40 m/s² (b) 640π m/s²
(c) 160π m/s² (d) 40π m/s². *(2003)*

35. A particle A is dropped from a height and another particle B is projected in horizontal direction with speed of 5 m/sec from the same height then correct statement is
(a) particle A will reach at ground first with respect to particle B
(b) particle B will reach at ground first with respect to particle A
(c) both particles will reach at ground simultaneously
(d) both particles will reach at ground with

same speed. *(2002)*

36. An object of mass 3 kg is at rest. Now a force of $\vec{F} = 6t^2\hat{i} + 4t\hat{j}$ is applied on the object then velocity of object at $t = 3$ sec. is
(a) $18\hat{i} + 3\hat{j}$ (b) $18\hat{i} + 6\hat{j}$
(c) $3\hat{i} + 18\hat{j}$ (d) $18\hat{i} + 4\hat{j}$. *(2002)*

37. If $|\vec{A}+\vec{B}| = |\vec{A}| + |\vec{B}|$ then angle between A and B will be
(a) 90° (b) 120°
(c) 0° (d) 60°. *(2001)*

38. Two particles having mass M and m are moving in a circular path having radius R and r. If their time period are same then the ratio of angular velocity will be
(a) $\frac{r}{R}$ (b) $\frac{R}{r}$
(c) 1 (d) $\sqrt{\frac{R}{r}}$. *(2001)*

39. The width of river is 1 km. The velocity of boat is 5 km/hr. The boat covered the width of river in shortest time 15 min. Then the velocity of river stream is
(a) 3 km/hr (b) 4 km/hr
(c) $\sqrt{29}$ km/hr (d) $\sqrt{41}$ km/hr. *(2000, 1998)*

40. Two projectiles of same mass and with same velocity are thrown at an angle 60° and 30° with the horizontal, then which will remain same
(a) time of flight
(b) range of projectile
(c) maximum height acquired
(d) all of them. *(2000)*

41. A man is slipping on a frictionless inclined plane and a bag falls down from the same height. Then the velocity of both is related as
(a) $v_B > v_m$
(b) $v_B < v_m$
(c) $v_B = v_m$
(d) v_B and v_m can't be related. *(2000)*

42. A 500 kg car takes a round turn of radius 50 m with a velocity of 36 km/hr. The centripetal force is
(a) 1000 N (b) 750 N
(c) 250 N (d) 1200 N *(1999)*

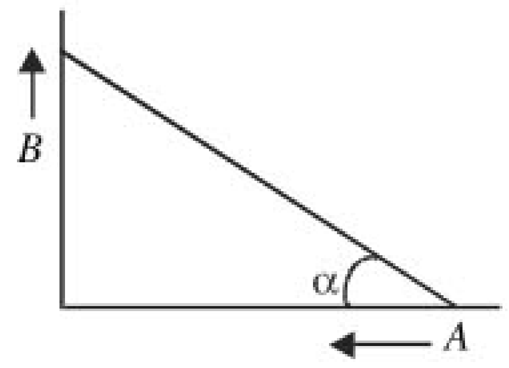
43. A person aiming to reach exactly opposite point on the bank of a stream is swimming with a speed of 0.5 m/s at an angle of 120° with the direction of flow of water. The speed of water in the stream, is
(a) 0.25 m/s (b) 0.5 m/s
(c) 1.0 m/s (d) 0.433 m/s *(1999)*

44. Two racing cars of masses m_1 and m_2 are moving in circles of radii r_1 and r_2 respectively. Their speeds are such that each makes a complete circle in the same time t. The ratio of the angular speeds of the first to the second car is
(a) $r_1 : r_2$ (b) $m_1 : m_2$
(c) 1 : 1 (d) $m_1 m_2 : r_1 r_2$ *(1999)*

45. If a unit vector is represented by $0.5\hat{i} - 0.8\hat{j} + c\hat{k}$ then the value of c is
(a) $\sqrt{0.01}$ (b) $\sqrt{0.11}$
(c) 1 (d) $\sqrt{0.39}$. *(1999)*

46. What is the value of linear velocity, if $\vec{r} = 3\hat{i} - 4\hat{j} + \hat{k}$ and $\vec{\omega} = 5\hat{i} - 6\hat{j} + 6\hat{k}$?
(a) $4\hat{i} - 13\hat{j} + 6\hat{k}$ (b) $18\hat{i} + 13\hat{j} - 2\hat{k}$
(c) $6\hat{i} + 2\hat{j} - 3\hat{k}$ (d) $6\hat{i} - 2\hat{j} + 8\hat{k}$. *(1999)*

47. Two particles A and B are connected by a rigid rod AB. The rod slides along perpendicular rails as shown here. The velocity of A to the left is 10 m/s. What is the velocity of B when angle $\alpha = 60°$?



(a) 10 m/s (b) 9.8 m/s
(c) 5.8 m/s (d) 17.3 m/s. *(1998)*

48. A ball of mass 0.25 kg attached to the end of a string of length 1.96 m is moving in a horizontal circle. The string will break if the tension is more than 25 N. What is the maximum speed with which the ball can be moved?
(a) 5 m/s (b) 3 m/s
(c) 14 m/s (d) 3.92 m/s. *(1998)*

49. Identify the vector quantity among the following
(a) distance (b) angular momentum
(c) heat (d) energy. *(1997)*

50. A body is whirled in a horizontal circle of radius 20 cm. It has an angular velocity of 10 rad/s. What is its linear velocity at any point on circular path?
(a) 20 m/s (b) $\sqrt{2}$ m/s
(c) 10 m/s (d) 2 m/s. *(1996)*

51. The position vector of a particle is $\vec{r} = (a\cos\omega t)\hat{i} + (a\sin\omega t)\hat{j}$. The velocity of the particle is

(a) directed towards the origin
(b) directed away from the origin
(c) parallel to the position vector
(d) perpendicular to the position vector. *(1995)*

52. The angular speed of a flywheel making 120 revolutions/minute is

(a) 4π rad/s (b) $4\pi^2$ rad/s
(c) π rad/s (d) 2π rad/s. *(1995)*

53. The angle between the two vectors $\vec{A} = 3\hat{i} + 4\hat{j} + 5\hat{k}$ and $\vec{B} = 3\hat{i} + 4\hat{j} - 5\hat{k}$ will be

(a) 90° (b) 180°
(c) zero (d) 45°. *(1994)*

54. A boat is sent across a river with a velocity of 8 km h^{-1}. If the resultant velocity of boat is 10 km h^{-1}, then velocity of river is

(a) 12.8 km h^{-1} (b) 6 km h^{-1}
(c) 8 km h^{-1} (d) 10 km h^{-1} *(1994, 1993)*

55. If a body A of mass M is thrown with velocity v at an angle of 30° to the horizontal and another body B of the same mass is thrown with the same speed at an angle of 60° to the horizontal, the ratio of horizontal range of A to B will be

(a) 1 : 3 (b) 1 : 1
(c) $1:\sqrt{3}$ (d) $\sqrt{3}:1$. *(1992, 90)*

56. The resultant of $\vec{A} \times 0$ will be equal to

(a) zero (b) A
(c) zero vector (d) unit vector. *(1992)*

57. An electric fan has blades of length 30 cm measured from the axis of rotation. If the fan is rotating at 120 rpm, the acceleration of a point on the tip of the blade is

(a) 1600 m s^{-2} (b) 47.4 m s^{-2}
(c) 23.7 m s^{-2} (d) 50.55 m s^{-2} *(1990)*

58. The maximum range of a gun of horizontal terrain is 16 km. If g = 10 ms^{-2}, then muzzle velocity of a shell must be

(a) 160 m s^{-1} (b) $200\sqrt{2}$ m s^{-1}
(c) 400 m s^{-1} (d) 800 m s^{-1} *(1990)*

59. A bus is moving on a straight road towards north with a uniform speed of 50 km/hour then it turns left through 90°. If the speed remains unchanged after turning, the increase in the velocity of bus in the turning process is

(a) 70.7 km/hr along south-west direction
(b) zero
(c) 50 km/hr along west
(d) 70.7 km/hr along north-west direction *(1989)*

60. The magnitude of vectors $\vec{A}, \vec{B}$ and $\vec{C}$ are 3, 4 and 5 units respectively. If $\vec{A} + \vec{B} = \vec{C}$, the angle between $\vec{A}$ and $\vec{B}$ is

(a) $\pi/2$ (b) $\cos^{-1}(0.6)$
(c) $\tan^{-1}(7/5)$ (d) $\pi/4$. *(1988)*

61. A train of 150 metre 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

(a) 12 sec (b) 8 sec
(c) 15 sec (d) 10 sec. *(1988)*

Answer Key

1.	(b)	**2.**	(c)	**3.**	(d)	**4.**	(a)	**5.**	(a)	**6.**	(a)	**7.**	(d)	**8.**	(a)	**9.**	(d)	**10.**	(a)
11.	(c)	**12.**	(b)	**13.**	(b)	**14.**	(d)	**15.**	(a)	**16.**	(d)	**17.**	(c)	**18.**	(b)	**19.**	(c)	**20.**	(a)
21.	(b)	**22.**	(d)	**23.**	(a)	**24.**	(d)	**25.**	(b)	**26.**	(b)	**27.**	(b)	**28.**	(d)	**29.**	(a, b)	**30.**	(d)
31.	(b)	**32.**	(a)	**33.**	(b)	**34.**	(a)	**35.**	(c)	**36.**	(b)	**37.**	(c)	**38.**	(c)	**39.**	(a)	**40.**	(b)
41.	(c)	**42.**	(a)	**43.**	(a)	**44.**	(c)	**45.**	(b)	**46.**	(b)	**47.**	(d)	**48.**	(c)	**49.**	(b)	**50.**	(d)
51.	(d)	**52.**	(a)	**53.**	(a)	**54.**	(b)	**55.**	(b)	**56.**	(c)	**57.**	(b)	**58.**	(c)	**59.**	(a)	**60.**	(a)
61.	(d)																		

EXPLANATIONS

1. **(b) :** $x = 5t - 2t^2, y = 10t$

$$\frac{dx}{dt} = 5 - 4t, \quad \frac{dy}{dt} = 10 \qquad \therefore \quad v_x = 5 - 4t, v_y = 10$$

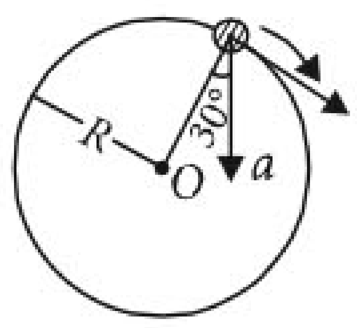
$$\frac{dv_x}{dt} = -4, \quad \frac{dv_y}{dt} = 0 \qquad \therefore \quad a_x = -4, a_y = 0$$

Acceleration, $\vec{a} = a_x\hat{i} + a_y\hat{j} = -4\hat{i}$

$\therefore$ The acceleration of the particle at t = 2 s is -4 m s^{-2}.

2. **(c) :** Here, a = 15 m s^{-2}
R = 2.5 m

From figure,



$a_c = a\cos 30° = 15 \times \frac{\sqrt{3}}{2}$ m s^{-2}

As we know, $a_c = \frac{v^2}{R} \Rightarrow v = \sqrt{a_c R}$

$$\therefore \quad v = \sqrt{15 \times \frac{\sqrt{3}}{2} \times 2.5} = 5.69 \simeq 5.7 \text{ m s}^{-1}$$

3. **(d) :** Let the two vectors be $\vec{A}$ and $\vec{B}$.

Then, magnitude of sum of $\vec{A}$ and $\vec{B}$,

$$|\vec{A}+\vec{B}| = \sqrt{A^2 + B^2 + 2AB\cos\theta}$$

and magnitude of difference of $\vec{A}$ and $\vec{B}$,

$$|\vec{A}-\vec{B}| = \sqrt{A^2 + B^2 - 2AB\cos\theta},$$

$$|\vec{A}+\vec{B}| = |\vec{A}-\vec{B}| \text{ (given)}$$

or $\sqrt{A^2 + B^2 + 2AB\cos\theta} = \sqrt{A^2 + B^2 - 2AB\cos\theta}$

$\Rightarrow$ $4AB\cos\theta = 0$

$\because$ $4AB \neq 0$, $\therefore \cos\theta = 0$ or $\theta = 90°$

4. **(a) :** Given, $\vec{r} = \cos\omega t\ \hat{x} + \sin\omega t\ \hat{y}$

$$\therefore \quad \vec{v} = \frac{d\vec{r}}{dt} = -\omega\sin\omega t\ \hat{x} + \omega\cos\omega t\ \hat{y}$$

$$\vec{a} = \frac{d\vec{v}}{dt} = -\omega^2\cos\omega t\ \hat{x} - \omega^2\sin\omega t\ \hat{y} = -\omega^2\vec{r}$$

Since position vector $(\vec{r})$ is directed away from the origin, so, acceleration $(-\omega^2\vec{r})$ is directed towards the origin.

Also,

$\vec{r}\cdot\vec{v} = (\cos\omega t\ \hat{x} + \sin\omega t\ \hat{y})\cdot(-\omega\sin\omega t\ \hat{x} + \omega\cos\omega t\ \hat{y})$

$= -\omega\sin\omega t\cos\omega t + \omega\sin\omega t\cos\omega t = 0$

$\Rightarrow \quad \vec{r} \perp \vec{v}$

5. **(a) :** Two vectors $\vec{A}$ and $\vec{B}$ are orthogonal to each other, if their scalar product is zero *i.e.* $\vec{A}\cdot\vec{B} = 0$.

Here, $\vec{A} = \cos\omega t\ \hat{i} + \sin\omega t\ \hat{j}$

and $\vec{B} = \cos\frac{\omega t}{2}\hat{i} + \sin\frac{\omega t}{2}\hat{j}$

$$\therefore \quad \vec{A}\cdot\vec{B} = (\cos\omega t\hat{i} + \sin\omega t\hat{j})\cdot\left(\cos\frac{\omega t}{2}\hat{i} + \sin\frac{\omega t}{2}\hat{j}\right)$$

$$= \cos\omega t\cos\frac{\omega t}{2} + \sin\omega t\sin\frac{\omega t}{2}$$

$(\because \hat{i}\cdot\hat{i} = \hat{j}\cdot\hat{j} = 1 \text{ and } \hat{i}\cdot\hat{j} = \hat{j}\cdot\hat{i} = 0)$

$$= \cos\left(\omega t - \frac{\omega t}{2}\right)$$

$(\because \cos(A - B) = \cos A\cos B + \sin A\sin B)$

But $\vec{A}\cdot\vec{B} = 0$ (as $\vec{A}$ and $\vec{B}$ are orthogonal to each other)

$$\therefore \quad \cos\left(\omega t - \frac{\omega t}{2}\right) = 0$$

$$\cos\left(\omega t - \frac{\omega t}{2}\right) = \cos\frac{\pi}{2} \text{ or } \omega t - \frac{\omega t}{2} = \frac{\pi}{2}$$

$$\frac{\omega t}{2} = \frac{\pi}{2} \text{ or } t = \frac{\pi}{\omega}$$

6. **(a) :** Here, $\vec{R} = 4\sin(2\pi t)\hat{i} + 4\cos(2\pi t)\hat{j}$

The velocity of the particle is

$$\vec{v} = \frac{d\vec{R}}{dt} = \frac{d}{dt}[4\sin(2\pi t)\hat{i} + 4\cos(2\pi t)\hat{j}]$$

$$= 8\pi\cos(2\pi t)\hat{i} - 8\pi\sin(2\pi t)\hat{j}$$

Its magnitude is

$$|\vec{v}| = \sqrt{(8\pi\cos(2\pi t))^2 + (-8\pi\sin(2\pi t))^2}$$

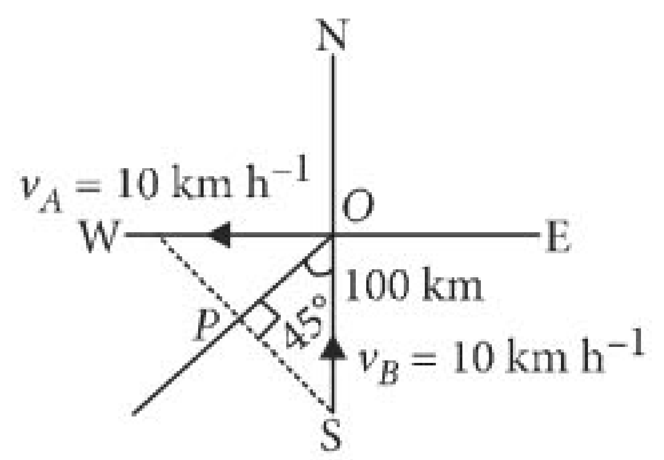
$$= \sqrt{64\pi^2\cos^2(2\pi t) + 64\pi^2\sin^2(2\pi t)}$$

$$= \sqrt{64\pi^2[\cos^2(2\pi t) + \sin^2(2\pi t)]}$$

$= \sqrt{64\pi^2}$ (as $\sin^2\theta + \cos^2\theta = 1$)

$= 8\pi$ m/s

7. **(d) :** Given situation is shown in the figure.



Velocity of ship A,

v_A = 10 km h^{-1} towards west

Velocity of ship B,

v_B = 10 km h^{-1} towards north

OS = 100 km

OP = shortest distance

Relative velocity between A and B is

$$v_{AB} = \sqrt{v_A^2 + v_B^2} = 10\sqrt{2} \text{ km h}^{-1}$$

$$\cos 45° = \frac{OP}{OS}; \frac{1}{\sqrt{2}} = \frac{OP}{100}$$

$$OP = \frac{100}{\sqrt{2}} = \frac{100\sqrt{2}}{2} = 50\sqrt{2} \text{ km}$$

The time after which distance between them equals to OP is given by

$$t = \frac{OP}{v_{AB}} = \frac{50\sqrt{2}}{10\sqrt{2}} \Rightarrow t = 5 \text{ h}$$

8. (a) : The equation of trajectory is

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

where θ is the angle of projection and u is the velocity with which projectile is projected.

For equal trajectories and for same angles of projection,

$$\frac{g}{u^2} = \text{constant}$$

As per question, $\frac{9.8}{5^2} = \frac{g'}{3^2}$

where g' is acceleration due to gravity on the planet.

$$g' = \frac{9.8 \times 9}{25} = 3.5 \text{ m s}^{-2}$$

9. (d) : At time t = 0, the position vector of the particle is

$$\vec{r}_1 = 2\hat{i} + 3\hat{j}$$

At time t = 5 s, the position vector of the particle is

$$\vec{r}_2 = 13\hat{i} + 14\hat{j}$$

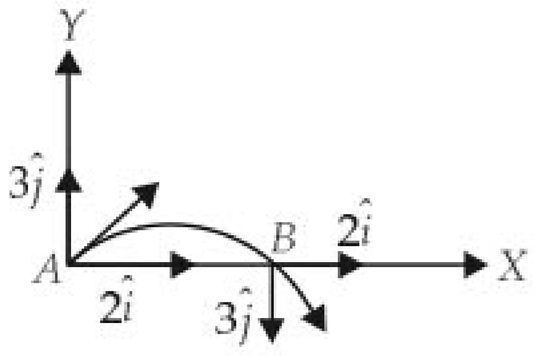
Displacement from $\vec{r}_1$ to $\vec{r}_2$ is

$$\Delta\vec{r} = \vec{r}_2 - \vec{r}_1 = (13\hat{i} + 14\hat{j}) - (2\hat{i} + 3\hat{j}) = 11\hat{i} + 11\hat{j}$$

$\therefore$ Average velocity,

$$\vec{v}_{av} = \frac{\Delta\vec{r}}{\Delta t} = \frac{11\hat{i} + 11\hat{j}}{5 - 0} = \frac{11}{5}(\hat{i} + \hat{j})$$

10. (a) :



At point B X component of velocity remains unchanged while Y component reverses its direction.

$\therefore$ The velocity of the projectile at point B is $2\hat{i} - 3\hat{j}$ m/s.

11. (c) : Vector triple product of three vectors $\vec{A}$, $\vec{B}$ and $\vec{C}$ is

$$\vec{A} \times (\vec{B} \times \vec{C}) = (\vec{A} \cdot \vec{C})\vec{B} - (\vec{A} \cdot \vec{B})\vec{C}$$

Given: $\vec{A} \cdot \vec{B} = 0$, $\vec{A} \cdot \vec{C} = 0$

$$\therefore \quad \vec{A} \times (\vec{B} \times \vec{C}) = 0$$

Thus the vector $\vec{A}$ is parallel to vector $\vec{B} \times \vec{C}$.

12. (b) : Horizontal range, $R = \frac{u^2 \sin 2\theta}{g}$

where u is the velocity of projection and θ is the angle of projection

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

According to question $R = H$

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

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

$\tan\theta = 4$ or $\theta = \tan^{-1}(4)$

13. (b) : Here, $\vec{u} = 2\hat{i} + 3\hat{j}$, $\vec{a} = 0.3\hat{i} + 0.2\hat{j}$, $t = 10$ s

As $\vec{v} = \vec{u} + \vec{a}t$

$$\therefore \quad \vec{v} = (2\hat{i} + 3\hat{j}) + (0.3\hat{i} + 0.2\hat{j})(10)$$

$$= 2\hat{i} + 3\hat{j} + 3\hat{i} + 2\hat{j} = 5\hat{i} + 5\hat{j}$$

$$|\vec{v}| = \sqrt{(5)^2 + (5)^2} = 5\sqrt{2} \text{ units}$$

14. (d) : Here, Radius, R = 5 cm = 5 × 10^{-2} m

Time period, $T = 0.2\pi$ s

Centripetal acceleration

$$a_c = \omega^2 R = \left(\frac{2\pi}{T}\right)^2 R = \left(\frac{2\pi}{0.2\pi}\right)^2 (5 \times 10^{-2}) = 5 \text{ m/s}^2$$

As particle moves with constant speed, therefore its tangential acceleration is zero. So, $a_t = 0$

The acceleration of the particle is

$$a = \sqrt{a_c^2 + a_t^2} = a_c = 5\ \text{m/s}^2$$

It acts towards the centre of the circle.

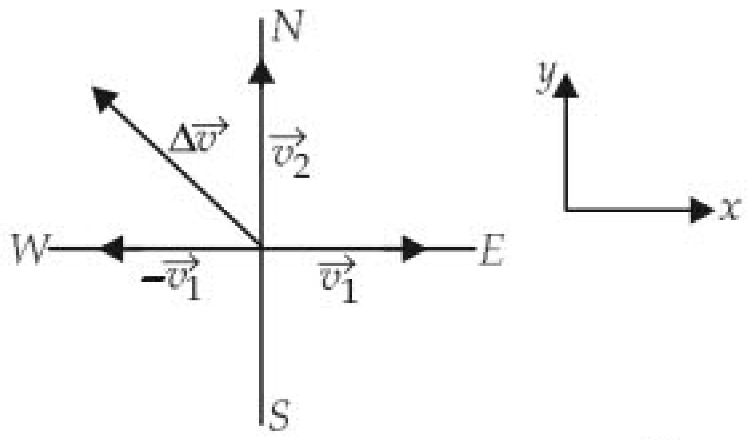
15. (a) : Here, $u = 20$ m/s, $g = 10$ m/s²

For maximum range, angle of projection is $\theta = 45°$

$$\therefore\ R_{\max} = \frac{u^2 \sin 90°}{g} = \frac{u^2}{g} \qquad \left(\because R = \frac{u^2 \sin 2\theta}{g}\right)$$

$$= \frac{(20\ \text{m/s})^2}{(10\ \text{m/s}^2)} = 40\ \text{m}$$

16. (d) :



Velocity towards east direction, $\vec{v}_1 = 30\hat{i}$ m/s

Velocity towards north direction, $\vec{v}_2 = 40\hat{j}$ m/s

Change in velocity, $\Delta\vec{v} = \vec{v}_2 - \vec{v}_1 = (40\hat{j} - 30\hat{i})$

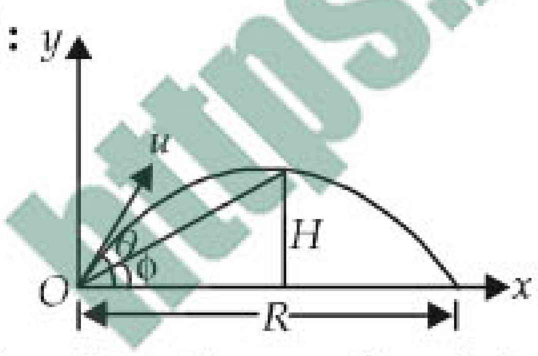
$\therefore\ |\Delta\vec{v}| = |40\hat{j} - 30\hat{i}| = 50$ m/s

Average acceleration, $\vec{a}_{av} = \dfrac{\text{Change in velocity}}{\text{Time interval}}$

$$\vec{a}_{av} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t} = \frac{\Delta\vec{v}}{\Delta t}$$

$$|\vec{a}_{av}| = \frac{|\Delta\vec{v}|}{\Delta t} = \frac{50\ \text{m/s}}{10\ \text{s}} = 5\ \text{m/s}^2$$

17. (c) :



Let ϕ be elevation angle of the projectile at its highest point as seen from the point of projection O and θ be angle of projection with the horizontal.

From figure, $\tan\phi = \dfrac{H}{R/2}$ ...(i)

In case of projectile motion

Maximum height, $H = \dfrac{u^2 \sin^2\theta}{2g}$

Horizontal range, $R = \dfrac{u^2 \sin 2\theta}{g}$

Substituting these values of H and R in (i), we get

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

$$\tan\phi = \frac{\sin^2\theta}{\sin 2\theta} = \frac{\sin^2\theta}{2\sin\theta\cos\theta} = \frac{1}{2}\tan\theta$$

$$\tan\phi = \frac{1}{2}\tan 45° = \frac{1}{2}$$

Here, $\theta = 45°$

$$\therefore\ \tan\phi = \frac{1}{2}\tan 45° = \frac{1}{2} \qquad (\because \tan 45° = 1)$$

$$\phi = \tan^{-1}\left(\frac{1}{2}\right)$$

18. (b) : Here,

Initial velocity, $\vec{u} = 3\hat{i} + 4\hat{j}$

Acceleration, $\vec{a} = 0.4\hat{i} + 0.3\hat{j}$

Time, $t = 10$ s

Let $\vec{v}$ be velocity of a particle after 10 s.

Using, $\vec{v} = \vec{u} + \vec{a}t$

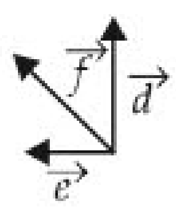
$$\therefore\ \vec{v} = (3\hat{i} + 4\hat{j}) + (0.4\hat{i} + 0.3\hat{j})(10)$$

$$= 3\hat{i} + 4\hat{j} + 4\hat{i} + 3\hat{j} = 7\hat{i} + 7\hat{j}$$

Speed of the particle after 10 s $= |\vec{v}|$

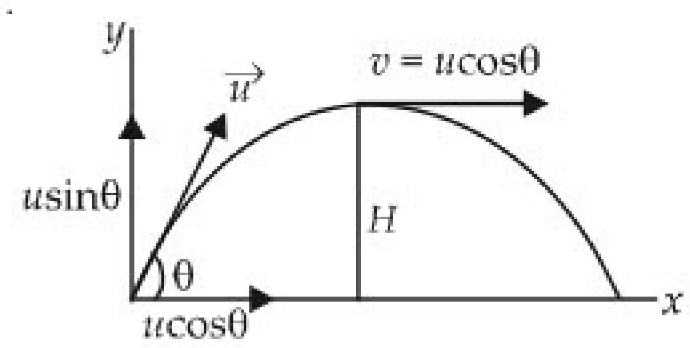
$$= \sqrt{(7)^2 + (7)^2} = 7\sqrt{2}\ \text{units}$$

19. (c) :



From figure, $\vec{d} + \vec{e} = \vec{f}$

20. (a) : Let v be velocity of a projectile at maximum height H.



$v = u\cos\theta$

According to given problem, $v = \dfrac{u}{2}$

$$\therefore\ \frac{u}{2} = u\cos\theta \Rightarrow \cos\theta = \frac{1}{2} \Rightarrow \theta = 60°$$

21. (b) : $x = a\sin\omega t$ or $\dfrac{x}{a} = \sin\omega t$ ...(i)

$y = a\cos\omega t$ or $\dfrac{y}{a} = \cos\omega t$ ...(ii)

Squaring and adding, we get

$$\frac{x^2}{a^2}+\frac{y^2}{a^2}=1 \qquad (\because \cos^2\omega t+\sin^2\omega t=1)$$

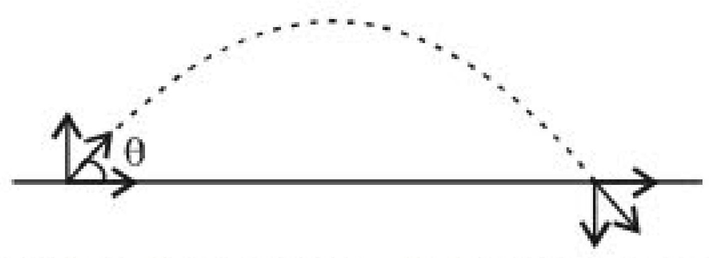
or $x^2+y^2=a^2$

This is the equation of a circle. Hence particle follows a circular path.

22. (d) : Because the slope is highest at C,

$$v=\frac{ds}{dt} \text{ is maximum.}$$

23. (a) :



The horizontal momentum does not change. The change in vertical momentum is

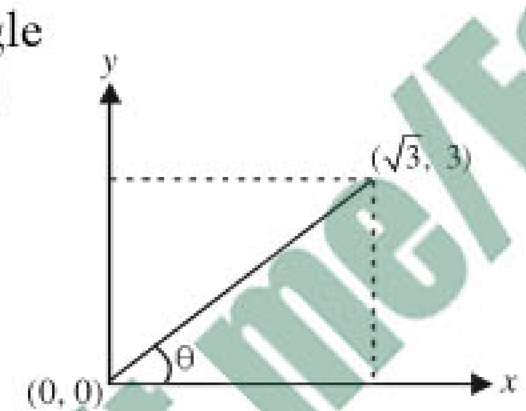
$$mv\sin\theta-(-mv\sin\theta)=2mv\frac{1}{\sqrt{2}}=\sqrt{2}mv$$

24. (d) : $|\vec{A}\times\vec{B}| = \sqrt{3}(\vec{A}\cdot\vec{B})$

$\therefore\ AB\sin\theta = \sqrt{3}AB\cos\theta$

or, $\tan\theta=\sqrt{3}$ or, $\theta=\tan^{-1}\sqrt{3}=60°$.

25. (b) : Let θ be the angle which the particle makes with an x-axis.



From figure,

$$\tan\theta=\frac{3}{\sqrt{3}}=\sqrt{3}$$

or, $\theta = \tan^{-1}(\sqrt{3}) = 60°$.

26. (b) : Horizontal range $R=\dfrac{u^2\sin 2\theta}{g}$

For angle of projection $(45° - \theta)$, the horizontal range is

$$\therefore\quad R_1=\frac{u^2\sin[2(45°-\theta)]}{g}=\frac{u^2\sin(90°-2\theta)}{g}=\frac{u^2\cos 2\theta}{g}$$

For angle of projection $(45° + \theta)$, the horizontal range is

$$R_2=\frac{u^2\sin[2(45°+\theta)]}{g}=\frac{u^2\sin(90°+2\theta)}{g}=\frac{u^2\cos 2\theta}{g}$$

$$\therefore\quad \frac{R_1}{R_2}=\frac{u^2\cos 2\theta/g}{u^2\cos 2\theta/g}=\frac{1}{1}.$$

$\therefore$ The range is the same.

27. (b) : Let θ be angle between $\vec{A}$ and $\vec{B}$

$|\vec{A}+\vec{B}|=|\vec{A}-\vec{B}|$, then $|\vec{A}+\vec{B}|^2=|\vec{A}-\vec{B}|^2$

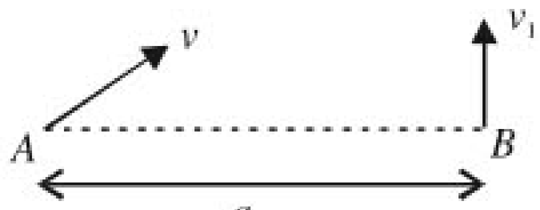
or $(\vec{A}+\vec{B})\cdot(\vec{A}+\vec{B})=(\vec{A}-\vec{B})\cdot(\vec{A}-\vec{B})$

or $\vec{A}\cdot\vec{A}+\vec{A}\cdot\vec{B}+\vec{B}\cdot\vec{A}+\vec{B}\cdot\vec{B}$

$$=\vec{A}\cdot\vec{A}-\vec{A}\cdot\vec{B}-\vec{B}\cdot\vec{A}+\vec{B}\cdot\vec{B}$$

or $4AB\cos\theta=0$ or $\cos\theta=0°$ or $\theta=90°$

28. (d) :



$$t=\frac{a}{v'}=\frac{a}{\sqrt{v^2-v_1^2}}$$

29. (a, b) : $a = r\omega^2$; $\omega = 2\pi\upsilon$

22 revolution = 44 sec

1 revolution = 44/22 = 2 sec.

υ = 1/2 Hz

$$a=r\omega^2=1\times\frac{4\pi^2}{4}=\pi^2 \text{ m/s}^2.$$

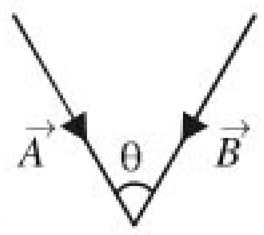
Towards the centre, the centripetal acceleration $= -\omega^2R$

and away from the centre, the centrifugal acceleration is $+\omega^2R$.

$\therefore$ (a) and (b) are correct as the directions are given.

30. (d) : Let $\vec{A}\times\vec{B}=\vec{C}$

The cross product of $\vec{B}$ and $\vec{A}$ is perpendicular to the plane containing $\vec{A}$ and $\vec{B}$ i.e. perpendicular to $\vec{A}$. If a dot product of this cross product and $\vec{A}$ is taken, as the cross product is perpendicular to $\vec{A}$, $\vec{C}\times\vec{A}=0$.



Therefore product of $(\vec{B}\times\vec{A})\cdot\vec{A}=0$.

31. (b) : $\vec{a}=2\hat{i}+3\hat{j}+8\hat{k}$, $\vec{b}=4\hat{j}-4\hat{i}+\alpha\hat{k}$

$\vec{a}\cdot\vec{b}=0$ if $\vec{a}\perp\vec{b}$

$(2\hat{i}+3\hat{j}+8\hat{k})\cdot(-4\hat{i}+4\hat{j}+\alpha\hat{k})=0$

or, $-8+12+8\alpha=0 \Rightarrow 4+8\alpha=0$

$\Rightarrow \alpha=-1/2$.

32. (a) : $|\vec{A}\times\vec{B}|=\sqrt{3}\vec{A}\cdot\vec{B}$

$|\vec{A}||\vec{B}|\sin\theta=\sqrt{3}|\vec{A}||\vec{B}|\cos\theta$

$\tan\theta=\sqrt{3}\Rightarrow\theta=60°$

$$|\vec{A}+\vec{B}|=\sqrt{|\vec{A}|^2+|\vec{B}|^2+2|\vec{A}||\vec{B}|\cos\theta}$$

$$=(A^2+B^2+AB)^{1/2}$$

33. (b) : Given : $(\vec{F}_1+\vec{F}_2)\perp(\vec{F}_1-\vec{F}_2)$

$\therefore (\vec{F}_1+\vec{F}_2)\cdot(\vec{F}_1-\vec{F}_2)=0$

$$F_1^2-F_2^2-\vec{F}_1\cdot\vec{F}_2+\vec{F}_2\cdot\vec{F}_1=0\Rightarrow F_1^2=F_2^2$$

i.e. F_1, F_2 are equal to each other in magnitude.

34. (a) : Given :

$r = \frac{20}{\pi}$ m, $v = 80$ m/s, $\theta = 2$ rev $= 4\pi$ rad.

From equation $\omega^2 = \omega_0^2 + 2\alpha\theta \quad (\omega_0 = 0)$

$\omega^2 = 2\alpha\theta \left(\omega = \frac{v}{r} \text{ and } a = r\alpha\right)$

$a = \frac{v^2}{2r\theta} = 40$ m/s^2.

35. (c) : Time required to reach the ground is dependent on the vertical motion of the particle. Vertical motion of both the particles A and B are exactly same. Although particle B has an initial velocity, but that is in horizontal direction and it has no component in vertical (component of a vector at a direction of 90° = 0) direction. Hence they will reach the ground simultaneously.

36. (b) : Mass, $m = 3$ kg, force, $F = 6t^2\,\hat{i} + 4t\,\hat{j}$

$\therefore$ acceleration,

$$a = F/m = \frac{6t^2\,\hat{i} + 4t\,\hat{j}}{3} = 2t^2\,\hat{i} + \frac{4}{3}t\,\hat{j}$$

Now, $a = \frac{dv}{dt} = 2t^2\,\hat{i} + \frac{4}{3}t\,\hat{j}$;

$\therefore\ dv = \left(2t^2\,\hat{i} + \frac{4}{3}t\,\hat{j}\right)dt \quad \therefore\ v = \int_0^3 \left(2t^2\,\hat{i} + \frac{4}{3}t\,\hat{j}\right)dt$

$= \left.\frac{2}{3}t^3\,\hat{i} + \frac{4}{6}t^2\,\hat{j}\,\right|_0^3 = 18\hat{i} + 6\,\hat{j}$.

37. (c) : $|\vec{A} + \vec{B}| = |\vec{A}| + |\vec{B}|$ if $\vec{A} \parallel \vec{B}$, $\theta = 0°$.

38. (c) : $\omega = \frac{2\pi}{t}$. t is same $\therefore \frac{\omega_1}{\omega_2} = 1$

39. (a) : $v_{\text{Resultant}} = \frac{1\text{ km}}{1/4\text{ hr}} = 4$ km/hr

$\therefore\ v_{\text{River}} = \sqrt{5^2 - 4^2} = 3$ km/hr

40. (b) : As $\theta_2 = (90 - \theta_1)$,

So range of projectile,

$$R_1 = \frac{v_0^2 \sin 2\theta}{g} = \frac{v_0^2\ 2\sin\theta\cos\theta}{g}$$

$$R_2 = \frac{v_0^2\ 2\sin(90-\theta_1)\cos(90-\theta_1)}{g}$$

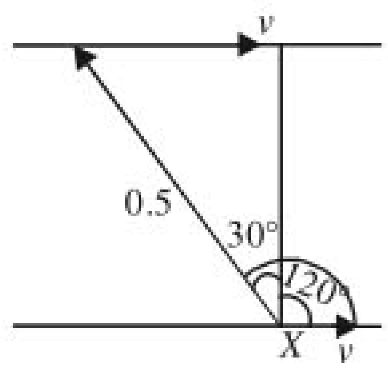
$$R_2 = \frac{v_0^2\ 2\cos\theta_1 \sin\theta_1}{g} = R_1$$

41. (c) : Vertical acceleration in both the cases is g, whereas horizontal velocity is constant.

42. (a) : $F_{\text{centripetal}} = \frac{mv^2}{R}$; $\quad v = \left(36 \times \frac{5}{18}\right)$ m/s

$$F_{\text{centripetal}} = \frac{500 \times \left(36 \times \frac{5}{18}\right)^2}{50} = 1000\text{ N}$$

43. (a) : Let v be the velocity of river water. As shown in figure,



$\sin 30° = \frac{v}{0.5}$

or, $v = 0.5 \sin 30°$

$= 0.5 \times (1/2) = 0.25$ m/s.

44. (c) : $t = \frac{2\pi}{\omega_1} = \frac{2\pi}{\omega_2} \Rightarrow \frac{\omega_1}{\omega_2} = \frac{1}{1}$

45. (b) : For a unit vector $\hat{n}, |\hat{n}| = 1$

$|0.5\hat{i} - 0.8\hat{j} + c\hat{k}|^2 = 1^2 \Rightarrow 0.25 + 0.64 + c^2 = 1$

or $c = \sqrt{0.11}$

46. (b) : $\vec{v} = \vec{\omega} \times \vec{r} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 5 & -6 & 6 \\ 3 & -4 & 1 \end{vmatrix} = 18\hat{i} + 13\hat{j} - 2\hat{k}$

47. (d) : Let particle B move upwards with velocity v, then $\tan 60° = \frac{v}{10}$; $\quad v = \sqrt{3} \times 10 = 17.3$ m/s.

48. (c) : $\frac{mv^2}{r} = 25$; $\quad v = \sqrt{\frac{25 \times 1.96}{0.25}} = 14$ m/s.

49. (b) : Since the angular momentum has both magnitude and direction, it is a vector quantity.

50. (d) : Radius of circle (r) = 20 cm = 0.2 m and angular velocity (ω) = 10 rad/s.

linear velocity $(v) = r\omega = 0.2 \times 10 = 2$ m/s.

51. (d) : Position vector of the particle

$\vec{r} = (a\cos\omega t)\,\hat{i} + (a\sin\omega t)\,\hat{j}$

velocity vector

$\vec{v} = \frac{d\vec{r}}{dt} = (-a\omega\sin\omega t)\hat{i} + (a\omega\cos\omega t)\hat{j}$

$= \omega\left[(-a\sin\omega t)\hat{i} + (a\cos\omega t)\hat{j}\right]$

$\vec{v}\cdot\vec{r} = \omega[(-a\sin\omega t)\hat{i} + (a\cos\omega t)\hat{j})]\cdot[(a\cos\omega t)\hat{i} + (a\sin\omega t)\hat{j})]$

$= \omega\,[-a^2\sin\omega t\cos\omega t + a^2\cos\omega t\sin\omega t] = 0$

Therefore velocity vector is perpendicular to the displacement vector.

52. (a) : Number of revolutions per minute $(n) = 120$.

Therefore angular speed (ω)

$= \frac{2\pi n}{60} = \frac{2\pi \times 120}{60} = 4\pi$ rad/s.

53. (a) : $\vec{A} = 3\hat{i} + 4\hat{j} + 5\hat{k}$ and $\vec{B} = 3\hat{i} + 4\hat{j} - 5\hat{k}$.

$\cos\theta = \frac{\vec{A}\cdot\vec{B}}{|\vec{A}||\vec{B}|}$

$$= \frac{(3\hat{i}+4\hat{j}+5\hat{k})\cdot(3\hat{i}+4\hat{j}-5\hat{k})}{[\sqrt{(3)^2+(4)^2+(5)^2}]\times[\sqrt{(3)^2+(4)^2+(5)^2}]}$$

$$= \frac{9+16-25}{50} = 0 \text{ or } \theta = 90^\circ.$$

54. (b) : Let the velocity of river be v_R and velocity of boat is v_B

$\therefore$ Resultant velocity $= \sqrt{v_B^2 + v_R^2 + 2v_Bv_R\cos\theta}$

$$(10) = \sqrt{v_B^2 + v_R^2 + 2v_Bv_R\cos 90^\circ}$$

$$(10) = \sqrt{(8)^2 + v_R^2} \quad \text{or} \quad (10)^2 = (8)^2 + v_R^2$$

$$v_R^2 = 100 - 64 \text{ or } v_R = 6 \text{ km/hr}$$

55. (b) : For the given velocity of projection u, the horizontal range is the same for the angle of projection θ and $90^\circ - \theta$

Horizontal range $R = \dfrac{u^2\sin 2\theta}{g}$

$\therefore$ For body A, $R_A = \dfrac{u^2\sin(2\times 30^\circ)}{g} = \dfrac{u^2\sin 60^\circ}{g}$

For body B, $R_B = \dfrac{u^2\sin(2\times 60^\circ)}{g}$

$$R_B = \frac{u^2\sin 120^\circ}{g} = \frac{u^2\sin(180^\circ - 60^\circ)}{g} = \frac{u^2\sin 60^\circ}{g}$$

The range is the same whether the angle is θ or $90^\circ - \theta$.

$\therefore$ The ratio of ranges is 1 : 1

56. (c) : The cross product $\vec{A}\times\vec{B}$ is a vector, with its direction perpendicular to both $\vec{A}$ and $\vec{B}$. $\vec{A}\times\vec{B}$ is area. If side B is zero, area is zero.

$\vec{A}\times 0$ is a zero vector.

If in case 0 is a scalar, then also the product is zero.
But a scalar × a vector is also a vector.
Hence one gets a zero vector in any case.

57. (b) : Frequency of rotation $\upsilon = 120$ rpm = 2 rps
length of blade $r = 30$ cm = 0.3 m
Centripetal acceleration $a = \omega^2 r = (2\pi\upsilon)^2 r$

$$= 4\pi^2\upsilon^2 r = 4\pi^2(2)^2(0.3) = 47.4 \text{ ms}^{-2}$$

58. (c) : Horizontal range $R = \dfrac{u^2\sin 2\theta}{g}$

For maximum horizontal range $\theta = 45^\circ$

or $R_m = \dfrac{u^2}{g}$

where u be muzzle velocity of a shell

$\therefore$ $(1600 \text{ m}) = \dfrac{u^2}{(10 \text{ ms}^{-2})^2}$ or $u = 400$ m s^{-1}.

59. (a) : v_1 = 50 km/hr due north
v_2 = 50 km/hr due west
$-v_1$ = 50 km/hr due south

Magnitude of change in velocity

$$= |\vec{v}_2 - \vec{v}_1| = |\vec{v}_2 + (-\vec{v}_1)|$$

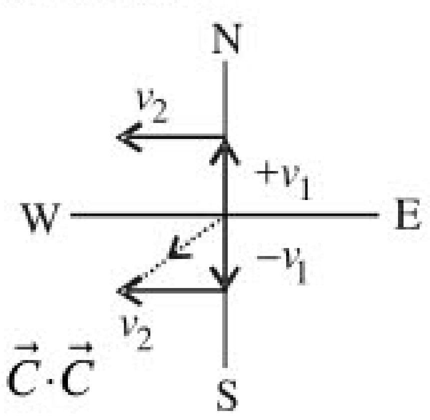
$$= \sqrt{v_2^2 + (-v_1)^2}$$

$$= \sqrt{(50)^2 + (50)^2} = 70.7 \text{ km/hr}$$

$\vec{v}$ = 70.7 km/hr along south-west direction

60. (a) : Let θ be angle between $\vec{A}$ and $\vec{B}$

Given : $A = |\vec{A}| = 3$ units
$B = |\vec{B}| = 4$ units
$C = |\vec{C}| = 5$ units
$\vec{A} + \vec{B} = \vec{C}$



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

$$\vec{A}\cdot\vec{A} + \vec{A}\cdot\vec{B} + \vec{B}\cdot\vec{A} + \vec{B}\cdot\vec{B} = \vec{C}\cdot\vec{C}$$

$$A^2 + 2AB\cos\theta + B^2 = C^2$$

$$9 + 2AB\cos\theta + 16 = 25 \text{ or } 2AB\cos\theta = 0$$

or $\cos\theta = 0 \therefore \theta = 90^\circ$.

61. (d) : Choose the positive direction of x-axis to be from south to north. Then

Velocity of train $v_T = +10$ m s^{-1}
Velocity of parrot $v_P = -5$ m s^{-1}

Relative velocity of parrot with respect to train

$= v_P - v_T = (-5 \text{ ms}^{-1}) - (+10 \text{ ms}^{-1}) = -15$ m s^{-1}

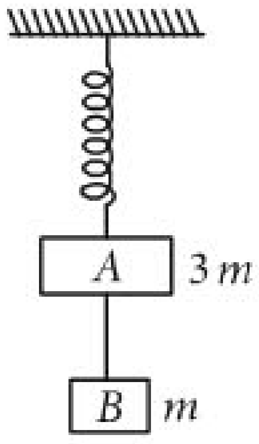
i.e. parrot appears to move with a speed of 15 m s^{-1} from north to south

$\therefore$ Time taken by parrot to cross the train

$$= \frac{150 \text{ m}}{15 \text{ m s}^{-1}} = 10 \text{ s}$$

Chapter 4 Laws of Motion

1. Two blocks A and B of masses $3m$ and m respectively are connected by a massless and inextensible string. The whole system is suspended by a massless spring as shown in figure. The magnitudes of acceleration of A and B immediately after the string is cut, are respectively



(a) $\frac{g}{3}, g$ (b) g, g (c) $\frac{g}{3}, \frac{g}{3}$ (d) $g, \frac{g}{3}$

(NEET 2017)

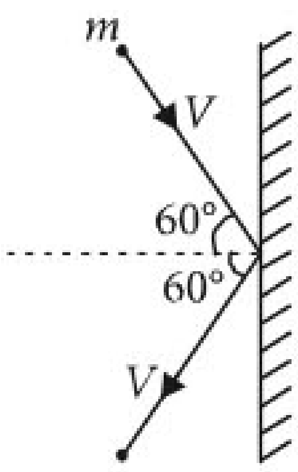
2. One end of string of length l is connected to a particle of mass 'm' and the other end is connected to a small peg on a smooth horizontal table. If the particle moves in circle with speed 'v', the net force on the particle (directed towards centre) will be (T represents the tension in the string)

(a) $T + \frac{mv^2}{l}$ (b) $T - \frac{mv^2}{l}$

(c) zero (d) T

(NEET 2017)

3. A rigid ball of mass m strikes a rigid wall at 60° and gets reflected without loss of speed as shown in the figure. The value of impulse imparted by the wall on the ball will be



(a) mV (b) $2mV$

(c) $\frac{mV}{2}$ (d) $\frac{mV}{3}$

(NEET-II 2016)

4. A car is negotiating a curved road of radius R. The road is banked at an angle θ. The coefficient of friction between the tyres of the car and the road is μ_s. The maximum safe velocity on this road is

(a) $\sqrt{\frac{g}{R}\frac{\mu_s + \tan\theta}{1 - \mu_s\tan\theta}}$ (b) $\sqrt{\frac{g}{R^2}\frac{\mu_s + \tan\theta}{1 - \mu_s\tan\theta}}$

(c) $\sqrt{gR^2\frac{\mu_s + \tan\theta}{1 - \mu_s\tan\theta}}$ (d) $\sqrt{gR\frac{\mu_s + \tan\theta}{1 - \mu_s\tan\theta}}$

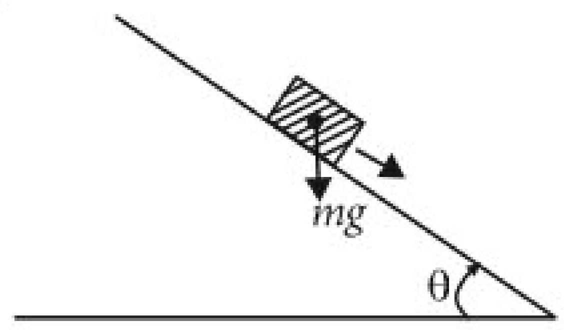
(NEET-I 2016)

5. Two stones of masses m and $2m$ are whirled in horizontal circles, the heavier one in a radius $\frac{r}{2}$ and the lighter one in radius r. The tangential speed of lighter stone is n times that of the value of heavier stone when they experience same centripetal forces. The value of n is

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

(2015)

6. A plank with a box on it at one end is gradually raised about the other end. As the angle of inclination with the horizontal reaches 30°, the box starts to slip and slides 4.0 m down the plank in 4.0 s.

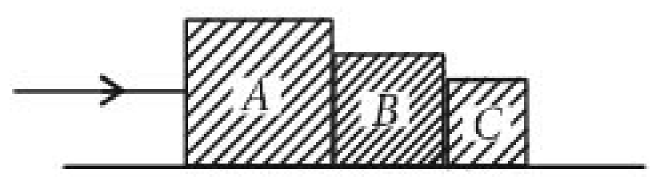


The coefficients of static and kinetic friction between the box and the plank will be, respectively

(a) 0.5 and 0.6 (b) 0.4 and 0.3
(c) 0.6 and 0.6 (d) 0.6 and 0.5

(2015)

7. Three blocks A, B and C, of masses 4 kg, 2 kg and 1 kg respectively, are in contact on a frictionless surface, as shown. If a force of 14 N is applied on the 4 kg block, then the contact force between A and B is



(a) 8 N (b) 18 N
(c) 2 N (d) 6 N

(2015 Cancelled)

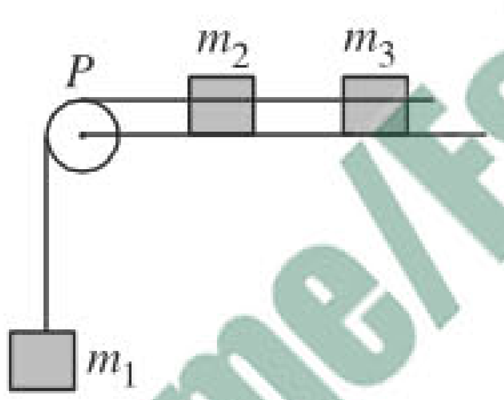
8. A block A of mass m_1 rests on a horizontal table. A light string connected to it passes over a frictionless pully at the edge of table and from its other end another block B of mass m_2 is suspended. The coefficient of kinetic friction between the block and the table is μ_k. When the block A is sliding on the table, the tension in the string is

(a) $\dfrac{m_1 m_2(1+\mu_k)g}{(m_1+m_2)}$ (b) $\dfrac{m_1 m_2(1-\mu_k)g}{(m_1+m_2)}$

(c) $\dfrac{(m_2+\mu_k m_1)g}{(m_1+m_2)}$ (d) $\dfrac{(m_2-\mu_k m_1)g}{(m_1+m_2)}$

(2015 Cancelled)

9. A system consists of three masses m_1, m_2 and m_3 connected by a string passing over a pulley P. The mass m_1 hangs freely and m_2 and m_3 are on a rough horizontal table (the coefficient of friction = μ). The pulley is frictionless and of negligible mass. The downward acceleration of mass m_1 is (Assume $m_1 = m_2 = m_3 = m$)



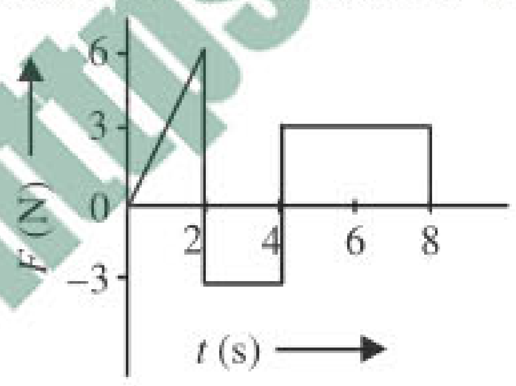
(a) $\dfrac{g(1-g\mu)}{9}$

(b) $\dfrac{2g\mu}{3}$

(c) $\dfrac{g(1-2\mu)}{3}$

(d) $\dfrac{g(1-2\mu)}{2}$ *(2014)*

10. The force F acting on a particle of mass m is indicated by the force-time graph shown below. The change in momentum of the particle over the time interval from zero to 8 s is



(a) 24 N s (b) 20 N s

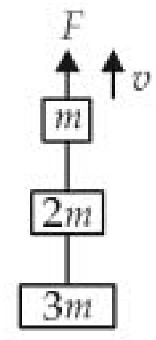
(c) 12 N s (d) 6 N s *(2014)*

11. A balloon with mass m is descending down with an acceleration a (where $a < g$). How much mass should be removed from it so that it starts moving up with an acceleration a?

(a) $\dfrac{2ma}{g+a}$ (b) $\dfrac{2ma}{g-a}$

(c) $\dfrac{ma}{g+a}$ (d) $\dfrac{ma}{g-a}$ *(2014)*

12. Three blocks with masses m, $2m$ and $3m$ are connected by strings, as shown in the figure. After an upward force F is applied on block m, the masses move upward at constant speed v. What is the net force on the block of mass $2m$? (g is the acceleration due to gravity)



(a) $3mg$

(b) $6mg$

(c) zero

(d) $2mg$ *(NEET 2013)*

13. An explosion breaks a rock into three parts in a horizontal plane. Two of them go off at right angles to each other. The first part of mass 1 kg moves with a speed of 12 m s^{-1} and the second part of mass 2 kg moves with 8 m s^{-1} speed. If the third part flies off with 4 m s^{-1} speed, then its mass is

(a) 7 kg (b) 17 kg

(c) 3 kg (d) 5 kg *(NEET 2013)*

14. The upper half of an inclined plane of inclination θ is perfectly smooth while lower half is rough. A block starting from rest at the top of the plane will again come to rest at the bottom, if the coefficient of friction between the block and lower half of the plane is given by

(a) $\mu = 2\tan\theta$ (b) $\mu = \tan\theta$

(c) $\mu = \dfrac{1}{\tan\theta}$ (d) $\mu = \dfrac{2}{\tan\theta}$

(NEET 2013)

15. A car is moving in a circular horizontal track of radius 10 m with a constant speed of 10 m/s. A bob is suspended from the roof of the car by a light wire of length 1.0 m. The angle made by the wire with the vertical is

(a) $\dfrac{\pi}{3}$ (b) $\dfrac{\pi}{6}$ (c) $\dfrac{\pi}{4}$ (d) $0°$

(Karnataka NEET 2013)

16. A person holding a rifle (mass of person and rifle together is 100 kg) stands on a smooth surface and fires 10 shots horizontally, in 5 s. Each bullet has a mass of 10 g with a muzzle velocity of 800 m s^{-1}. The final velocity acquired by the person and the average force exerted on the person are

(a) -0.08 ms^{-1}, 16 N (b) -0.8 ms^{-1}, 8 N
(c) -1.6 ms^{-1}, 16 N (d) -1.6 ms^{-1}, 8 N
(Karnataka NEET 2013)

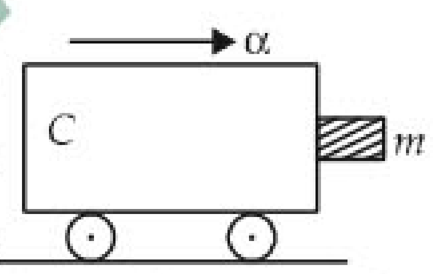
17. A stone is dropped from a height h. It hits the ground with a certain momentum P. If the same stone is dropped from a height 100% more than the previous height, the momentum when it hits the ground will change by
(a) 68% (b) 41%
(c) 200% (d) 100% *(Mains 2012)*

18. A person of mass 60 kg is inside a lift of mass 940 kg and presses the button on control panel. The lift starts moving upwards with an acceleration 1.0 m/s². If g = 10 m s^{-2}, the tension in the supporting cable is
(a) 8600 N (b) 9680 N
(c) 11000 N (d) 1200 N *(2011)*

19. A body of mass M hits normally a rigid wall with velocity V and bounces back with the same velocity. The impulse experienced by the body is
(a) MV (b) 1.5MV
(c) 2MV (d) zero *(2011)*

20. A conveyor belt is moving at a constant speed of 2 m s^{-1}. A box is gently dropped on it. The coefficient of friction between them is μ = 0.5. The distance that the box will move relative to belt before coming to rest on it, taking g = 10 m s^{-2}, is
(a) 0.4 m (b) 1.2 m
(c) 0.6 m (d) zero *(Mains 2011)*

21. A block of mass m is in contact with the cart C as shown in the figure.



The coefficient of static friction between the block and the cart is μ. The acceleration α of the cart that will prevent the block from falling satisfies

(a) $\alpha > \frac{mg}{\mu}$ (b) $\alpha > \frac{g}{\mu m}$

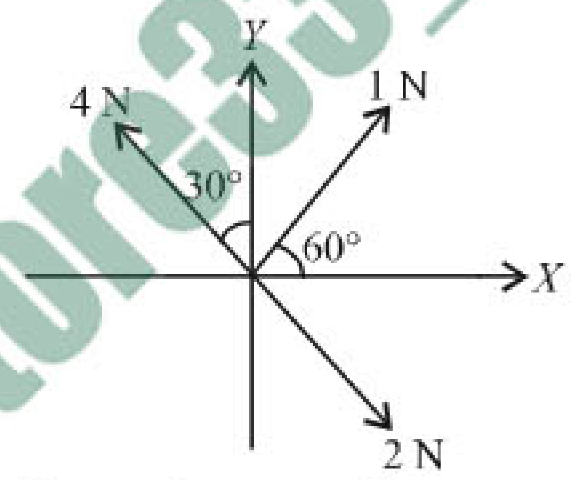
(c) $\alpha \geq \frac{g}{\mu}$ (d) $\alpha < \frac{g}{\mu}$ *(2010)*

22. The mass of a lift is 2000 kg. When the tension in the supporting cable is 28000 N, then its acceleration is
(a) 4 m s^{-2} upwards (b) 4 m s^{-2} downwards
(c) 14 m s^{-2} upwards (d) 30 m s^{-2} downwards
(2009)

23. A body, under the action of a force $\vec{F} = 6\hat{i} - 8\hat{j} + 10\hat{k}$, acquires an acceleration of 1 m/s². The mass of this body must be
(a) 10 kg (b) 20 kg
(c) $10\sqrt{2}$ kg (d) $2\sqrt{10}$ kg *(2009)*

24. A roller coaster is designed such that riders experience "weightlessness" as they go round the top of a hill whose radius of curvature is 20 m. The speed of the car at the top of the hill is between
(a) 16 m/s and 17 m/s
(b) 13 m/s and 14 m/s
(c) 14 m/s and 15 m/s
(d) 15 m/s and 16 m/s *(2008)*

25.

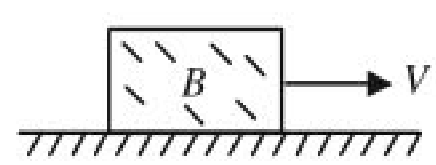


Three forces acting on a body are shown in the figure. To have the resultant force only along the y-direction, the magnitude of the minimum additional force needed is

(a) $\frac{\sqrt{3}}{4}$ N (b) $\sqrt{3}$ N
(c) 0.5 N (d) 1.5 N *(2008)*

26. Sand is being dropped on a conveyer belt at the rate of M kg/s. The force necessary to keep the belt moving with a constant velocity of v m/s will be
(a) $\frac{Mv}{2}$ newton (b) zero
(c) Mv newton (d) 2 Mv newton
(2008)

27. A block B is pushed momentarily along a horizontal surface with an initial velocity V. If μ is the coefficient of sliding friction between B and the surface, block B will come to rest after a time



(a) $g\mu/V$
(b) g/V
(c) V/g
(d) $V/(g\mu)$. *(2007)*

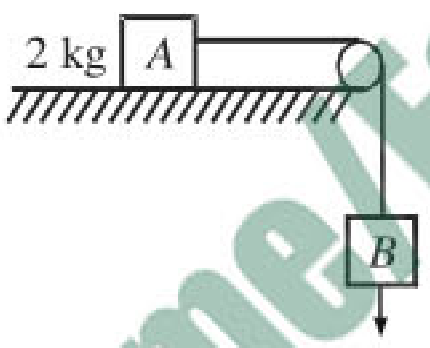
28. A 0.5 kg ball moving with a speed of 12 m/s strikes a hard wall at an angle of 30° with the wall. It is reflected with the same speed at the same angle. If the ball is in contact with the wall for 0.25 seconds, the average force acting on the wall is

(a) 96 N (b) 48 N
(c) 24 N (d) 12 N. *(2006)*

29. A block of mass m is placed on a smooth wedge of inclination θ. The whole system is accelerated horizontally so that the block does not slip on the wedge. The force exerted by the wedge on the block will be (g is acceleration due to gravity)

(a) $mg \cos \theta$ (b) $mg \sin \theta$
(c) mg (d) $mg/\cos \theta$ *(2004)*

30. The coefficient of static friction, μ_s, between block A of mass 2 kg and the table as shown in the figure is 0.2. What would be the maximum mass value of block B so that the two blocks do not move? The string and the pulley are assumed to be smooth and massless. ($g = 10$ m/s^2)



(a) 2.0 kg
(b) 4.0 kg
(c) 0.2 kg
(d) 0.4 kg *(2004)*

31. A man weighs 80 kg. He stands on a weighing scale in a lift which is moving upwards with a uniform acceleration of 5 m/s^2. What would be the reading on the scale ? (g = 10 m/s^2)

(a) zero (b) 400 N
(c) 800 N (d) 1200 N *(2003)*

32. A monkey of mass 20 kg is holding a vertical rope. The rope will not break when a mass of 25 kg is suspended from it but will break if the mass exceeds 25 kg. What is the maximum acceleration with which the monkey can climb up along the rope ?(g = 10 m/s^2)

(a) 5 m/s^2 (b) 10 m/s^2
(c) 25 m/s^2 (d) 2.5 m/s^2 *(2003)*

33. A lift of mass 1000 kg which is moving with acceleration of 1 m/s^2 in upward direction, then the tension developed in string which is connected to lift is

(a) 9800 N (b) 10,800 N
(c) 11,000 N (d) 10,000 N. *(2002)*

34. A block of mass 10 kg placed on rough horizontal surface having coefficient of friction m = 0.5, if a horizontal force of 100 N acting on it then acceleration of the block will be

(a) 10 m/s^2 (b) 5 m/s^2
(c) 15 m/s^2 (d) 0.5 m/s^2. *(2002)*

35. 250 N force is required to raise 75 kg mass from a pulley. If rope is pulled 12 m then the load is lifted to 3 m, the efficiency of pulley system will be

(a) 25% (b) 33.3%
(c) 75% (d) 90%. *(2001)*

36. On the horizontal surface of a truck a block of mass 1 kg is placed (m = 0.6) and truck is moving with acceleration 5 m/sec^2 then the frictional force on the block will be

(a) 5 N (b) 6 N
(c) 5.88 N (d) 8 N. *(2001)*

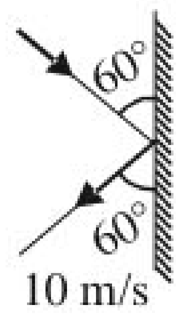
37. A cricketer catches a ball of mass 150 gm in 0.1 sec moving with speed 20 m/s, then he experiences force of

(a) 300 N (b) 30 N
(c) 3 N (d) 0.3 N. *(2001)*

38. A 1 kg stationary bomb is exploded in three parts having mass 1 : 1 : 3 respectively. Parts having same mass move in perpendicular direction with velocity 30 m/s, then the velocity of bigger part will be

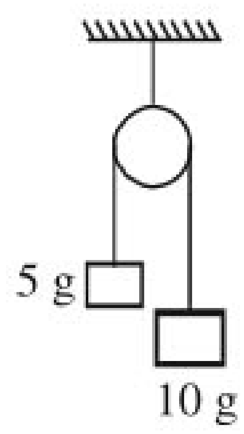
(a) $10\sqrt{2}$ m/sec (b) $\frac{10}{\sqrt{2}}$ m/sec
(c) $15\sqrt{2}$ m/sec (d) $\frac{15}{\sqrt{2}}$ m/sec. *(2001)*

39. A body of mass 3 kg hits a wall at an angle of 60° and returns at the same angle. The impact time was 0.2 sec. The force exerted on the wall



(a) $150\sqrt{3}$ N
(b) $50\sqrt{3}$ N
(c) 100 N
(d) $75\sqrt{3}$ N. *(2000)*

40. Two masses as shown in the figure are suspended from a massless pulley. The acceleration of the system when masses are left free is



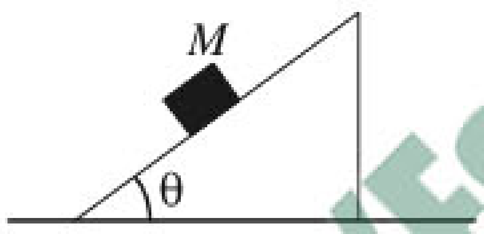
(a) $\frac{2g}{3}$ (b) $\frac{g}{3}$
(c) $\frac{g}{9}$ (d) $\frac{g}{7}$. *(2000)*

41. If the force on a rocket, moving with a velocity of 300 m/s is 210 N, then the rate of combustion of the fuel is
(a) 0.07 kg/s (b) 1.4 kg/s
(c) 0.7 kg/s (d) 10.7 kg/s *(1999)*

42. A mass of 1 kg is suspended by a thread. It is
(i) lifted up with an acceleration 4.9 m/s^2,
(ii) lowered with an acceleration 4.9 m/s^2.
The ratio of the tensions is
(a) 1 : 3 (b) 1 : 2
(c) 3 : 1 (d) 2 : 1 *(1998)*

43. A bullet is fired from a gun. The force on the bullet is given by
$$F = 600 - 2 \times 10^5\, t$$
where, F is in newton and t in seconds. The force on the bullet becomes zero as soon as it leaves the barrel. What is the average impulse imparted to the bullet?
(a) 9 N-s (b) zero
(c) 1.8 N-s (d) 0.9 N-s *(1998)*

44. A mass M is placed on a very smooth wedge resting on a surface without friction. Once the mass is released, the acceleration to be given to the wedge so that M remains at rest is a where



(a) a is applied to the left and $a = g\tan\theta$
(b) a is applied to the right and $a = g\tan\theta$
(c) a is applied to the left and $a = g\sin\theta$
(d) a is applied to the left and $a = g\cos\theta$
(1998)

45. A 5000 kg rocket is set for vertical firing. The exhaust speed is 800 m s^{-1}. To give an initial upward acceleration of 20 m s^{-2}, the amount of gas ejected per second to supply the needed thrust will be (g = 10 m s^{-2})
(a) 185.5 kg s^{-1} (b) 187.5 kg s^{-1}
(c) 127.5 kg s^{-1} (d) 137.5 kg s^{-1} *(1998)*

46. A force of 6 N acts on a body at rest and of mass 1 kg. During this time, the body attains a velocity of 30 m/s. The time for which the force acts on the body is
(a) 7 seconds (b) 5 seconds
(c) 10 seconds (d) 8 seconds. *(1997)*

47. A 10 N force is applied on a body produce in it an acceleration of 1 m/s^2. The mass of the body is
(a) 15 kg (b) 20 kg
(c) 10 kg (d) 5 kg. *(1996)*

48. A force vector applied on a mass is represented as $\vec{F} = 6\hat{i} - 8\hat{j} + 10\hat{k}$ and accelerates with 1 m/s^2. What will be the mass of the body?
(a) 10 kg (b) 20 kg
(c) $10\sqrt{2}$ kg (d) $2\sqrt{10}$ kg. *(1996)*

49. A man fires a bullet of mass 200 gm at a speed of 5 m/s. The gun is of one kg mass. By what velocity the gun rebounds backward?
(a) 1 m/s (b) 0.01 m/s
(c) 0.1 m/s (d) 10 m/s. *(1996)*

50. In a rocket, fuel burns at the rate of 1 kg/s. This fuel is ejected from the rocket with a velocity of 60 km/s. This exerts a force on the rocket equal to
(a) 6000 N (b) 60000 N
(c) 60 N (d) 600 N. *(1994)*

51. A block has been placed on a inclined plane with the slope angle θ, block slides down the plane at constant speed. The coefficient of kinetic friction is equal to
(a) sin θ (b) cos θ
(c) g (d) tan θ *(1993)*

52. A monkey is decending from the branch of a tree with constant acceleration. If the breaking strength is 75% of the weight of the monkey, the minimum acceleration with which monkey can slide down without branch is
(a) g (b) $\frac{3g}{4}$
(c) $\frac{g}{4}$ (d) $\frac{g}{2}$ *(1993)*

53. Consider a car moving along a straight horizontal road with a speed of 72 km/h. If the coefficient of static friction between the tyres and the road is 0.5, the shortest distance in which the car can be stopped is (taking g = 10 m/s^2)
(a) 30 m (b) 40 m
(c) 72 m (d) 20 m *(1992)*

54. Physical independence of force is a consequence of
(a) third law of motion
(b) second law of motion
(c) first law of motion
(d) all of these laws *(1991)*

55. A heavy uniform chain lies on horizontal table top. If the coefficient of friction between the chain and the table surface is 0.25, then the maximum fraction of the length of the chain that can hang over one edge of the table is
(a) 20% (b) 25%
(c) 35% (d) 15% *(1991)*

56. When milk is churned, cream gets separated due to

(a) centripetal force (b) centrifugal force
(c) fricitional force (d) gravitational force *(1991)*

57. A particle of mass m is moving with a uniform velocity v_1. It is given an impulse such that its velocity becomes v_2. The impulse is equal to

(a) $m[|v_2| - |v_1|]$ (b) $\frac{1}{2}m[v_2^2 - v_1^2]$
(c) $m[v_1 + v_2]$ (d) $m[v_2 - v_1]$ *(1990)*

58. A 600 kg rocket is set for a vertical fring. If the exhaust speed is 1000 ms^{-1}, the mass of the gas ejected per second to supply the thrust needed to overcome the weight of rocket is

(a) 117.6 kg s^{-1} (b) 58.6 kg s^{-1}
(c) 6 kg s^{-1} (d) 76.4 kg s^{-1} *(1990)*

59. A body of mass 5 kg explodes at rest into three fragments with masses in the ratio 1 : 1 : 3. The fragments with equal masses fly in mutually perpendicular directions with speeds of 21 m/s. The velocity of heaviest fragment in m/s will be

(a) $7\sqrt{2}$ (b) $5\sqrt{2}$
(c) $3\sqrt{2}$ (d) $\sqrt{2}$ *(1989)*

60. Starting from rest, a body slides down a 45° inclined plane in twice the time it takes to slide down the same distance in the absence of friction. The coefficient of friction between the body and the inclined plane is

(a) 0.80 (b) 0.75
(c) 0.25 (d) 0.33 *(1988)*

Answer Key

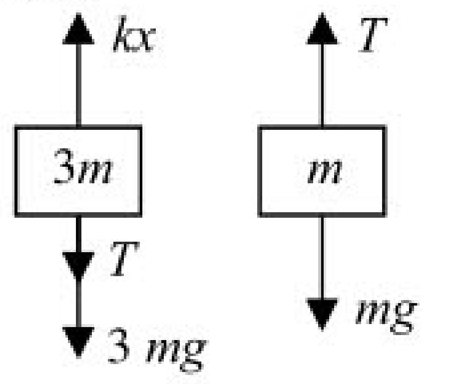
1.	(a)	**2.**	(d)	**3.**	(a)	**4.**	(d)	**5.**	(c)	**6.**	(d)	**7.**	(d)	**8.**	(a)	**9.**	(c)	**10.**	(c)
11.	(a)	**12.**	(c)	**13.**	(d)	**14.**	(a)	**15.**	(c)	**16.**	(b)	**17.**	(b)	**18.**	(c)	**19.**	(c)	**20.**	(a)
21.	(c)	**22.**	(a)	**23.**	(c)	**24.**	(c)	**25.**	(c)	**26.**	(c)	**27.**	(d)	**28.**	(c)	**29.**	(d)	**30.**	(d)
31.	(d)	**32.**	(d)	**33.**	(b)	**34.**	(b)	**35.**	(c)	**36.**	(a)	**37.**	(b)	**38.**	(a)	**39.**	(a)	**40.**	(b)
41.	(c)	**42.**	(c)	**43.**	(d)	**44.**	(a)	**45.**	(b)	**46.**	(b)	**47.**	(c)	**48.**	(c)	**49.**	(a)	**50.**	(b)
51.	(d)	**52.**	(c)	**53.**	(b)	**54.**	(c)	**55.**	(a)	**56.**	(b)	**57.**	(d)	**58.**	(c)	**59.**	(a)	**60.**	(b)

EXPLANATIONS

1. (a) : Before the string is cut

$kx = T + 3mg$ ...(i)

$T = mg$ ...(ii)



Before the string is cut

From eqns. (i) and (ii)

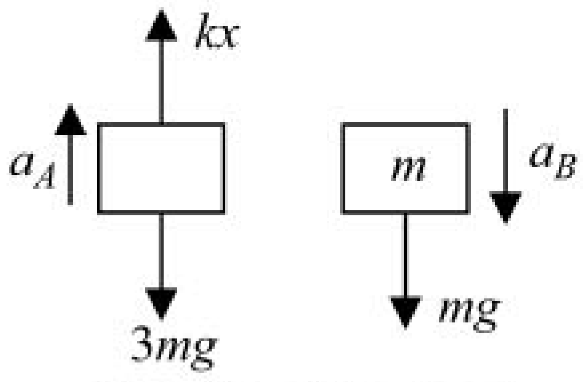
$kx = 4mg$

Just after the string is cut

$T = 0$

$$a_A = \frac{kx - 3mg}{3m}$$

$$a_A = \frac{4mg - 3mg}{3m} = \frac{mg}{3m} = \frac{g}{3}$$



After the string is cut

and also $a_B = g$.

2. (d) : Centripetal force $\left(\frac{mv^2}{l}\right)$ is provided by tension so net force on the particle will be equal to tension T.

3. (a) : Given, $p_i = p_f = mV$

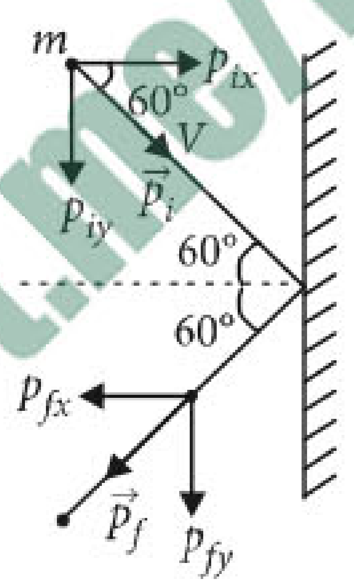
Change in momentum of the ball

$= \vec{p}_f - \vec{p}_i$

$= (-p_{fx}\hat{i} - p_{fy}\hat{j}) - (p_{ix}\hat{i} - p_{iy}\hat{j})$

$= -\hat{i}(p_{fx} + p_{ix}) - \hat{j}(p_{fy} - p_{iy})$

$= -2p_{ix}\hat{i} = -mV\hat{i}$ $[\because p_{fy} - p_{iy} = 0]$



Here, $p_{ix} = p_{fx} = p_i \cos 60° = \frac{mV}{2}$

$\because$ Impulse imparted by the wall = change in the momentum of the ball = mV.

4. (d) :

For vertical equilibrium on the road,

$N\cos\theta = mg + f\sin\theta$

$mg = N\cos\theta - f\sin\theta$ ...(i)

Centripetal force for safe turning,

$$N\sin\theta + f\cos\theta = \frac{mv^2}{R} \quad ...(ii)$$

From eqns. (i) and (ii), we get

$$\frac{v^2}{Rg} = \frac{N\sin\theta + f\cos\theta}{N\cos\theta - f\sin\theta}$$

$$\Rightarrow \frac{v^2_{max}}{Rg} = \frac{N\sin\theta + \mu_s N\cos\theta}{N\cos\theta - \mu_s N\sin\theta}$$

$$v_{max} = \sqrt{Rg\left(\frac{\mu_s + \tan\theta}{1 - \mu_s\tan\theta}\right)}$$

5. (c) : Let v be tangential speed of heavier stone. Then, centripetal force experienced by lighter stone is

$(F_c)_{lighter} = \frac{m(nv)^2}{r}$ and that of heavier stone is

$$(F_c)_{heavier} = \frac{2mv^2}{(r/2)}$$

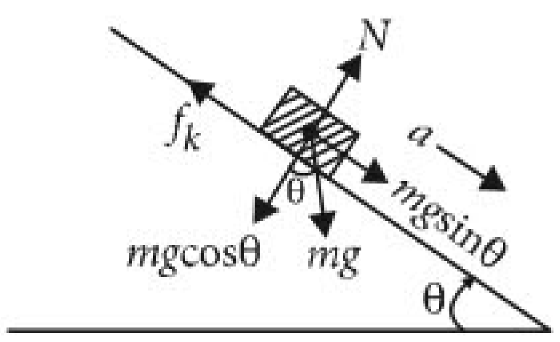
But $(F_c)_{lighter} = (F_c)_{heavier}$ (given)

$$\therefore \frac{m(nv)^2}{r} = \frac{2mv^2}{(r/2)}$$

$$n^2\left(\frac{mv^2}{r}\right) = 4\left(\frac{mv^2}{r}\right)$$

$n^2 = 4$ or $n = 2$

6. (d) : Let μ_s and μ_k be the coefficients of static and kinetic friction between the box and the plank respectively.



When the angle of inclination θ reaches 30°, the block just slides,

$$\therefore \mu_s = \tan\theta = \tan 30° = \frac{1}{\sqrt{3}} = 0.6$$

If a is the acceleration produced in the block, then

$ma = mg\sin\theta - f_k$

(where f_k is force of kinetic friction)

$= mg\sin\theta - \mu_k N$ (as $f_k = \mu_k N$)

$= mg\sin\theta - \mu_k mg\cos\theta$ (as $N = mg\cos\theta$)

$a = g(\sin\theta - \mu_k\cos\theta)$

As $g = 10$ ms^{-2} and $\theta = 30°$

$\therefore a = (10 \text{ ms}^{-2})(\sin 30° - \mu_k \cos 30°)$ ...(i)

If s is the distance travelled by the block in time t, then

$$s = \frac{1}{2}at^2 \qquad (\text{as } u = 0)$$

$$\text{or} \quad a = \frac{2s}{t^2}$$

But $s = 4.0$ m and $t = 4.0$ s (given)

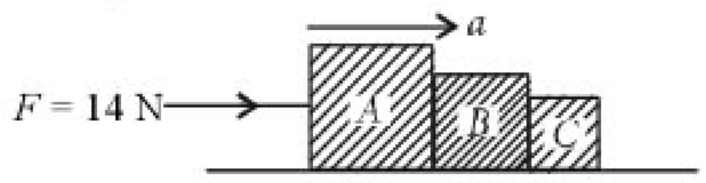
$$\therefore \quad a = \frac{2(4.0\text{ m})}{(4.0\text{ s})^2} = \frac{1}{2}\text{ ms}^{-2}$$

Substituting this value of a in eqn. (i), we get

$$\frac{1}{2}\text{ ms}^{-2} = (10\text{ ms}^{-2})\left(\frac{1}{2} - \mu_k\frac{\sqrt{3}}{2}\right)$$

$$\frac{1}{10} = 1 - \sqrt{3}\mu_k \quad \text{or} \quad \sqrt{3}\mu_k = 1 - \frac{1}{10} = \frac{9}{10} = 0.9$$

$$\mu_k = \frac{0.9}{\sqrt{3}} = 0.5$$

7. (d) : 

Here, $M_A = 4$ kg, $M_B = 2$ kg, $M_C = 1$ kg, $F = 14$ N

Net mass, $M = M_A + M_B + M_C = 4 + 2 + 1 = 7$ kg

Let a be the acceleration of the system.

Using Newton's second law of motion,

$$F = Ma$$

$$14 = 7a \quad \therefore \quad a = 2\text{ m s}^{-2}$$

Let F' be the force applied on block A by block B *i.e.* the contact force between A and B. Free body diagram for block A

Again using Newton's second law of motion,

$$F - F' = 4a$$

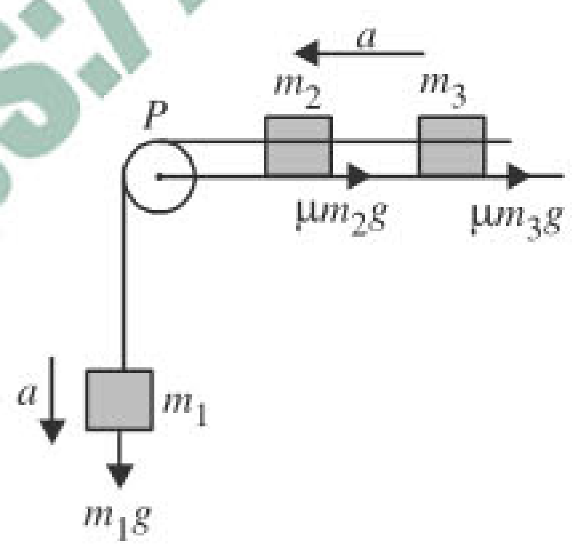
$$14 - F' = 4 \times 2 \quad \Rightarrow 14 - 8 = F' \quad \therefore \quad F' = 6\text{ N}$$

8. (a)

9. (c) : Force of friction on mass $m_2 = \mu m_2 g$

Force of friction on mass $m_3 = \mu m_3 g$

Let a be common acceleration of the system.



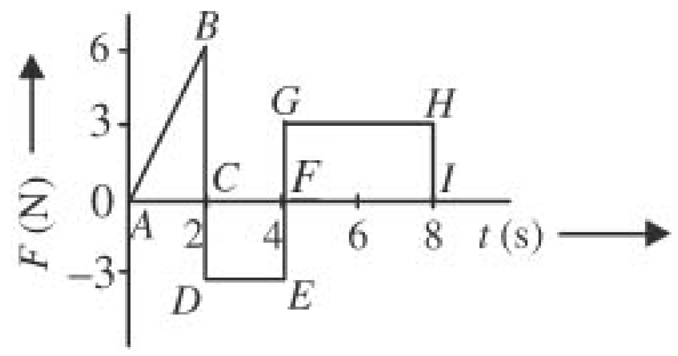
$$\therefore \quad a = \frac{m_1 g - \mu m_2 g - \mu m_3 g}{m_1 + m_2 + m_3}$$

Here, $m_1 = m_2 = m_3 = m$

$$\therefore a = \frac{mg - \mu mg - \mu mg}{m + m + m} = \frac{mg - 2\mu mg}{3m} = \frac{g(1 - 2\mu)}{3}$$

Hence, the downward acceleration of mass m_1 is $\frac{g(1-2\mu)}{3}$.

10. (c) :



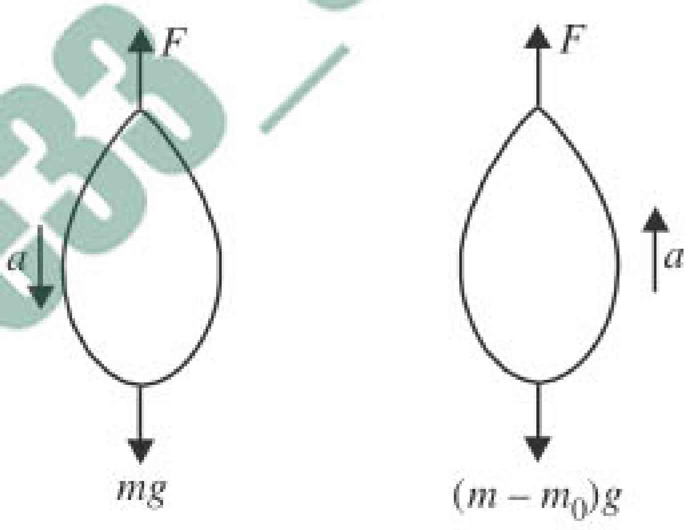
Change in momentum = Area under F-t graph in that interval

= Area of ΔABC – Area of rectangle $CDEF$ + Area of rectangle $FGHI$

$$= \frac{1}{2} \times 2 \times 6 - 3 \times 2 + 4 \times 3 = 12\text{ N s}$$

11. (a) : Let F be the upthrust of the air. As the balloon is descending down with an acceleration a,

$$\therefore \quad mg - F = ma \qquad \text{... (i)}$$



Let mass m_0 be removed from the balloon so that it starts moving up with an acceleration a. Then,

$$F - (m - m_0)g = (m - m_0)a$$

$$F - mg + m_0 g = ma - m_0 a \qquad \text{... (ii)}$$

Adding eqn. (i) and eqn. (ii), we get

$$m_0 g = 2ma - m_0 a$$

$$m_0 g + m_0 a = 2ma$$

$$m_0(g + a) = 2ma$$

$$m_0 = \frac{2ma}{a + g}$$

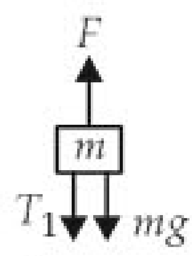
12. (c) : Let T_1 be tension in string connecting m and $2m$ and T_2 be tension in string connecting $2m$ and $3m$. Let a be common acceleration of the system.

$$\therefore \quad a = \frac{F - (m + 2m + 3m)g}{m + 2m + 3m} = \frac{F - 6mg}{6m}$$

As the system moves with constant speed, therefore, $a = 0$

$$\therefore \quad F - 6mg = 0 \quad \text{or} \quad F = 6mg$$

The free body diagram of block m is as shown in the figure.



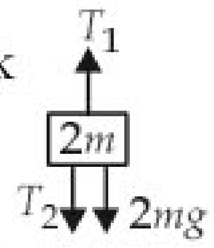
The equation of motion of block of mass m is

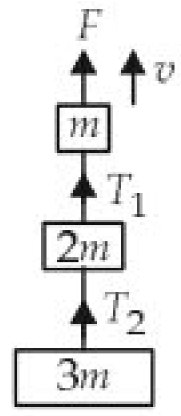
$$F - T_1 - mg = 0$$

$$6mg - T_1 - mg = 0$$

$$T_1 = 5mg \qquad \text{...(i)}$$

The free body diagram of block of mass $2m$ is as shown in the figure.





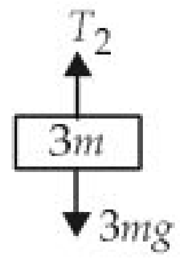
The equation of motion of block of mass $2m$ is

$$T_1 - T_2 - 2mg = 0$$

$$5mg - T_2 - 2mg = 0 \qquad \text{(Using (i))}$$

$$T_2 = 3mg$$

The free body diagram of block of mass $3m$ is as shown in the figure.



The equation of motion of block of mass $3m$ is

$$T_2 - 3mg = 0$$

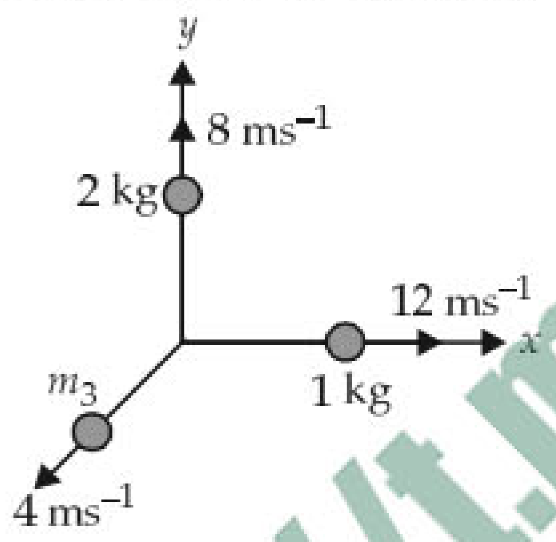
$$T_2 = 3mg$$

Net force on the block of mass $2m$ is

$$F_{net} = T_1 - T_2 - 2mg = 5mg - 3mg - 2mg = 0$$

Alternate solution: As all blocks are moving with constant speed, therefore, acceleration is zero. So net force on each block is zero.

13. (d) : The situation is as shown in the figure.



According to law of conservation of linear momentum

$$\vec{p}_1 + \vec{p}_2 + \vec{p}_3 = 0 \quad \therefore \quad \vec{p}_3 = -(\vec{p}_1 + \vec{p}_2)$$

Here, $\vec{p}_1 = (1 \text{ kg})(12 \text{ m s}^{-1})\hat{i} = 12\hat{i} \text{ kg m s}^{-1}$

$$\vec{p}_2 = (2 \text{ kg})(8 \text{ m s}^{-1})\hat{j} = 16\hat{j} \text{ kg m s}^{-1}$$

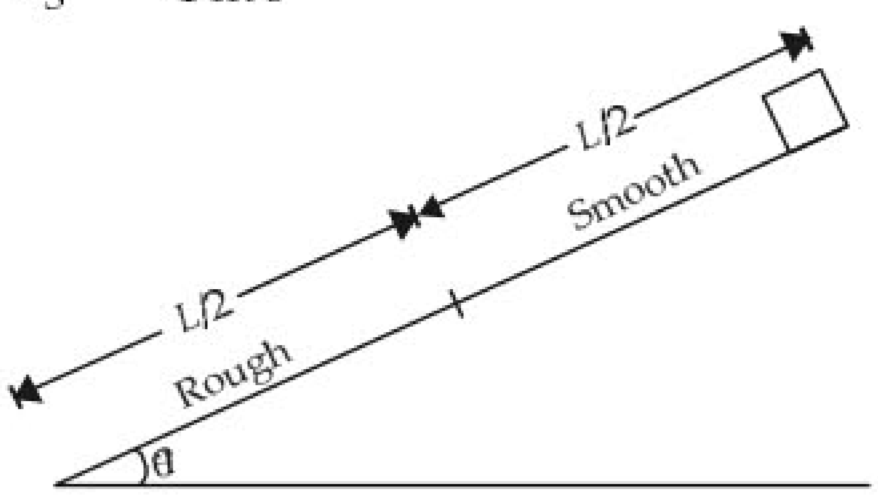
$$\therefore \quad \vec{p}_3 = -(12\hat{i} + 16\hat{j}) \text{kg m s}^{-1}$$

The magnitude of p_3 is

$$p_3 = \sqrt{(12)^2 + (16)^2} = 20 \text{ kg m s}^{-1}$$

$$\therefore \quad m_3 = \frac{p_3}{v_3} = \frac{20 \text{ kg m s}^{-1}}{4 \text{ m s}^{-1}} = 5 \text{ kg}$$

14. (a) :



Let m be mass of the block and L be length of the inclined plane.

According to work-energy theorem

$$W = \Delta K = 0 \quad (\because \text{ Initial and final speeds are zero})$$

$\therefore$ Work done by friction + Work done by gravity = 0

$$-\mu mg\cos\theta\frac{L}{2} + mg\sin\theta L = 0$$

$$\frac{\mu}{2}\cos\theta = \sin\theta$$

$$\mu = \frac{2\sin\theta}{\cos\theta} = 2\tan\theta$$

Alternate solution

For upper half smooth plane

Acceleration of the block, $a = g\sin\theta$

Here, $u = 0$ ($\because$ block starts from rest)

$$a = g\sin\theta, \; s = \frac{L}{2}$$

Using, $v^2 - u^2 = 2as$, we have

$$v^2 - 0 = 2 \times g\sin\theta \times \frac{L}{2}$$

$$v = \sqrt{gL\sin\theta} \qquad \text{...(i)}$$

For lower half rough plane

Acceleration of the block, $a' = g\sin\theta - \mu g\cos\theta$

where μ is the coefficient of friction between the block and lower half of the plane

Here, $u = v = \sqrt{gL\sin\theta}$,

$v = 0$ ($\because$ block comes to rest)

$$a = a' = g\sin\theta - \mu g\cos\theta, \; s = \frac{L}{2}$$

Again, using $v^2 - u^2 = 2as$, we have

$$0 - (\sqrt{gL\sin\theta})^2 = 2 \times (g\sin\theta - \mu g\cos\theta) \times \frac{L}{2}$$

$$-gL\sin\theta = (g\sin\theta - \mu g\cos\theta)L$$

$$-\sin\theta = \sin\theta - \mu\cos\theta$$

$$\mu\cos\theta = 2\sin\theta$$

$$\mu = 2\tan\theta$$

15. (c) : Let θ is the angle made by the wire with the vertical.

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

Here, $v = 10$ m/s, $r = 10$ m, $g = 10$ m/s^2

$$\therefore \quad \tan\theta = \frac{(10 \text{ m/s})^2}{10 \text{ m}(10 \text{ m/s}^2)} = 1$$

$$\theta = \tan^{-1}(1) = \frac{\pi}{4}$$

16. (b)

17. (b) : When a stone is dropped from a height h, it hits the ground with a momentum

$$P = m\sqrt{2gh} \quad ...(i)$$

where m is the mass of the stone.

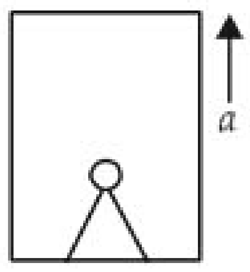
When the same stone is dropped from a height $2h$ (*i.e.* 100% of initial), then its momentum with which it hits the ground becomes

$$P' = m\sqrt{2g(2h)} = \sqrt{2}P \quad \text{(Using (i))} ...(ii)$$

$$\%\text{ change in momentum} = \frac{P'-P}{P} \times 100\%$$

$$= \frac{\sqrt{2}P - P}{P} \times 100\% = 41\%$$

18. (c) : Here, Mass of a person, m = 60 kg



Mass of lift, $M = 940$ kg,

$a = 1$ m/s^2, $g = 10$ m/s^2

Let T be the tension in the supporting cable.

$\therefore \quad T - (M+m)g = (M+m)a$

$T = (M+m)(a+g) = (940+60)(1+10) = 11000$ N

19. (c) : Impulse = Change in linear momentum

$= MV - (-MV) = 2MV$

20. (a) : Force of friction, $f = \mu mg$

$$\therefore \quad a = \frac{f}{m} = \frac{\mu mg}{m} = \mu g = 0.5 \times 10 = 5 \text{ m s}^{-2}$$

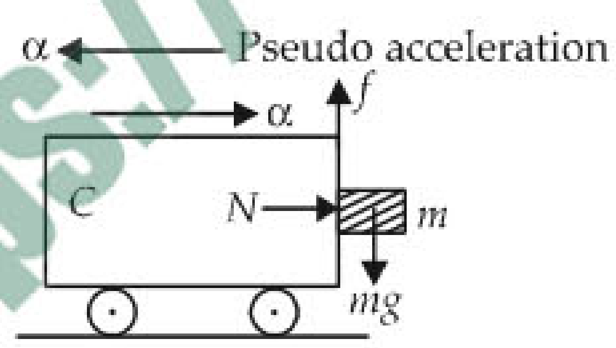
Using $v^2 - u^2 = 2aS$

$0^2 - 2^2 = 2(-5) \times S \Rightarrow \quad S = 0.4$ m

21. (c) : Pseudo force or fictitious force, $F_{fic} = m\alpha$

Force of friction, $f = \mu N = \mu m\alpha$

The block of mass m will not fall as long as

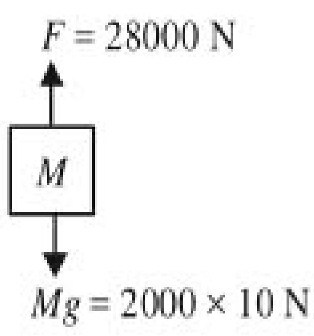


$f \geq mg$

$\mu m\alpha \geq mg$

$\alpha \geq \frac{g}{\mu}$

22. (a) : $F - Mg = Ma$



$8000 = 2000a$

$\therefore$ Acceleration is 4 m s^{-2} upwards.

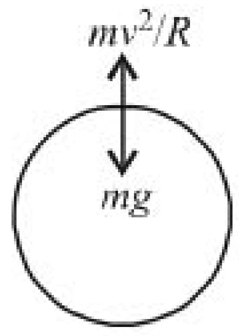
23. (c) : $\vec{F} = 6\hat{i} - 8\hat{j} + 10\hat{k}$

$$|\vec{F}| = \sqrt{36+64+100} = \sqrt{200} \text{ N} = 10\sqrt{2} \text{ N.}$$

Acceleration, a = 1 m s^{-2}

$$\therefore \quad \text{Mass, } M = \frac{10\sqrt{2}}{1} = 10\sqrt{2} \text{ kg.}$$

24. (c) :

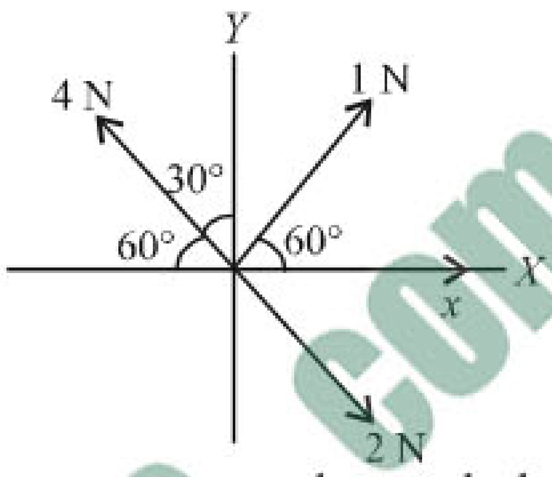


$$mg = \frac{mv^2}{R} \Rightarrow v = \sqrt{Rg}$$

$$v = \sqrt{20 \times 10} = \sqrt{200} = 14.1 \text{ m/s}$$

i.e., Between 14 and 15 m/s.

25. (c) :



Taking x-components, the total should be zero.

$1 \times \cos 60° + 2\cos 60° + x - 4\cos 60° = 0$

$\therefore \quad x = 0.5$ N

26. (c) : $F = \frac{d}{dt}(Mv) = v\frac{dM}{dt} + M\frac{dv}{dt}$

As v is a constant,

$$F = v\frac{dM}{dt}. \qquad \text{But } \frac{dM}{dt} = M \text{ kg/s}$$

$\therefore$ To keep the conveyer belt moving at v m/s, force needed = vM newton.

27. (d) : Given $u = V$, final velocity = 0.

Using $v = u + at$

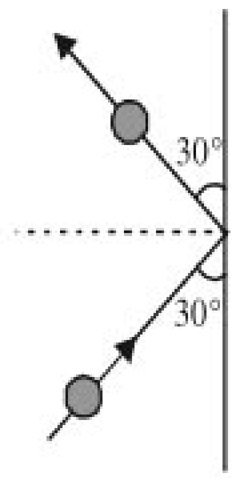
$$\therefore \quad 0 = V - at \quad \text{or,} \quad -a = \frac{0-V}{t} = -\frac{V}{t}$$

$f = \mu R = \mu mg$ (f is the force of friction)

$\therefore$ Retardation, $a = \mu g$

$$\therefore \quad t = \frac{V}{a} = \frac{V}{\mu g}.$$

28. (c) : Components of momentum parallel to the wall add each other and components of momentum in the perpendicular to the wall are opposite to each other. Therefore change of momentum is final momentum – initial momentum



i.e., ($mv\sin\theta$ after collision – ($-mv\sin\theta$) before collision)

$F \times t$ = change in momentum

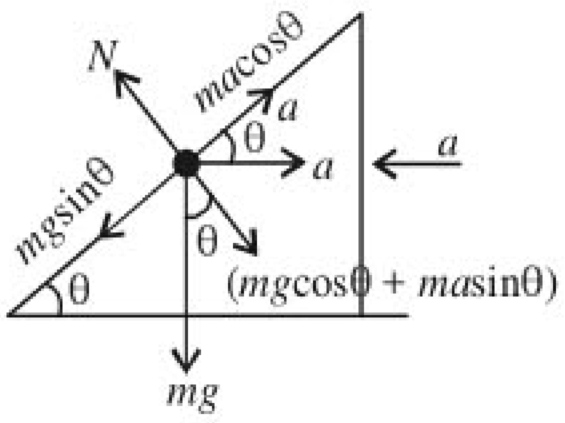
$= 2mv\sin\theta$

$$\therefore \quad F = \frac{2mv\sin\theta}{t}$$

$$= \frac{2 \times 0.5 \times 12 \times \sin 30°}{0.25} = 48 \times \frac{1}{2} = 24 \text{ N.}$$

29. (d) : The wedge is given an acceleration to the left.

$\therefore$ The block has a pseudo acceleration to the right, pressing against the wedge because of which the block is not moving.



$\therefore$ $mg\sin\theta = ma\cos\theta$

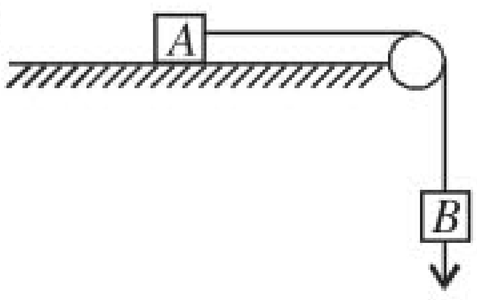
or $a = \dfrac{g\sin\theta}{\cos\theta}$

Total reaction of the wedge on the block is $N = mg\cos\theta + ma\sin\theta$.

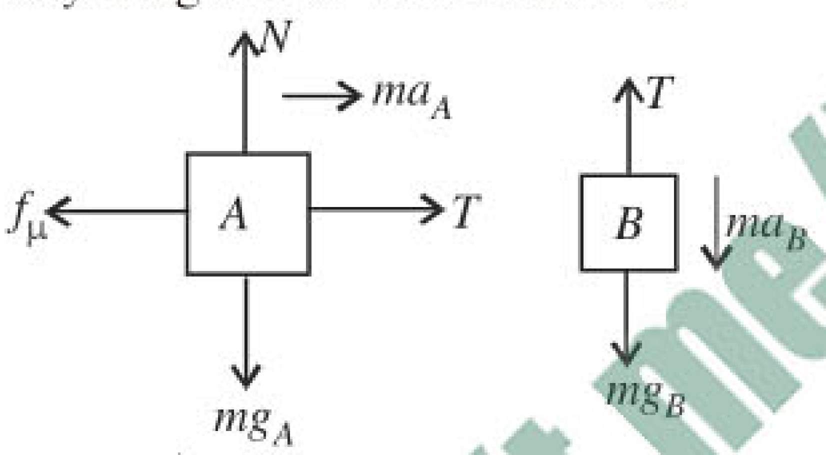
or $\quad N = mg\cos\theta + \dfrac{mg\sin\theta \cdot \sin\theta}{\cos\theta}$

or $\quad N = \dfrac{mg(\cos^2\theta + \sin^2\theta)}{\cos\theta} = \dfrac{mg}{\cos\theta}$.

30. (d) :



Free body diagram of two masses is



We get equations

$T + ma = f_\mu$ or $T = \mu N_A$ (for $a = 0$)

and $T = ma + mg$ or $T = m_B g$ (for $a = 0$)

$\therefore$ $\mu N_A = m_B g \Rightarrow m_B = \mu m_A = 0.2 \times 2 = 0.4$ kg.

31. (d) : When the lift is accelerating upwards with acceleration a, then reading on the scale

$R = m(g + a) = 80\,(10 + 5)$ N $= 1200$ N.

32. (d) : Let T be the tension in the rope when monkey climbs up with an acceleration a. Then,

$T - mg = ma$

$25\,g - 20\,g = 20\,a \;\Rightarrow\; a = \dfrac{5 \times 10}{20} = 2.5$ m/s^2.

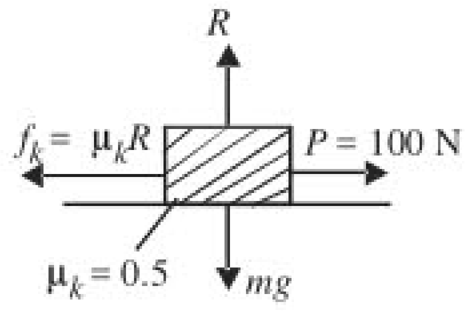
33. (b) : For a lift which is moving in upward direction with an acceleration a, the tension T developed in the string connected to the lift is given by

$T = m\,(g + a)$.

Here $m = 1000$ kg, $a = 1$ m/s^2, $g = 9.8$ m/s^2

$\therefore$ $T = 1000(9.8 + 1) = 10{,}800$ N.

34. (b) : $m = 10$ kg,



$R = mg$

$\therefore$ Frictional force $= f_k$

$= \mu_k R = \mu_k mg$

$= 0.5 \times 10 \times 10$

$= 50$ N [$g = 10$ m/sec^2]

$\therefore$ Net force acting on the body $= F = P - f_k$

$= 100 - 50 = 50$ N.

$\therefore$ Acceleration of the block $= a = F/m$

$= 50/10 = 5$ m/sec^2.

35. (c) : Load $W = Mg = 75 \times 10 = 750$ N

Effort (P) $= 250$ N

$\therefore$ Mechanical advantage

$= \dfrac{\text{load}}{\text{effort}} = \dfrac{W}{P} = \dfrac{750}{250} = 3.$

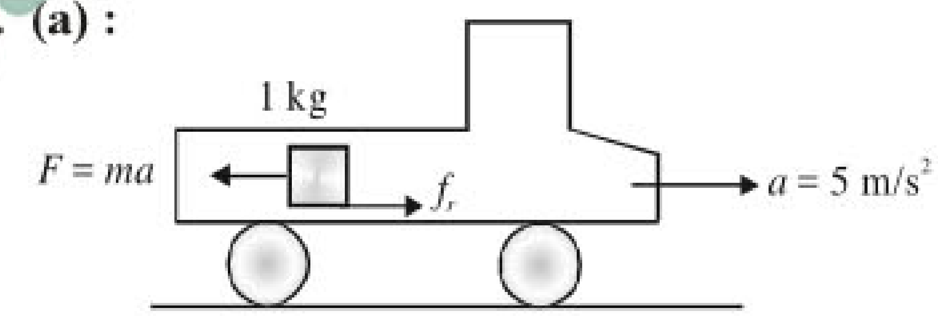
Velocity ratio

$= \dfrac{\text{distance travelled by effort}}{\text{distance travelled by load}} = \dfrac{12}{3} = 4$

Efficiency, $\eta = \dfrac{\text{Mechanical advantage}}{\text{Velocity ratio}}$

$= (3/4) \times 100 = 75\%$.

36. (a) :



$f_{rL} = \mu_s N = \mu_s \times mg = 0.6 \times 1 \times 10 = 6$ N.

where f_{rL} is the force of limiting friction.

Pseudo force $= ma = 1 \times 5$; $F = 5$ N

If $F < f_{rL}$ block does not move. So static friction is present.

Static friction = applied force . $\therefore$ $f_r = 5$ N.

37. (b) : Impulse = Change in momentum

$F \cdot \Delta t = m \cdot v$; $F = \dfrac{m \cdot v}{\Delta t} = \dfrac{150 \times 10^{-3} \times 20}{0.1} = 30$ N.

38. (a) : Apply conservation of linear momentum.

Total momentum before explosion

= total momentum after explosion

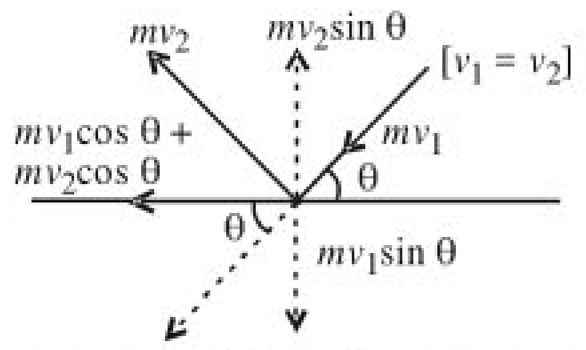
$0 = \dfrac{m}{5}v_1\hat{i} + \dfrac{m}{5}v_2\hat{j} + \dfrac{3m}{5}\vec{v}_3$;

$\dfrac{3m}{5}\vec{v}_3 = -\dfrac{m}{5}[v_1\hat{i} + v_2\hat{j}]$

$\vec{v}_3 = \dfrac{-v_1}{3}\hat{i} - \dfrac{v_2}{3}\hat{j} \qquad \because\ v_1 = v_2 = 30$ m/sec.

$\vec{v}_3 = -10\,\hat{i} - 10\,\hat{j}$; $v_3 = 10\sqrt{2}$ m/sec.

39. (a) :



$mv_2\sin\theta - (-mv_1\sin\theta) = 2mv\sin\theta$

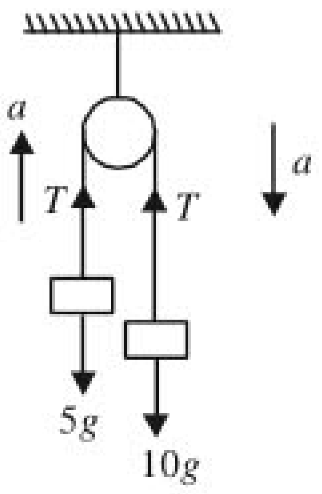
Change in momentum = $2 \times 3 \times 10 \times \sin 60°$

$$= 60 \times \frac{\sqrt{3}}{2}$$

Force = Change in momentum/Impact time

$$= \frac{30\sqrt{3}}{0.2} = 150\sqrt{3}\text{ N}$$

40. (b) : The force equations are



$T - 5g = 5a,$

$10g - T = 10a$

Adding, $10g - 5g = 15a$

or, $a = \frac{5g}{15} = \frac{g}{3}.$

41. (c) : Force $= \frac{d}{dt}$(momentum)

$$= \frac{d}{dt}(mv) = v\left(\frac{dm}{dt}\right) \Rightarrow 210 = 300\left(\frac{dm}{dt}\right)$$

$$\frac{dm}{dt} = \text{rate of combustion } = \frac{210}{300} = 0.7\text{ kg/s}$$

42. (c) : Upward acceleration, $ma = T_1 - mg$

$T_1 = m(g + a)$

Downward acceleration, $ma = mg - T_2$

or, $T_2 = m(g - a)$

$$\frac{T_1}{T_2} = \frac{g+a}{g-a} = \frac{9.8+4.9}{9.8-4.9} = 3:1.$$

43. (d) : When $F = 0$, $600 - 2 \times 10^5 t = 0$

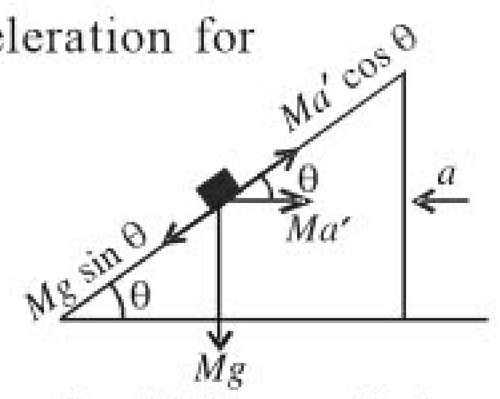
$$\therefore\quad t = \frac{600}{2\times10^5} = 3\times10^{-3}\text{ s}.$$

Now, impulse, $I = \int_0^t F dt = \int_0^t (600 - 2\times10^5 t)dt$

$$600t - 2\times10^5\frac{t^2}{2} = 600 \times 3 \times 10^{-3} - 10^5 \times (3 \times 10^{-3})^2$$

or, $I = 1.8 - 0.9 = 0.9$ N-s.

44. (a) : The pseudo acceleration for the body $a' = a$



If the pseudo force $Ma\cos\theta = Mg\sin\theta$, then the body will be at rest, $a = g\tan\theta$.

This horizontal acceleration should be applied to the wedge to the left.

45. (b) : Thrust $= M(g + a) = u\frac{dm}{dt}$

$$\frac{dm}{dt} = \frac{M(g+a)}{u} = \frac{5000(10+20)}{800} = 187.5\text{ kg/s}$$

46. (b) : Force (F) = 6 N; Initial velocity (u) = 0; Mass (m) = 1 kg and final velocity (v) = 30 m/s.

Therefore acceleration (a) = $\frac{F}{m} = \frac{6}{1} = 6$ m/s^2 and final velocity (v) = 30 = $u + at = 0 + 6 \times t$

or $t = 5$ seconds.

47. (c) : Force (F) = 10 N and acceleration (a) = 1 m/s^2.

Mass (m) = $\frac{F}{a} = \frac{10}{1} = 10$ kg.

48. (c) : Force $(\vec{F}) = 6\hat{i} - 8\hat{j} + 10\hat{k}$ and acceleration (a) = 1 m/s^2.

$$\text{Mass } (m) = \frac{|\vec{F}|}{a} = \frac{|6\hat{i} - 8\hat{j} + 10\hat{k}|}{1}$$

$$= \sqrt{36+64+100} = \sqrt{200} = 10\sqrt{2}\text{ kg.}$$

49. (a) : Mass of bullet (m_1) = 200 gm = 0.2 kg; Speed of bullet (v_1) = 5 m/sec. and mass of gun (m_2) = 1 kg. Before firing, total momentum is zero.

$\therefore$ After firing total momentum is $m_1v_1 + m_2v_2$

From the law of conservation of momentum

$m_1v_1 + m_2v_2 = 0$

$$\text{or}\quad v_2 = \frac{-m_1v_1}{m_2} = \frac{-0.2\times5}{1} = -1\text{ m/sec.}$$

50. (b) : Rate of burning of fuel $\left(\frac{dm}{dt}\right)$ = 1 kg/s and velocity of ejected fuel (v) = 60 km/s = 60×10^3 m/s.

Force = Rate of change of momentum

$$= \frac{dp}{dt} = \frac{d(mv)}{dt} = v\frac{dm}{dt} = (60 \times 10^3) \times 1 = 60000\text{ N.}$$

51. (d) : The acceleration is nullified by force of kinetic friction/mass

$mg\sin\theta$ is force downwards.

μ_k is the coefficient of kinetic friction.

$\mu_k mg\cos\theta$ is force acting upwards.

$\therefore$ $mg\sin\theta - \mu_k mg\cos\theta$ = mass × acceleration.

acceleration = 0 as v is constant

$\therefore$ $\mu_k = \tan\theta.$

52. (c) : Let T be the tension in the branch of a tree when monkey is decending with acceleration a

Thus, $mg - T = ma$

also, T = 75% of weight of monkey

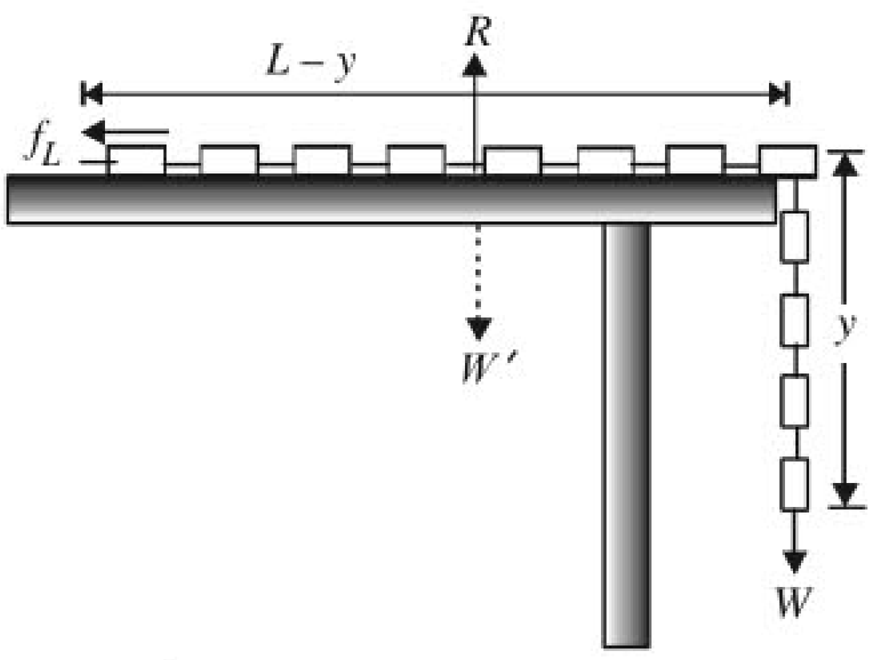
$$T = \left(\frac{75}{100}\right)mg = \frac{3}{4}mg$$

$$\therefore\quad ma = mg - \left(\frac{3}{4}\right)mg = \frac{1}{4}mg \text{ or } a = \frac{g}{4}$$

53. (b)

54. (c) : Newton's first law of motion is related to physical independence of force.

55. (a) : Let M is the mass of the chain of length L. If y is the maximum length of chain which can hang outside the table without sliding, then for equilibrium of the chain, the weight of hanging part must be balanced by the force of friction on the portion on the table.



$W = f_L$ .....(i)

But from figure

$$W = \frac{M}{L}yg \text{ and } R = W' = \frac{M}{L}(L-y)g$$

So that $f_L = \mu R = \mu\frac{M}{L}(L-y)g$

Substituting these values of W and f_L in eqn.(i),

we get $\mu\frac{M}{L}(L-y)g = \frac{M}{L}yg$

or $\mu(L-y) = y$ or $y = \frac{\mu L}{\mu+1} = \frac{0.25\,L}{1.25} = \frac{L}{5}$

or $\frac{y}{L} = \frac{1}{5} = \frac{1}{5}\times 100\% = 20\%$

56. (b) : When milk is churned, cream gets separated due to centrifugal force.

57. (d) : Impulse is a vector quantity and is equal to change in momentum of the body thus, (same as $F \times t$ where t is short)

Impulse $= mv_2 - mv_1 = m(v_2 - v_1)$

58. (c) : Thrust is the force with which the rocket moves upward given by

$$F = u\frac{dm}{dt}$$

Thus mass of the gas ejected per second to supply the thrust needed to overcome the weight of the rocket is

$$\frac{dm}{dt} = \frac{F}{u} = \frac{m\times a}{u} \text{ or } \frac{dm}{dt} = \frac{600\times 10}{1000} = 6 \text{ kgs}^{-1}$$

59. (a) : Since 5 kg body explodes into three fragments with masses in the ratio 1 : 1 : 3 thus, masses of fragments will be 1 kg, 1 kg and 3 kg respectively. The magnitude of resultant momentum of two fragments each of mass 1 kg, moving with velocity 21 m/s, in perpendicular directions is $\sqrt{(m_1v_1)^2 + (m_2v_2)^2}$

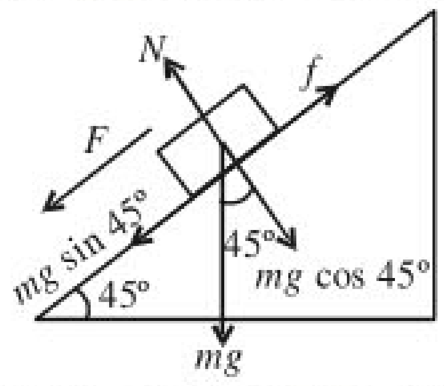
$$m'v' = \sqrt{(21)^2 + (21)^2} = 21\sqrt{2} \text{ kg m/s}$$

According to law of conservation of linear momentum

$$m_3v_3 = m'v' = 21\sqrt{2} \text{ or } 3v_3 = 21\sqrt{2}$$

or $v_3 = 7\sqrt{2}$ m/s

60. (b) : The various forces acting on the body have been shown in the figure. The force on the body down the inclined plane in presence of friction μ is



$$F = mg\sin\theta - f = mg\sin\theta - \mu N = ma$$

or $a = g\sin\theta - \mu g\cos\theta$.

Since block is at rest thus initial velocity $u = 0$

∴ Time taken to slide down the plane

$$t_1 = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2s}{g\sin\theta - \mu g\cos\theta}}$$

In absence of friction time taken will be $t_2 = \sqrt{\frac{2s}{g\sin\theta}}$

Given : $t_1 = 2t_2$.

∴ $t_1^2 = 4t_2^2$ or $\frac{2s}{g(\sin\theta - \mu\cos\theta)} = \frac{2s\times 4}{g(\sin\theta)}$

or $\sin\theta = 4\sin\theta - 4\mu\cos\theta$ or $\mu = \frac{3}{4}\tan\theta = 0.75$

Chapter 5 Work, Energy and Power

1. Consider a drop of rain water having mass 1 g falling from a height of 1 km. It hits the ground with a speed of 50 m s^{-1}. Take 'g' constant with a value 10 m s^{-2}. The work done by the (i) gravitational force and the (ii) resistive force of air is
(a) (i) 1.25 J (ii) –8.25 J
(b) (i) 100 J (ii) 8.75 J
(c) (i) 10 J (ii) –8.75 J
(d) (i) –10 J (ii) –8.25 J
(NEET 2017)

2. A bullet of mass 10 g moving horizontally with a velocity of 400 m s^{-1} strikes a wood block of mass 2 kg which is suspended by light inextensible string of length 5 m. As a result, the centre of gravity of the block found to rise a vertical distance of 10 cm. The speed of the bullet after it emerges out horizontally from the block will be
(a) 100 m s^{-1} (b) 80 m s^{-1}
(c) 120 m s^{-1} (d) 160 m s^{-1}
(NEET-II 2016)

3. Two identical balls A and B having velocities of 0.5 m s^{-1} and –0.3 m s^{-1} respectively collide elastically in one dimension. The velocities of B and A after the collision respectively will be
(a) –0.5 m s^{-1} and 0.3 m s^{-1}
(b) 0.5 m s^{-1} and –0.3 m s^{-1}
(c) –0.3 m s^{-1} and 0.5 m s^{-1}
(d) 0.3 m s^{-1} and 0.5 m s^{-1}
(NEET-II 2016, 1994, 1991)

4. A particle moves from a point $(-2\hat{i}+5\hat{j})$ to $(4\hat{j}+3\hat{k})$ when a force of $(4\hat{i}+3\hat{j})$ N is applied. How much work has been done by the force ?
(a) 8 J (b) 11 J (c) 5 J (d) 2 J
(Neet-II 2016)

5. A particle of mass 10 g moves along a circle of radius 6.4 cm with a constant tangential acceleration. What is the magnitude of this acceleration if the kinetic energy of the particle becomes equal to 8×10^{-4} J by the end of the second revolution after the beginning of the motion?
(a) 0.18 m/s^2 (b) 0.2 m/s^2
(c) 0.1 m/s^2 (d) 0.15 m/s^2
(NEET-I 2016)

6. A body of mass 1 kg begins to move under the action of a time dependent force $\vec{F}=(2t\,\hat{i}+3t^2\,\hat{j})$N, where $\hat{i}$ and $\hat{j}$ are unit vectors along x and y axis. What power will be developed by the force at the time t?
(a) $(2t^3+3t^4)$ W (b) $(2t^3+3t^5)$ W
(c) $(2t^2+3t^3)$ W (d) $(2t^2+4t^4)$ W
(NEET-I 2016)

7. What is the minimum velocity with which a body of mass m must enter a vertical loop of radius R so that it can complete the loop?
(a) $\sqrt{3gR}$ (b) $\sqrt{5gR}$
(c) $\sqrt{gR}$ (d) $\sqrt{2gR}$
(NEET-I 2016)

8. Two particles A and B, move with constant velocities $\vec{v}_1$ and $\vec{v}_2$. At the initial moment their position vectors are $\vec{r}_1$ and $\vec{r}_2$ respectively. The condition for particles A and B for their collision is
(a) $\vec{r}_1\times\vec{v}_1=\vec{r}_2\times\vec{v}_2$ (b) $\vec{r}_1-\vec{r}_2=\vec{v}_1-\vec{v}_2$
(c) $\dfrac{\vec{r}_1-\vec{r}_2}{|\vec{r}_1-\vec{r}_2|}=\dfrac{\vec{v}_2-\vec{v}_1}{|\vec{v}_2-\vec{v}_1|}$ (d) $\vec{r}_1\cdot\vec{v}_1=\vec{r}_2\cdot\vec{v}_2$
(2015)

9. The heart of a man pumps 5 litres of blood through the arteries per minute at a pressure of 150 mm of mercury. If the density of mercury be 13.6×10^3 kg/m^3 and g = 10 m/s^2 then the power (in watt) is
(a) 3.0 (b) 1.50 (c) 1.70 (d) 2.35
(2015)

10. A ball is thrown vertically downwards from a height of 20 m with an initial velocity v_0. It collides with the ground, loses 50 percent of its energy in collision and rebounds to the same height. The initial velocity v_0 is (Take $g = 10$ m s^{-2})
(a) 28 m s^{-1} (b) 10 m s^{-1}
(c) 14 m s^{-1} (d) 20 m s^{-1} *(2015)*

11. On a frictionless surface, a block of mass M moving at speed v collides elastically with another block of same mass M which is initially at rest. After collision the first block moves at an angle θ to its initial direction and has a speed $\frac{v}{3}$. The second block's speed after the collision is
(a) $\frac{3}{\sqrt{2}}v$ (b) $\frac{\sqrt{3}}{2}v$
(c) $\frac{2\sqrt{2}}{3}v$ (d) $\frac{3}{4}v$ *(2015)*

12. A particle of mass m is driven by a machine that delivers a constant power k watts. If the particle starts from rest the force on the particle at time t is
(a) $\sqrt{2mk}\, t^{-1/2}$ (b) $\frac{1}{2}\sqrt{mk}\, t^{-1/2}$
(c) $\sqrt{\frac{mk}{2}}\, t^{-1/2}$ (d) $\sqrt{mk}\, t^{-1/2}$
(2015 Cancelled)

13. A block of mass 10 kg, moving in x direction with a constant speed of 10 m s^{-1}, is subjected to a retarding force $F = 0.1x$ J/m during its travel from $x = 20$ m to 30 m. Its final KE will be
(a) 275 J (b) 250 J (c) 475 J (d) 450 J
(2015 Cancelled)

14. Two particles of masses m_1, m_2 move with initial velocities u_1 and u_2. On collision, one of the particles get excited to higher level, after absorbing energy ε. If final velocities of particles be v_1 and v_2 then we must have
(a) $\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 - \varepsilon = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$
(b) $\frac{1}{2}m_1^2u_1^2 + \frac{1}{2}m_2^2u_2^2 + \varepsilon = \frac{1}{2}m_1^2v_1^2 + \frac{1}{2}m_2^2v_2^2$
(c) $m_1^2u_1 + m_2^2u_2 - \varepsilon = m_1^2v_1 + m_2^2v_2$
(d) $\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 - \varepsilon$
(2015 Cancelled)

15. Two similar springs P and Q have spring constants K_P and K_Q, such that $K_P > K_Q$. They are stretched first by the same amount (case a), then by the same force (case b). The work done by the springs W_P and W_Q are related as, in case (a) and case (b) respectively
(a) $W_P > W_Q$; $W_Q > W_P$
(b) $W_P < W_Q$; $W_Q < W_P$
(c) $W_P = W_Q$; $W_P > W_Q$
(d) $W_P = W_Q$; $W_P = W_Q$ *(2015 Cancelled)*

16. A body of mass $(4m)$ is lying in x-y plane at rest. It suddenly explodes into three pieces. Two pieces, each of mass (m) move perpendicular to each other with equal speeds (v). The total kinetic energy generated due to explosion is
(a) mv^2 (b) $\frac{3}{2}mv^2$ (c) $2mv^2$ (d) $4mv^2$
(2014)

17. A uniform force of $(3\hat{i} + \hat{j})$ newton acts on a particle of mass 2 kg. Hence the particle is displaced from position $(2\hat{i} + \hat{k})$ metre to position $(4\hat{i} + 3\hat{j} - \hat{k})$ metre. The work done by the force on the particle is
(a) 13 J (b) 15 J (c) 9 J (d) 6 J
(NEET 2013)

18. A particle with total energy E is moving in a potential energy region $U(x)$. Motion of the particle is restricted to the region when
(a) $U(x) < E$ (b) $U(x) = 0$
(c) $U(x) \le E$ (d) $U(x) > E$
(Karnataka NEET 2013)

19. One coolie takes 1 minute to raise a suitcase through a height of 2 m but the second coolie takes 30 s to raise the same suitcase to the same height. The powers of two coolies are in the ratio
(a) 1 : 3 (b) 2 : 1 (c) 3 : 1 (d) 1 : 2
(Karnataka NEET 2013)

20. The potential energy of a particle in a force field is $U = \frac{A}{r^2} - \frac{B}{r}$ where A and B are positive constants and r is the distance of particle from the centre of the field. For stable equilibrium, the distance of the particle is
(a) $\frac{B}{2A}$ (b) $\frac{2A}{B}$ (c) $\frac{A}{B}$ (d) $\frac{B}{A}$
(2012)

21. A solid cylinder of mass 3 kg is rolling on a horizontal surface with velocity 4 m s^{-1}. It collides with a horizontal spring of force constant 200 N m^{-1}. The maximum compression produced in the spring will be
(a) 0.5 m (b) 0.6 m (c) 0.7 m (d) 0.2 m
(2012)

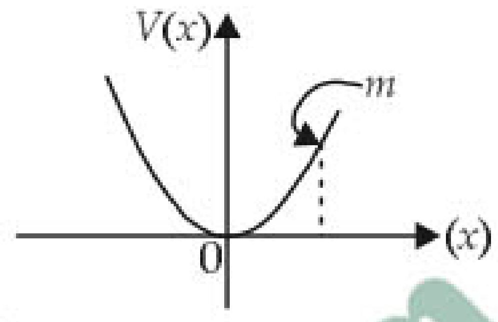
22. Two spheres A and B of masses m_1 and m_2 respectively collide. A is at rest initially and B is moving with velocity v along x-axis. After collision B has a velocity in a direction perpendicular to the original direction. The mass A moves after collision in the direction
(a) same as that of B
(b) opposite to that of B
(c) $\theta = \tan^{-1}\left(\frac{1}{2}\right)$ to the x-axis
(d) $\theta = \tan^{-1}\left(-\frac{1}{2}\right)$ to the x-axis *(2012)*

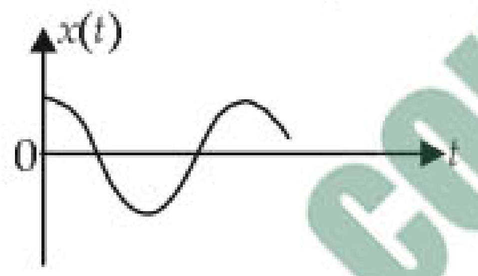
23. A car of mass m starts from rest and accelerates so that the instantaneous power delivered to the car has a constant magnitude P_0. The instantaneous velocity of this car is proportional to
(a) t^2P_0 (b) $t^{1/2}$ (c) $t^{-1/2}$ (d) $\frac{t}{\sqrt{m}}$
(Mains 2012)

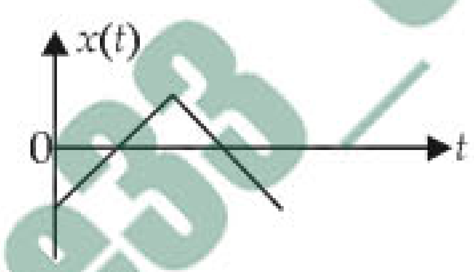
24. The potential energy of a system increases if work is done
(a) upon the system by a nonconservative force.
(b) by the system against a conservative force.
(c) by the system against a nonconservative force.
(d) upon the system by a conservative force.
(2011)

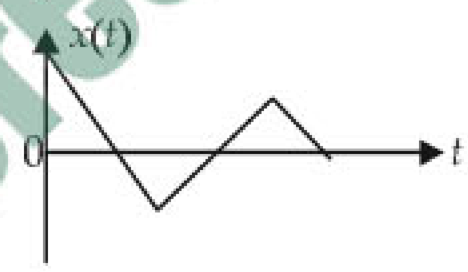
25. A body projected vertically from the earth reaches a height equal to earth's radius before returning to the earth. The power exerted by the gravitational force is greatest
(a) at the highest position of the body.
(b) at the instant just before the body hits the earth.
(c) it remains constant all through.
(d) at the instant just after the body is projected. *(2011)*

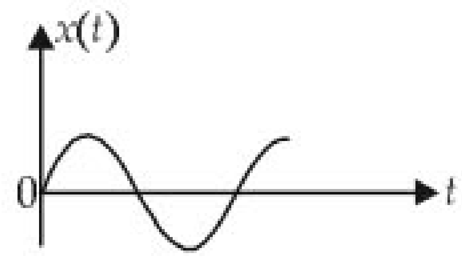
26. A particle of mass m is released from rest and follows a parabolic path as shown. Assuming that the displacement of the mass from the origin is small, which graph correctly depicts the position of the particle as a function of time?



(a)


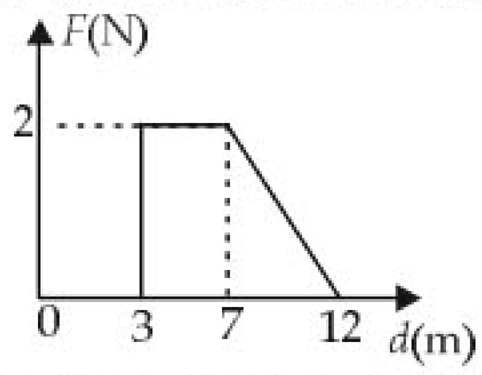
(b)


(c)


(d)


(2011)

27. Force F on a particle moving in a straight line varies with distance d as shown in figure.



The work done on the particle during its displacement of 12 m is
(a) 18 J (b) 21 J (c) 26 J (d) 13 J
(2011)

28. A mass m moving horizontally (along the x-axis) with velocity v collides and sticks to a mass of $3m$ moving vertically upward (along the y-axis) with velocity $2v$. The final velocity of the combination is
(a) $\frac{3}{2}v\hat{i} + \frac{1}{4}v\hat{j}$ (b) $\frac{1}{4}v\hat{i} + \frac{3}{2}v\hat{j}$
(c) $\frac{1}{3}v\hat{i} + \frac{2}{3}v\hat{j}$ (d) $\frac{2}{3}v\hat{i} + \frac{1}{3}v\hat{j}$
(Mains 2011)

29. A ball moving with velocity 2 m/s collides head on with another stationary ball of double the mass. If the coefficient of restitution is 0.5, then their velocities (in m/s) after collision will be
(a) 0, 1 (b) 1, 1 (c) 1, 0.5 (d) 0, 2 *(2010)*

30. An engine pumps water through a hose pipe. Water passes through the pipe and leaves it with a velocity of 2 m/s. The mass per unit length of water in the pipe is 100 kg/m. What is the power of the engine?
(a) 400 W (b) 200 W
(c) 100 W (d) 800 W *(2010)*

31. A particle of mass M, starting from rest, undergoes uniform acceleration. If the speed acquired in time T is V, the power delivered to the particle is
(a) $\frac{MV^2}{T}$ (b) $\frac{1}{2}\frac{MV^2}{T^2}$
(c) $\frac{MV^2}{T^2}$ (d) $\frac{1}{2}\frac{MV^2}{T}$ *(Mains 2010)*

32. A block of mass M is attached to the lower end of a vertical spring. The spring is hung from a ceiling and has force constant value k. The mass is released from rest with the spring initially unstretched. The maximum extension produced in the length of the spring will be
(a) $2Mg/k$ (b) $4Mg/k$
(c) $Mg/2k$ (d) Mg/k *(2009)*

33. A body of mass 1 kg is thrown upwards with a velocity 20 m/s. It momentarily comes to rest after attaining a height of 18 m. How much energy is lost due to air friction? (g = 10 m/s²)
(a) 30 J (b) 40 J (c) 10 J (d) 20 J *(2009)*

34. An explosion blows a rock into three parts. Two parts go off at right angles to each other. These two are, 1 kg first part moving with a velocity of 12 m s^{-1} and 2 kg second part moving with a velocity 8 m s^{-1}. If the third part flies off with a velocity of 4 m s^{-1}, its mass would be
(a) 7 kg (b) 17 kg (c) 3 kg (d) 5 kg *(2009)*

35. An engine pumps water continuously through a hose. Water leaves the hose with a velocity v and m is the mass per unit length of the water jet. What is the rate at which kinetic energy is imparted to water?
(a) mv^3 (b) $\frac{1}{2}mv^2$
(c) $\frac{1}{2}m^2v^2$ (d) $\frac{1}{2}mv^3$ *(2009)*

36. A shell of mass 200 gm is ejected from a gun of mass 4 kg by an explosion that generates 1.05 kJ of energy. The initial velocity of the shell is
(a) 40 ms^{-1} (b) 120 ms^{-1}
(c) 100 ms^{-1} (d) 80 ms^{-1} *(2008)*

37. Water falls from a height of 60 m at the rate of 15 kg/s to operate a turbine. The losses due to frictional forces are 10% of energy. How much power is generated by the turbine ? (g = 10 m/s²)
(a) 12.3 kW (b) 7.0 kW
(c) 8.1 kW (d) 10.2 kW *(2008)*

38. A vertical spring with force constant k is fixed on a table. A ball of mass m at a height h above the free upper end of the spring falls vertically on the spring so that the spring is compressed by a distance d. The net work done in the process is
(a) $mg(h+d)-\frac{1}{2}kd^2$
(b) $mg(h-d)-\frac{1}{2}kd^2$
(c) $mg(h-d)+\frac{1}{2}kd^2$
(d) $mg(h+d)+\frac{1}{2}kd^2$. *(2007)*

39. 300 J of work is done in sliding a 2 kg block up an inclined plane of height 10 m. Work done against friction is (Take g = 10 m/s²)
(a) 1000 J (b) 200 J
(c) 100 J (d) zero. *(2006)*

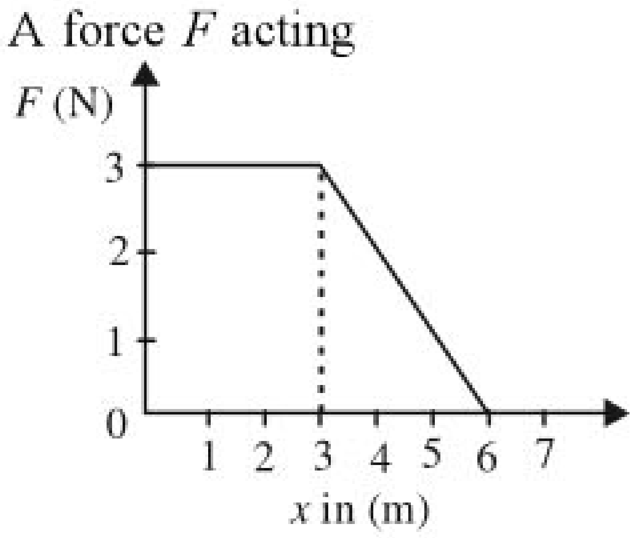
40. The potential energy of a long spring when stretched by 2 cm is U. If the spring is stretched by 8 cm the potential energy stored in it is
(a) $U/4$ (b) $4U$ (c) $8U$ (d) $16U$. *(2006)*

41. A body of mass 3 kg is under a constant force which causes a displacement s in metres in it, given by the relation $s = \frac{1}{3}t^2$, where t is in seconds. Work done by the force in 2 seconds is

(a) $\frac{19}{5}$ J (b) $\frac{5}{19}$ J
(c) $\frac{3}{8}$ J (d) $\frac{8}{3}$ J. *(2006)*

42. A bomb of mass 30 kg at rest explodes into two pieces of masses 18 kg and 12 kg. The velocity of 18 kg mass is 6 m s^{-1}. The kinetic energy of the other mass is
(a) 324 J (b) 486 J
(c) 256 J (d) 524 J. *(2005)*

43. A force F acting

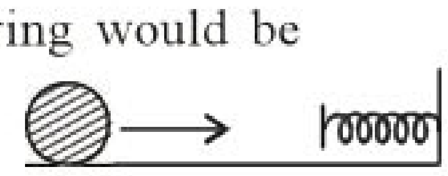


on an object varies with distance x as shown here. The force is in N and x in m. The work done by the force in moving the object from $x = 0$ to $x = 6$ m is
(a) 18.0 J (b) 13.5 J
(c) 9.0 J (d) 4.5 J. *(2005)*

44. A particle of mass m_1 is moving with a velocity v_1 and another particle of mass m_2 is moving with a velocity v_2. Both of them have the same momentum but their different kinetic energies are E_1 and E_2 respectively. If $m_1 > m_2$ then
(a) $E_1 < E_2$ (b) $\frac{E_1}{E_2} = \frac{m_1}{m_2}$
(c) $E_1 > E_2$ (d) $E_1 = E_2$ *(2004)*

45. A ball of mass 2 kg and another of mass 4 kg are dropped together from a 60 feet tall building. After a fall of 30 feet each towards earth, their respective kinetic energies will be in the ratio of
(a) $\sqrt{2} : 1$ (b) 1 : 4
(c) 1 : 2 (d) $1 : \sqrt{2}$ *(2004)*

46. A mass of 0.5 kg moving with a speed of 1.5 m/s on a horizontal smooth surface, collides with a nearly weightless spring of force constant $k = 50$ N/m. The maximum compression of the spring would be



(a) 0.15 m (b) 0.12 m
(c) 1.5 m (d) 0.5 m *(2004)*

47. When a long spring is stretched by 2 cm, its potential energy is U. If the spring is stretched by 10 cm, the potential energy stored in it will be
(a) $U/5$ (b) $5U$
(c) $10U$ (d) $25U$ *(2003)*

48. A stationary particle explodes into two particles of masses m_1 and m_2 which move in opposite directions with velocities v_1 and v_2. The ratio of their kinetic energies E_1/E_2 is
(a) m_2/m_1 (b) m_1/m_2
(c) 1 (d) m_1v_2/m_2v_1
(2003)

49. If kinetic energy of a body is increased by 300% then percentage change in momentum will be
(a) 100% (b) 150%
(c) 265% (d) 73.2%. *(2002)*

50. A child is sitting on a swing. Its minimum and maximum heights from the ground 0.75 m and 2 m respectively, its maximum speed will be
(a) 10 m/s (b) 5 m/s
(c) 8 m/s (d) 15 m/s. *(2001)*

51. Two springs A and B having spring constant K_A and K_B ($K_A = 2K_B$) are stretched by applying force of equal magnitude. If energy stored in spring A is E_A then energy stored in B will be
(a) $2E_A$ (b) $E_A/4$
(c) $E_A/2$ (d) $4E_A$. *(2001)*

52. A particle is projected making an angle of 45° with horizontal having kinetic energy K. The kinetic energy at highest point will be
(a) $\frac{K}{\sqrt{2}}$ (b) $\frac{K}{2}$ (c) $2K$ (d) K.
(2001, 1997)

53. If $\vec{F} = (60\hat{i} + 15\hat{j} - 3\hat{k})$ N and $\vec{v} = (2\hat{i} - 4\hat{j} + 5\hat{k})$ m/s, then instantaneous power is
(a) 195 watt (b) 45 watt
(c) 75 watt (d) 100 watt. *(2000)*

54. A mass of 1 kg is thrown up with a velocity of 100 m/s. After 5 seconds, it explodes into two parts. One part of mass 400 g comes down with a velocity 25 m/s. The velocity of other part is (Take $g = 10$ ms^{-2})
(a) 40 m/s (b) 40 m/s
(c) 100 m/s (d) 60 m/s *(2000)*

55. Two bodies with kinetic energies in the ratio of 4 : 1 are moving with equal linear momentum. The ratio of their masses is
(a) 4 : 1 (b) 1 : 1
(c) 1 : 2 (d) 1 : 4. *(1999)*

56. Two equal masses m_1 and m_2 moving along the same straight line with velocities + 3 m/s and –5 m/s respectively collide elastically. Their velocities after the collision will be respectively
(a) – 4 m/s and +4 m/s
(b) +4 m/s for both
(c) – 3 m/s and +5 m/s
(d) – 5 m/s and + 3 m/s. *(1998)*

57. A force acts on a 3 g particle in such a way that the position of the particle as a function of time is given by $x = 3t - 4t^2 + t^3$, where x is in metres and t is in seconds. The work done during the first 4 second is
(a) 490 mJ (b) 450 mJ
(c) 576 mJ (d) 530 mJ. *(1998)*

58. A shell, in flight, explodes into four unequal parts. Which of the following is conserved?
(a) Potential energy (b) Momentum
(c) Kinetic energy (d) Both (a) and (c). *(1998)*

59. Two bodies of masses m and $4m$ are moving with equal kinetic energies. The ratio of their linear momenta is
(a) 1 : 2 (b) 1 : 4 (c) 4 : 1 (d) 1 : 1. *(1998, 1997, 1989)*

60. A metal ball of mass 2 kg moving with speed of 36 km/h has a head on collision with a stationary ball of mass 3 kg. If after collision, both the balls move as a single mass, then the loss in K.E. due to collision is
(a) 100 J (b) 140 J
(c) 40 J (d) 60 J. *(1997)*

61. A body moves a distance of 10 m along a straight line under the action of a 5 N force. If the work done is 25 J, then angle between the force and direction of motion of the body is
(a) 60° (b) 75°
(c) 30° (d) 45°. *(1997)*

62. A moving body of mass m and velocity 3 km/hour collides with a rest body of mass $2m$ and sticks to it. Now the combined mass starts to move. What will be the combined velocity?
(a) 3 km/hour (b) 4 km/hour
(c) 1 km/hour (d) 2 km/hour. *(1996)*

63. The potential energy between two atoms, in a molecule, is given by $U(x) = \frac{a}{x^{12}} - \frac{b}{x^6}$ where a and b are positive constants and x is the distance between the atoms. The atom is in stable equilibrium, when
(a) $x = \left(\frac{2a}{b}\right)^{1/6}$ (b) $x = \left(\frac{11a}{5b}\right)^{1/6}$
(c) $x = 0$ (d) $x = \left(\frac{a}{2b}\right)^{1/6}$. *(1995)*

64. A body, constrained to move in y-direction, is subjected to a force given by $\vec{F} = (-2\hat{i} + 15\hat{j} + 6\hat{k})$ N. The work done by this force in moving the body through a distance of $10\hat{j}$ m along y-axis, is
(a) 150 J (b) 20 J
(c) 190 J (d) 160 J. *(1994)*

65. The kinetic energy acquired by a mass m in travelling distance d, starting from rest, under the action of a constant force is directly proportional to
(a) m (b) m^0
(c) $\sqrt{m}$ (d) $1/\sqrt{m}$. *(1994)*

66. A position dependent force, $F = (7 - 2x + 3x^2)$ N acts on a small body of mass 2 kg and displaces it from $x = 0$ to $x = 5$ m. The work done in joule is
(a) 135 (b) 270
(c) 35 (d) 70. *(1994, 1992)*

67. When a body moves with a constant speed along a circle
(a) no work is done on it
(b) no acceleration is produced in it
(c) its velocity remains constant
(d) no force acts on it. *(1994)*

68. Two masses of 1 g and 9 g are moving with equal kinetic energies. The ratio of the magnitudes of their respective linear momenta is
(a) 1 : 9 (b) 9 : 1
(c) 1 : 3 (d) 3 : 1 *(1993)*

69. A particle of mass M is moving in a horizontal circle of radius R with uniform speed v. When it moves from one point to a diametrically opposite point, its

(a) kinetic energy change by $Mv^2/4$
(b) momentum does not change
(c) momentum change by $2Mv$
(d) kinetic energy changes by Mv^2 *(1992)*

70. How much water a pump of 2 kW can raise in one minute to a height of 10 m ? (take g = 10 m/s^2)
(a) 1000 litres
(b) 1200 litres
(c) 100 litres
(d) 2000 litres *(1990)*

71. A bullet of mass 10 g leaves a rifle at an initial velocity of 1000 m/s and strikes the earth at the same level with a velocity of 500 m/s. The work done in joule overcoming the resistance of air will be
(a) 375 (b) 3750
(c) 5000 (d) 500 *(1989)*

72. The coefficient of restitution e for a perfectly elastic collision is
(a) 1 (b) 0
(c) ∞ (d) -1 *(1988)*

Answer Key

1.	(c)	**2.**	(c)	**3.**	(b)	**4.**	(c)	**5.**	(c)	**6.**	(b)	**7.**	(b)	**8.**	(c)	**9.**	(c)	**10.**	(d)
11.	(c)	**12.**	(c)	**13.**	(c)	**14.**	(a)	**15.**	(a)	**16.**	(b)	**17.**	(c)	**18.**	(c)	**19.**	(d)	**20.**	(b)
21.	(b)	**22.**	(d)	**23.**	(b)	**24.**	(b)	**25.**	(b)	**26.**	(a)	**27.**	(d)	**28.**	(b)	**29.**	(a)	**30.**	(d)
31.	(d)	**32.**	(a)	**33.**	(d)	**34.**	(d)	**35.**	(d)	**36.**	(c)	**37.**	(c)	**38.**	(a)	**39.**	(c)	**40.**	(d)
41.	(d)	**42.**	(b)	**43.**	(b)	**44.**	(a)	**45.**	(c)	**46.**	(a)	**47.**	(d)	**48.**	(a)	**49.**	(a)	**50.**	(b)
51.	(a)	**52.**	(b)	**53.**	(b)	**54.**	(c)	**55.**	(d)	**56.**	(d)	**57.**	(c)	**58.**	(b)	**59.**	(a)	**60.**	(d)
61.	(a)	**62.**	(c)	**63.**	(a)	**64.**	(a)	**65.**	(b)	**66.**	(a)	**67.**	(a)	**68.**	(c)	**69.**	(c)	**70.**	(b)
71.	(b)	**72.**	(a)																

EXPLANATIONS

1. (c) : Here, $m = 1$ g $= 10^{-3}$ kg, $h = 1$ km $= 1000$ m, $v = 50$ m s^{-1}, $g = 10$ m s^{-2}.

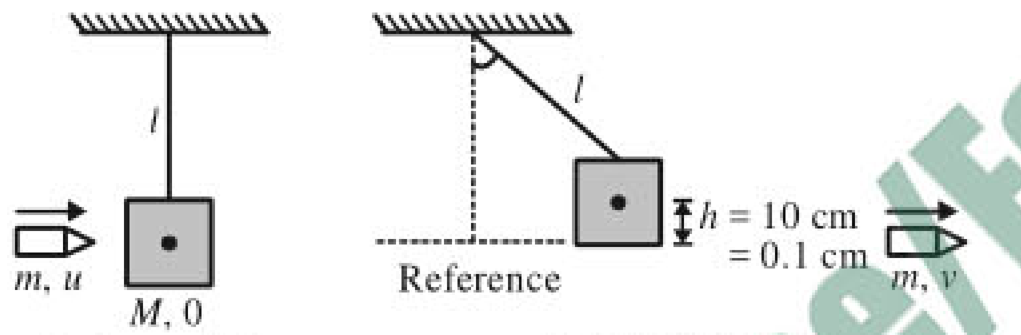
(i) The work done by the gravitational force $= mgh = 10^{-3} \times 10 \times 1000 = 10$ J

(ii) The total work done by gravitational force and the resistive force of air is equal to change in kinetic energy of rain drop.

$$\therefore \quad W_g + W_r = \frac{1}{2}mv^2 - 0$$

$$10 + W_r = \frac{1}{2} \times 10^{-3} \times 50 \times 50 \text{ or } W_r = -8.75 \text{ J}$$

2. (c) : Mass of bullet, $m = 10$ g $= 0.01$ kg
Initial speed of bullet, $u = 400$ m s^{-1}
Mass of block, $M = 2$ kg
Length of string, $l = 5$ m
Speed of the block after collision $= v_1$
Speed of the bullet on emerging from block, $v = ?$



Before collision After collision

Using energy conservation principle for the block,

$$(KE + PE)_{\text{Reference}} = (KE + PE)_h$$

$$\Rightarrow \frac{1}{2}Mv_1^2 = Mgh \quad \text{or,} \quad v_1 = \sqrt{2gh}$$

$$v_1 = \sqrt{2 \times 10 \times 0.1} = \sqrt{2} \text{ m s}^{-1}$$

Using momentum conservation principle for block and bullet system,

$$(M \times 0 + mu)_{\text{Before collision}} = (M \times v_1 + mv)_{\text{After collision}}$$

$$\Rightarrow 0.01 \times 400 = 2\sqrt{2} + 0.01 \times v$$

$$\Rightarrow v = \frac{4 - 2\sqrt{2}}{0.01} = 117.15 \text{ m s}^{-1} \approx 120 \text{ m s}^{-1}$$

3. (b) : Masses of the balls are same and collision is elastic, so their velocity will be interchanged after collision.

4. (c) : Here $\vec{r}_1 = (-2\hat{i} + 5\hat{j})$m, $\vec{r}_2 = (4\hat{j} + 3\hat{k})$m
$\vec{F} = (4\hat{i} + 3\hat{j})$N, W = ?

Work done by force F in moving from $\vec{r}_1$ to $\vec{r}_2$,

$$W = \vec{F} \cdot (\vec{r}_2 - \vec{r}_1) \Rightarrow W = (4\hat{i} + 3\hat{j}) \cdot (4\hat{j} + 3\hat{k} + 2\hat{i} - 5\hat{j})$$

$$= (4\hat{i} + 3\hat{j}) \cdot (2\hat{i} - \hat{j} + 3\hat{k}) = 8 + (-3) = 5 \text{ J}$$

5. (c) : Here, $m = 10$ g $= 10^{-2}$ kg,
$R = 6.4$ cm $= 6.4 \times 10^{-2}$ m, $K_f = 8 \times 10^{-4}$ J, $K_i = 0$, $a_t = ?$
Using work energy theorem,
Work done by all the forces = Change in KE

$$W_{\text{tangential force}} + W_{\text{centripetal force}} = K_f - K_i$$

$$\Rightarrow a_t = \frac{K_f}{4\pi Rm} = \frac{8 \times 10^{-4}}{4 \times \frac{22}{7} \times 6.4 \times 10^{-2} \times 10^{-2}}$$

$$= 0.099 \approx 0.1 \text{ m s}^{-2}$$

6. (b) : Here, $\vec{F} = (2t\hat{i} + 3t^2\hat{j})$ N, $m = 1$ kg

Acceleration of the body, $\vec{a} = \frac{\vec{F}}{m} = \frac{(2t\hat{i} + 3t^2\hat{j})\text{ N}}{1\text{kg}}$

Velocity of the body at time t,

$$\vec{v} = \int \vec{a}\,dt = \int (2t\hat{i} + 3t^2\hat{j})dt = t^2\hat{i} + t^3\hat{j} \text{ m s}^{-1}$$

$\therefore$ Power developed by the force at time t,

$$P = \vec{F} \cdot \vec{v} = (2t\hat{i} + 3t^2\hat{j}) \cdot (t^2\hat{i} + t^3\hat{j}) \text{ W} = (2t^3 + 3t^5) \text{ W}$$

7. (b)

8. (c) : Let the particles A and B collide at time t. For their collision, the position vectors of both particles should be same at time t, *i.e.*,

$$\vec{r}_1 + \vec{v}_1 t = \vec{r}_2 + \vec{v}_2 t \,;\; \vec{r}_1 - \vec{r}_2 = \vec{v}_2 t - \vec{v}_1 t = (\vec{v}_2 - \vec{v}_1)t \quad \text{...(i)}$$

Also, $|\vec{r}_1 - \vec{r}_2| = |\vec{v}_2 - \vec{v}_1| t$ or $t = \frac{|\vec{r}_1 - \vec{r}_2|}{|\vec{v}_2 - \vec{v}_1|}$

Substituting this value of t in eqn. (i), we get

$$\vec{r}_1 - \vec{r}_2 = (\vec{v}_2 - \vec{v}_1)\frac{|\vec{r}_1 - \vec{r}_2|}{|\vec{v}_2 - \vec{v}_1|}$$

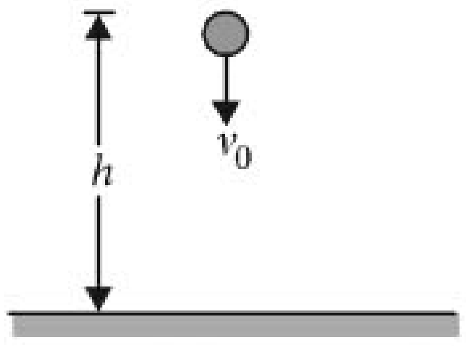
$$\text{or} \quad \frac{\vec{r}_1 - \vec{r}_2}{|\vec{r}_1 - \vec{r}_2|} = \frac{(\vec{v}_2 - \vec{v}_1)}{|\vec{v}_2 - \vec{v}_1|}$$

9. (c) : Here, Volume of blood pumped by man's heart,
$V = 5$ litres $= 5 \times 10^{-3}$ m^3 ($\because$ 1 litre $= 10^{-3}$ m^3)
Time in which this volume of blood pumps,
$t = 1$ min $= 60$ s
Pressure at which the blood pumps,
$P = 150$ mm of Hg $= 0.15$ m of Hg
$= (0.15 \text{ m})(13.6 \times 10^3 \text{ kg/m}^3)(10 \text{ m/s}^2)$ ($\because P = h\rho g$)
$= 20.4 \times 10^3$ N/m^2

$$\therefore \text{ Power of the heart} = \frac{PV}{t}$$

$$= \frac{(20.4 \times 10^3 \text{ N/m}^2)(5 \times 10^{-3} \text{ m}^3)}{60 \text{ s}} = 1.70 \text{ W}$$

10. (d) : The situation is shown in the figure. Let v be the velocity of the ball with which it collides with ground. Then according to the law of conservation of energy,



Gain in kinetic energy = loss in potential energy

i.e. $\frac{1}{2}mv^2 - \frac{1}{2}mv_0^2 = mgh$

(where m is the mass of the ball)

or $v^2 - v_0^2 = 2gh$ ... (i)

Now, when the ball collides with the ground, 50% of its energy is lost and it rebounds to the same height h.

$\therefore \frac{50}{100}\left(\frac{1}{2}mv^2\right) = mgh$

$\frac{1}{4}v^2 = gh$ or $v^2 = 4gh$

Substituting this value of v^2 in eqn. (i), we get

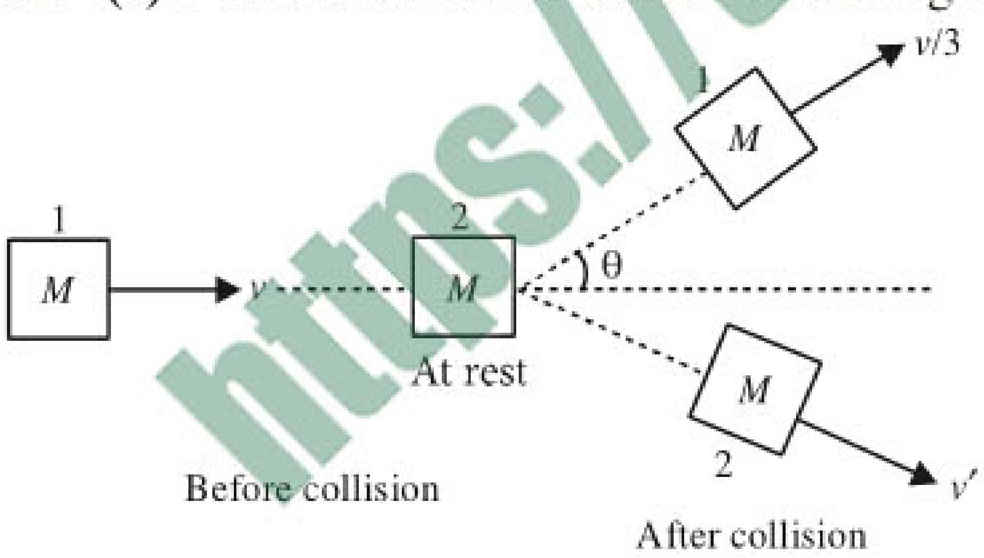
$4gh - v_0^2 = 2gh$

or $v_0^2 = 4gh - 2gh = 2gh$ or $v_0 = \sqrt{2gh}$

Here, $g = 10$ ms^{-2} and $h = 20$ m

$\therefore v_0 = \sqrt{2(10\text{ ms}^{-2})(20\text{m})} = 20\text{ ms}^{-1}$

11. (c) : The situation is shown in the figure.



Let v' be speed of second block after the collision. As the collision is elastic, so kinetic energy is conserved.

According to conservation of kinetic energy,

$\frac{1}{2}Mv^2 + 0 = \frac{1}{2}M\left(\frac{v}{3}\right)^2 + \frac{1}{2}Mv'^2$

$v^2 = \frac{v^2}{9} + v'^2$ or $v'^2 = v^2 - \frac{v^2}{9} = \frac{9v^2 - v^2}{9} = \frac{8}{9}v^2$

$v' = \sqrt{\frac{8}{9}v^2} = \frac{\sqrt{8}}{3}v = \frac{2\sqrt{2}}{3}v$

12. (c) : Constant power acting on the particle of mass m is k watt.

or $P = k$

$\frac{dW}{dt} = k;\quad dW = kdt$

Integrating both sides, $\int_0^W dW = \int_0^t k\,dt$

$\Rightarrow W = kt$ ... (i)

Using work energy theorem, $W = \frac{1}{2}mv^2 - \frac{1}{2}m(0)^2$

$kt = \frac{1}{2}mv^2$ [Using equation (i)]

$v = \sqrt{\frac{2kt}{m}}$

Acceleration of the particle, $a = \frac{dv}{dt}$

$a = \frac{1}{2}\sqrt{\frac{2k}{m}}\frac{1}{\sqrt{t}} = \sqrt{\frac{k}{2mt}}$

Force on the particle, $F = ma = \sqrt{\frac{mk}{2t}} = \sqrt{\frac{mk}{2}}\,t^{-1/2}$

13. (c) : Here, $m = 10$ kg, $v_i = 10$ m s^{-1}

Initial kinetic energy of the block is

$K_i = \frac{1}{2}mv_i^2 = \frac{1}{2}\times(10\text{ kg})\times(10\text{ m s}^{-1})^2 = 500\text{ J}$

Work done by retarding force

$W = \int_{x_1}^{x_2} F_r dx = \int_{20}^{30} -0.1\,x dx = -0.1\left[\frac{x^2}{2}\right]_{20}^{30}$

$= -0.1\left[\frac{900-400}{2}\right] = -25\text{ J}$

According to work-energy theorem,

$W = K_f - K_i$

$K_f = W + K_i = -25\text{ J} + 500\text{ J} = 475\text{ J}$

14. (a) : Total initial energy of two particles

$= \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2$

Total final energy of two particles

$= \frac{1}{2}m_2v_2^2 + \frac{1}{2}m_1v_1^2 + \varepsilon$

Using energy conservation principle,

$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 + \varepsilon$

$\therefore \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 - \varepsilon = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$

15. **(a) :** Here, $K_P > K_Q$

Case (a) : Elongation (x) in each spring is same.

$$W_P = \frac{1}{2}K_P x^2,\ W_Q = \frac{1}{2}K_Q x^2$$

$\therefore \quad W_P > W_Q$

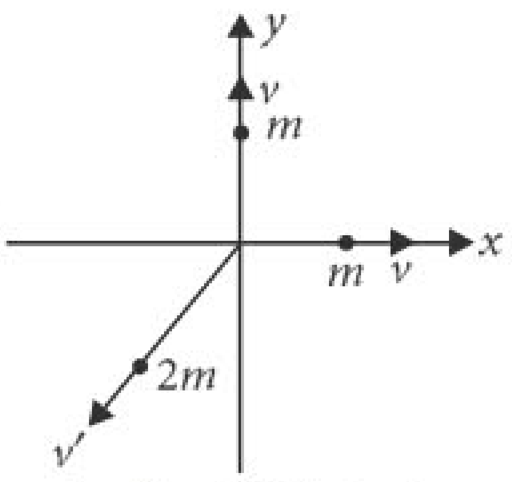
Case (b) : Force of elongation is same.

So, $x_1 = \frac{F}{K_P}$ and $x_2 = \frac{F}{K_Q}$

$$W_P = \frac{1}{2}K_P x_1^2 = \frac{1}{2}\frac{F^2}{K_P}$$

$$W_Q = \frac{1}{2}K_Q x_2^2 = \frac{1}{2}\frac{F^2}{K_Q} \qquad \therefore \ W_P < W_Q$$

16. **(b) :**



Let $\vec{v}'$ be velocity of third piece of mass $2m$.

Initial momentum, $\vec{p}_i = 0$ (As the body is at rest)

Final momentum, $\vec{p}_f = mv\hat{i} + mv\hat{j} + 2m\vec{v}'$

According to law of conservation of momentum

$$\vec{p}_i = \vec{p}_f$$

$$0 = mv\hat{i} + mv\hat{j} + 2m\vec{v}'$$

$$\vec{v}' = -\frac{v}{2}\hat{i} - \frac{v}{2}\hat{j}$$

The magnitude of $\vec{v}'$ is

$$v' = \sqrt{\left(-\frac{v}{2}\right)^2 + \left(-\frac{v}{2}\right)^2} = \frac{v}{\sqrt{2}}$$

Total kinetic energy generated due to explosion

$$= \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}(2m)v'^2$$

$$= \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}(2m)\left(\frac{v}{\sqrt{2}}\right)^2$$

$$= mv^2 + \frac{mv^2}{2} = \frac{3}{2}mv^2$$

17. **(c) :** Here, $\vec{F} = (3\hat{i} + \hat{j})$ N

Initial position, $\vec{r}_1 = (2\hat{i} + \hat{k})$ m

Final position, $\vec{r}_2 = (4\hat{i} + 3\hat{j} - \hat{k})$ m

Displacement, $\vec{r} = \vec{r}_2 - \vec{r}_1$

$$\vec{r} = (4\hat{i} + 3\hat{j} - \hat{k})\text{ m} - (2\hat{i} + \hat{k})\text{ m} = 2\hat{i} + 3\hat{j} - 2\hat{k}\text{ m}$$

Work done,

$$W = \vec{F}\cdot\vec{r} = (3\hat{i} + \hat{j})\cdot(2\hat{i} + 3\hat{j} - 2\hat{k}) = 6 + 3 = 9\text{ J}$$

18. **(c)**

19. **(d) :** Power, $P = \frac{\text{Work done}}{\text{Time taken}}$

Here work done ($= mgh$) is same in both cases.

$$\therefore \quad \frac{P_1}{P_2} = \frac{t_2}{t_1} = \frac{30\text{ s}}{1\text{ min}} = \frac{30\text{ s}}{60\text{ s}} = \frac{1}{2}$$

20. **(b) :** Here, $U = \frac{A}{r^2} - \frac{B}{r}$

For equilibrium, $\frac{dU}{dr} = 0$

$$\therefore \quad -\frac{2A}{r^3} + \frac{B}{r^2} = 0 \text{ or } \frac{2A}{r^3} = \frac{B}{r^2} \text{ or } r = \frac{2A}{B}$$

For stable equilibrium, $\frac{d^2U}{dr^2} > 0$

$$\frac{d^2U}{dr^2} = \frac{6A}{r^4} - \frac{2B}{r^3}$$

$$\left.\frac{d^2U}{dr^2}\right|_{r=(2A/B)} = \frac{6AB^4}{16A^4} - \frac{2B^4}{8A^3} = \frac{B^4}{8A^3} > 0$$

So for stable equilibrium, the distance of the particle is $\frac{2A}{B}$.

21. **(b) :** At maximum compression the solid cylinder will stop.

According to law of conservation of mechanical energy

Loss in kinetic energy = Gain in potential energy of cylinder of spring

$$\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = \frac{1}{2}kx^2$$

$$\frac{1}{2}mv^2 + \frac{1}{2}\left(\frac{mR^2}{2}\right)\left(\frac{v}{R}\right)^2 = \frac{1}{2}kx^2z$$

($\because$ $v = R\omega$ and for solid cylinder, $I = \frac{1}{2}mR^2$)

$$\frac{1}{2}mv^2 + \frac{1}{4}mv^2 = \frac{1}{2}kx^2$$

$$\frac{3}{4}mv^2 = \frac{1}{2}kx^2 \text{ or } x^2 = \frac{3}{2}\frac{mv^2}{k}$$

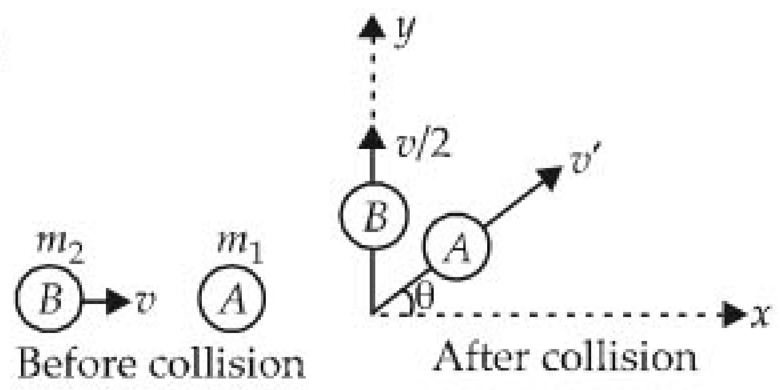
Here, $m = 3$ kg, $v = 4$ m s^{-1}, $k = 200$ N m^{-1}

Substituting the given values, we get

$$x^2 = \frac{3 \times 3 \times 4 \times 4}{2 \times 200}$$

$$x^2 = \frac{36}{100} \text{ or } x = 0.6\text{ m}$$

22. (d) :



According to law of conservation of linear momentum along x-axis, we get

$m_1 \times 0 + m_2 \times v = m_1 v' \cos\theta$

$m_2 v = m_1 v' \cos\theta$

or $\cos\theta = \frac{m_2 v}{m_1 v'}$ ...(i)

According to law of conservation of linear momentum along y-axis, we get

$$m_1 \times 0 + m_2 \times 0 = m_1 v' \sin\theta + m_2 \frac{v}{2}$$

$$-m_2 \frac{v}{2} = m_1 v' \sin\theta$$

$$\sin\theta = -\frac{m_2 v}{2 m_1 v'} \quad ...(ii)$$

Divide (ii) by (i), we get

$\tan\theta = -\frac{1}{2}$ or $\theta = \tan^{-1}\left(-\frac{1}{2}\right)$ to the x-axis

23. (b) : $P_0 = Fv$

$\because \quad F = ma = m\frac{dv}{dt}$

$\therefore \quad P_0 = mv\frac{dv}{dt}$ or $P_0 dt = mvdv$

Integrating both sides, we get $\int_0^t P_0 dt = m\int_0^v v dv$

$$P_0 t = \frac{mv^2}{2}$$

$$v = \left(\frac{2P_0 t}{m}\right)^{1/2} \text{ or } v \propto \sqrt{t}$$

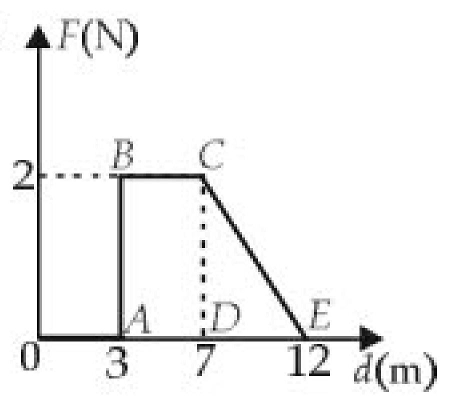
24. (b)

25. (b) : Power, $P = \vec{F}\cdot\vec{v} = Fv\cos\theta$

Just before hitting the earth $\theta = 0°$. Hence, the power exerted by the gravitational force is greatest at the instant just before the body hits the earth.

26. (a)

27. (d) :

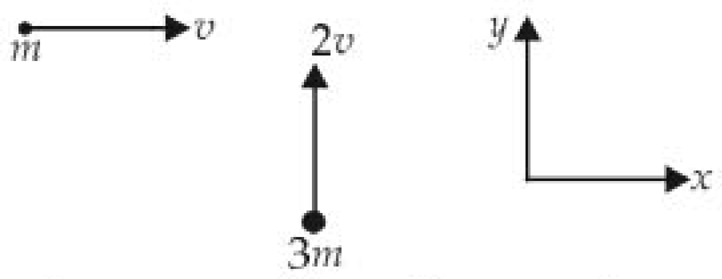


Work done = Area under (F-d) graph

= Area of rectangle $ABCD$ + Area of triangle DCE

$= 2 \times (7 - 3) + \frac{1}{2} \times 2 \times (12 - 7) = 8 + 5 = 13$ J

28. (b) :



According to conservation of momentum, we get

$mv\hat{i} + (3m)2v\hat{j} = (m + 3m)\vec{v'}$

where $\vec{v'}$ is the final velocity after collision

$\vec{v'} = \frac{1}{4}v\hat{i} + \frac{6}{4}v\hat{j} = \frac{1}{4}v\hat{i} + \frac{3}{2}v\hat{j}$

29. (a) : Here, $m_1 = m$, $m_2 = 2m$

$u_1 = 2$ m/s, $u_2 = 0$

Coefficient of restitution, $e = 0.5$

Let v_1 and v_2 be their respective velocities after collision.

Applying the law of conservation of linear momentum, we get

$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$

$\therefore \quad m \times 2 + 2m \times 0 = m \times v_1 + 2m \times v_2$

or $\quad 2m = mv_1 + 2mv_2$

or $\quad 2 = (v_1 + 2v_2)$ ...(i)

By definition of coefficient of restitution,

$e = \frac{v_2 - v_1}{u_1 - u_2}$

or $\quad e(u_1 - u_2) = v_2 - v_1 \Rightarrow 0.5(2 - 0) = v_2 - v_1$ ...(ii)

$1 = v_2 - v_1$

Solving equations (i) and (ii), we get

$v_1 = 0$ m/s, $v_2 = 1$ m/s

30. (d) : Here,

Mass per unit length of water, $\mu = 100$ kg/m

Velocity of water, $v = 2$ m/s

Power of the engine, $P = \mu v^3 = (100 \text{ kg/m})(2 \text{ m/s})^3$
$= 800$ W

31. (d) : Power delivered in time T is

$P = F{\cdot}V = MaV$

or $P = MV\frac{dV}{dT} \Rightarrow PdT = MVdV$

$\Rightarrow \quad PT = \frac{MV^2}{2}$ or $P = \frac{1}{2}\frac{MV^2}{T}$

32. (a) : When the mass attached to a spring fixed at the other end is allowed to fall suddenly, it extends the spring by x. Potential energy lost by the mass is gained by the spring.

$Mgx = \frac{1}{2}kx^2 \Rightarrow x = \frac{2Mg}{k}$.

33. **(d) :** Initial velocity $u = 20$ m/s; $m = 1$ kg

Kinetic energy = maximum potential energy

Initial kinetic energy $= \frac{1}{2} \times 1 \times 20^2 = 200$ J

Mgh (max) = 200 J.

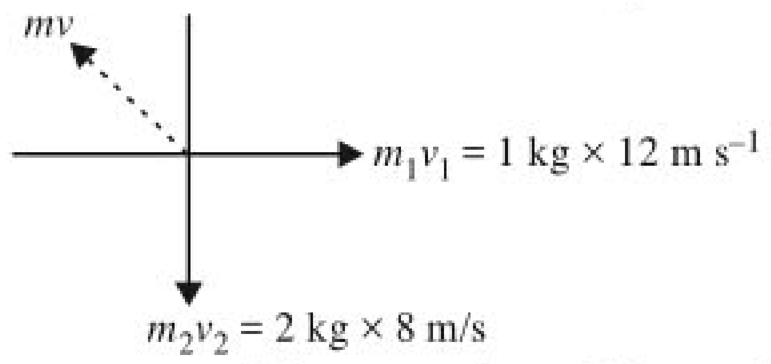
$\therefore$ $h = 20$ m.

The height travelled by the body, $h' = 18$ m

$\therefore$ Loss of energy due to air friction $= mgh - mgh'$

$\Rightarrow$ Energy lost = 200 J – 1 × 10 × 18 J = 20 J.

34. **(d) :** When an explosion breaks a rock, by the law of conservation of momentum, initial momentum is zero and for the three pieces,



Total momentum of the two pieces 1 kg and 2 kg

$= \sqrt{12^2 + 16^2} = 20$ kg ms^{-1}.

The third piece has the same momentum and in the direction opposite to the resultant of these two momenta.

$\therefore$ Momentum of the third piece = 20 kg ms^{-1}

Velocity = 4 ms^{-1}

$\therefore$ Mass of the 3rd piece $= \frac{mv}{v} = \frac{20}{4} = 5$ kg

35. **(d) :** Velocity of water is v, mass flowing per unit length is m.

$\therefore$ Mass flowing per second $= mv$

$\therefore$ Rate of kinetic energy or K.E. per second

$= \frac{1}{2}(mv)v^2 = \frac{1}{2}mv^3$.

36. **(c) :** $mv = Mv' \Rightarrow v' = \left(\frac{m}{M}\right)v$

Total K.E. of the bullet and gun

$= \frac{1}{2}mv^2 + \frac{1}{2}Mv'^2$

Total K.E $= \frac{1}{2}mv^2 + \frac{1}{2}M \cdot \frac{m^2}{M^2}v^2$

Total K.E. $= \frac{1}{2}mv^2\left\{1 + \frac{m}{M}\right\}$

$= \left\{\frac{1}{2} \times 0.2\right\}\left\{1 + \frac{0.2}{4}\right\}v^2 = 1.05 \times 1000$ J

$\Rightarrow v^2 = \frac{4 \times 1.05 \times 1000}{0.1 \times 4.2} = 100^2$;

$\therefore$ $v = 100$ ms^{-1}

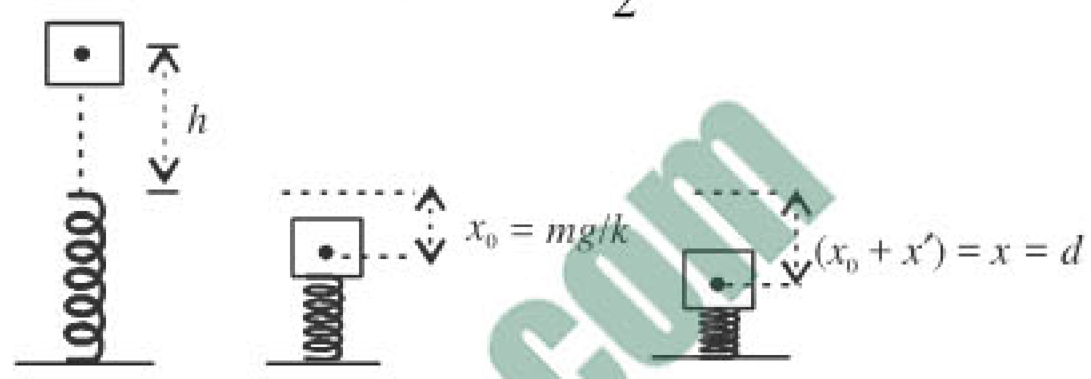
37. **(c) :** Mass of water falling/second = 15 kg/s

$h = 60$ m, $g = 10$ m/s^2, loss = 10% *i.e.*, 90% is used.

Power generated = 15 × 10 × 60 × 0.9 = 8100 W = 8.1 kW.

38. **(a) :** When a mass falls on a spring from a height h the work done by the loss of granitational potential energy of the mass is stored as the potential energy of the spring.

One can write $mg(h + d) = \frac{1}{2}kd^2$



$mg(h + d) = \frac{1}{2}kx^2 = \frac{1}{2}kd^2$

The two energies are equal.

If work done is initial P.E. – final P.E., it is zero. Work done is totally converted (assuming there is no loss). The work done in compression or expansion is always positive as it is $\propto x^2$. The answer expected is

$mg(h + d) - \frac{1}{2}kd^2$ or, $\frac{1}{2}kd^2 - mg(h + d)$ as seen from options, but it is not justified.

Question could have been more specific like work done by oscillation.

39. **(c) :** Loss in potential energy $= mgh$

= 2 × 10 × 10 = 200 J.

Gain in kinetic energy = work done = 300 J

$\therefore$ Work done against friction = 300 – 200 = 100 J

40. **(d) :** Potential energy of a spring

$= \frac{1}{2} \times$ force constant × (extension)^2

$\therefore$ Potential energy $\propto$ (extension)^2.

or, $\frac{U_1}{U_2} = \left(\frac{x_1}{x_2}\right)^2$ or, $\frac{U_1}{U_2} = \left(\frac{2}{8}\right)^2$

or, $\frac{U_1}{U_2} = \frac{1}{16}$ or, $U_2 = 16U_1 = 16U$. $(\because U_1 = U)$

41. **(d) :** $s = \frac{t^2}{3}$; $\frac{ds}{dt} = \frac{2t}{3}$; $\frac{d^2s}{dt^2} = \frac{2}{3}$

Work done, $W = \int F ds = \int m \frac{d^2s}{dt^2} ds$

$= \int m \frac{d^2s}{dt^2}\frac{ds}{dt}dt = \int_0^2 3 \times \frac{2}{3} \times \frac{2t}{3}dt = \frac{4}{3}\int_0^2 t\,dt$

$= \frac{4}{3}\int_0^2 t\,dt = \frac{4}{3}\left|\frac{t^2}{2}\right|_0^2 = \frac{4}{3} \times 2 = \frac{8}{3}$ J.

42. (b) : According to law of conservation of angular momentum,
$30 \times 0 = 18 \times 6 + 12 \times v$
$\Rightarrow \quad 108 = 12v \Rightarrow v = -9$ m/s.
Negative sign indicates that both fragments move in opposite direction.

K.E. of 12 kg $= \frac{1}{2}mv^2 = \frac{1}{2}\times 12\times 81 = 486$ J.

43. (b) : Work done = area under F-x curve
$= \text{area of trapezium} = \frac{1}{2}\times(6+3)\times 3 = \frac{9\times 3}{2} = 13.5$ J.

44. (a) : Kinetic energy $= \frac{p^2}{2m}$

$\therefore \frac{E_1}{E_2} = \frac{p_1^2/2m_1}{p_2^2/2m_2} \Rightarrow \frac{E_1}{E_2} = \frac{m_2}{m_1}$ as $m_1 > m_2$

$\therefore E_1 < E_2$.

45. (c) : Ratio of their kinetic energy is given as
$\frac{KE_1}{KE_2} = \frac{(1/2)\, m_1 v_1^2}{(1/2)\, m_2 v_2^2}$
$\Rightarrow \quad v^2 = 2gs$ (zero initial velocity)
which is same for both
$\therefore \quad \frac{\text{KE}_1}{\text{KE}_2} = \frac{m_1}{m_2} = \frac{2}{4} = \frac{1}{2}$.

46. (a) : The kinetic energy of mass is converted into energy required to compress a spring which is given by
$\Rightarrow \frac{1}{2}mv^2 = \frac{1}{2}kx^2$
$\Rightarrow x = \sqrt{\frac{mv^2}{k}} = \sqrt{\frac{0.5\times(1.5)^2}{50}} = 0.15$ m.

47. (d) : $U = -kx^2$, k = Spring constant
$\frac{U_1}{U_2} = \frac{x_1^2}{x_2^2} = \frac{4}{100} \Rightarrow U_2 = 25\, U_1$

48. (a) : $m_1v_1 = m_2v_2$ (conservation of linear momentum)
$\frac{E_1}{E_2} = \frac{(1/2)m_1v_1^2}{(1/2)m_2v_2^2} = \frac{m_1^2v_1^2}{m_2^2v_2^2}\cdot\frac{m_2}{m_1} = \frac{m_2}{m_1}$.

49. (a) : Let m be the mass of the body and v_1 and v_2 be the initial and final velocities of the body respectively.
$\therefore$ Initial kinetic energy $= \frac{1}{2}mv_1^2$
Final kinetic energy $= \frac{1}{2}mv_2^2$
Initial kinetic energy is increased 300% to get the final kinetic energy.

$\therefore \quad \frac{1}{2}mv_2^2 = \frac{1}{2}\left(1+\frac{300}{100}\right)mv_1^2$
$\Rightarrow \quad v_2 = 2v_1$ or $v_2/v_1 = 2$ ... (i)
Initial momentum = $p_1 = mv_1$
Final momentum = $p_2 = mv_2$
$\therefore \quad \frac{p_2}{p_1} = \frac{mv_2}{mv_1} = \frac{v_2}{v_1} = 2$;
$\therefore \quad p_2 = 2\,p_1 = \left(1+\frac{100}{100}\right)p_1$
So momentum has increased 100%.

50. (b) : Drop in P.E = maximum K.E.
$mg\,(2-0.75) = 1\,mv^2 \Rightarrow v = \sqrt{2g(1.25)} = 5$ m/s.

51. (a) : Energy $= \frac{1}{2}Kx^2 = \frac{1}{2}\frac{F^2}{K}$.
$\frac{K_A}{K_B} = 2$
$\therefore \quad \frac{E_A}{E_B} = \frac{1}{2}$ or $E_B = 2E_A$.

52. (b) : Kinetic energy of the ball = K and angle of projection (θ) = 45°.
Velocity of the ball at the highest point = $v\cos\theta$
$= v\cos 45° = \frac{v}{\sqrt{2}}$.
Therefore kinetic energy of the ball
$= \frac{1}{2}m\times\left(\frac{v}{\sqrt{2}}\right)^2 = \frac{1}{4}mv^2 = \frac{K}{2}$.

53. (b) : $P = \vec{F}\cdot\vec{v} = (60\hat{i}+15\hat{j}-3\hat{k})\cdot(2\hat{i}-4\hat{j}+5\hat{k})$
$= 120 - 60 - 15 = 45$ watts.

54. (c) : Velocity after 5 sec, $v = u - gt$
$= 100 - 10 \times 5 = 50$ m/s
By conservation of momentum
$1 \times 50 = 0.4 \times (-25) + 0.6 \times v'$
$60 = 0.6 \times v' \Rightarrow v' = 100$ m/s upwards

55. (d) : $\text{K.E.} = \frac{p^2}{2m} \Rightarrow \frac{\text{K.E.}_1}{\text{K.E.}_2} = \frac{m_2}{m_1} = \frac{4}{1}$
or $\quad \frac{m_1}{m_2} = \frac{1}{4}$

56. (d) : Equal masses after elastic collision interchange their velocities.
-5 m/s and $+3$ m/s.

57. (c) : $x = 3t - 4t^2 + t^3$ or, $\frac{d^2x}{dt^2} = -8 + 6t$
or $\quad \left.\frac{d^2x}{dt^2}\right|_{t=4} = 16$ or $x|_{t=4} = 12$
Work done $= F\cdot s = mas = 3 \times 10^{-3} \times 16 \times 12 = 576$ mJ.

58. (b)

59. (a) : Mass of first body = m;
Mass of second body = $4m$ and $KE_1 = KE_2$.
Linear momentum of a body

$p = \sqrt{2mE} \propto \sqrt{m}$.

Therefore $\frac{p_1}{p_2} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{m}{4m}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$

or $p_1 : p_2 = 1 : 2$.

60. (d) : Mass of metal ball = 2 kg;
Speed of metal ball (v_1) = 36 km/h = 10 m/s and mass of stationary ball = 3 kg.
Applying law of conservation of momentum,
$m_1v_1 + m_2v_2 = (m_1 + m_2)v$

or, $v = \frac{m_1v_1 + m_2v_2}{m_1 + m_2} = \frac{(2\times10)+(3\times0)}{2+3} = \frac{20}{5} = 4$ m/s.

Therefore loss of energy

$= \left[\frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2\right] - \frac{1}{2}\times(m_1+m_2)v^2$

$= \left[\frac{1}{2}\times2\times(10)^2 + \frac{1}{2}\times3(0)^2\right] - \frac{1}{2}\times(2+3)\times(4)^2$

$= 100 - 40 = 60$ J.

61. (a) : Distance (s) = 10 m; Force (F) = 5 N and work done (W) = 25 J.
Work done (W) = $Fs\cos\theta = 25$
$\therefore$ $25 = 5 \times 10\cos\theta = 50\cos\theta$
or $\cos q = 25/50 = 0.5$ or $\theta = 60°$.

62. (c) : Mass of body (m_1) = m; Velocity of first body (u_1) = 3 km/hour; Mass of second body in rest (m_2) = $2m$ and velocity of second body (u_2) = 0.
After combination, mass of the body
$M = m + 2m = 3m$
From the law of conservation of momentum, we get
$Mv = m_1u_1 + m_2u_2$
or $3mv = (m \times 3) + (2m \times 0) = 3m$
or $v = 1$ km/hour.

63. (a) : $U(x) = \frac{a}{x^{12}} - \frac{b}{x^6}$ or $-\frac{12a}{x^{13}} - \frac{-6b}{x^7} = 0$

or $x^6 = \frac{2a}{b}$. Therefore $x = \left(\frac{2a}{b}\right)^{1/6}$.

64. (a) : Force $\vec{F} = (-2\hat{i} + 15\hat{j} + 6\hat{k})$ N and distance (d) = $10\hat{j}$ m.
Work done

$W = \vec{F}\cdot\vec{d} = (-2\hat{i}+15\hat{j}+6\hat{k})\cdot(10\hat{j}) = 150$ N-m = 150 J.

65. (b) : $v^2 = u^2 + 2as$ or $v^2 - u^2 = 2as$

or $v^2 - (0)^2 = 2\times\frac{F}{m}\times s$ or $v^2 = \frac{2Fs}{m}$ and

K.E. $= \frac{1}{2}mv^2 = \frac{1}{2}m\times\frac{2Fs}{m} = Fs.$

Thus K.E. is independent of m or directly proportional to m^0.

66. (a) : Force (F) = $7 - 2x + 3x^2$; Mass (m) = 2 kg and displacement (d) = 5 m. Therefore work done

$(W) = \int F dx = \int_0^5 (7-2x+3x^2)dx = (7x - x^2 + x^3)_0^5$

$= (7 \times 5) - (5)^2 + (5)^3 = 35 - 25 + 125 = 135$ J.

67. (a)

68. (c) : $\frac{K_1}{K_2} = \frac{p_1^2}{p_2^2} \times \frac{M_2^2}{M_1^2}$

when $K_1 = K_2$

$\frac{p_1}{p_2} = \sqrt{\frac{M_1}{M_2}} = \sqrt{\frac{1}{9}} = \frac{1}{3}$

$\therefore$ $p_1 : p_2 = 1 : 3$

69. (c) : On the diametrically opposite points, the velocities have same magnitude but opposite directions. Therefore change in momentum is $Mv - (-Mv) = 2Mv$

70. (b) : Power $= \frac{\text{work done}}{\text{time taken}} = \frac{W}{t}$

but W = mass × gravity × height

$\therefore$ $P = \frac{M \times g \times h}{t}$

$\Rightarrow$ $M = \frac{p \times t}{g \times h} = \frac{2000 \times 60}{10 \times 10} = 1200$ kg.

i.e., 1200 litres as one litre has a mass of 1 kg.

71. (b) : Work done = change in kinetic energy of the body

$W = \frac{1}{2}\times 0.01[(1000)^2 - (500)^2] = 3750$ joule.

72. (a) : Coefficient of restitution or resilience of two bodies is defined as the constant ratio of relative velocity after impact to the relative velocity of the bodies before impact when the two bodies collide head on. There velocities are in the opposite directions.

Thus $\frac{v_1 - v_2}{u_1 - u_2}$ = constant = $-e$

The constant e is known as coeff. of restitution or resilience of two bodies. For a perfectly elastic collision, $e = 1$ and for a perfectly inelastic collision, $e = 0$. Thus $0 \le e \le 1$.

Chapter 6 System of Particles and Rotational Motion

1. A rope is wound around a hollow cylinder of mass 3 kg and radius 40 cm. What is the angular acceleration of the cylinder if the rope is pulled with a force of 30 N?
(a) 0.25 rad s^{-2} (b) 25 rad s^{-2}
(c) 5 m s^{-2} (d) 25 m s^{-2}
(NEET 2017)

2. Two discs of same moment of inertia rotating about their regular axis passing through centre and perpendicular to the plane of disc with angular velocities ω_1 and ω_2. They are brought into contact face to face coinciding the axis of rotation. The expression for loss of energy during this process is
(a) $\frac{1}{4}I(\omega_1-\omega_2)^2$ (b) $I(\omega_1-\omega_2)^2$
(c) $\frac{1}{8}I(\omega_1-\omega_2)^2$ (d) $\frac{1}{2}I(\omega_1+\omega_2)^2$
(NEET 2017)

3. Which of the following statements are correct?
(1) Centre of mass of a body always coincides with the centre of gravity of the body.
(2) Centre of mass of a body is the point at which the total gravitational torque on the body is zero.
(3) A couple on a body produces both translational and rotational motion in a body.
(4) Mechanical advantage greater than one means that small effort can be used to lift a large load.
(a) (1) and (2) (b) (2) and (3)
(c) (3) and (4) (d) (2) and (4)
(NEET 2017)

4. Two rotating bodies A and B of masses m and $2m$ with moments of inertia I_A and I_B $(I_B > I_A)$ have equal kinetic energy of rotation. If L_A and L_B be their angular momenta respectively, then
(a) $L_A=\frac{L_B}{2}$ (b) $L_A=2L_B$
(c) $L_B>L_A$ (d) $L_A>L_B$
(NEET-II 2016)

5. A solid sphere of mass m and radius R is rotating about its diameter. A solid cylinder of the same mass and same radius is also rotating about its geometrical axis with an angular speed twice that of the sphere. The ratio of their kinetic energies of rotation $(E_{sphere}/E_{cylinder})$ will be
(a) 2 : 3 (b) 1 : 5
(c) 1 : 4 (d) 3 : 1
(NEET-II 2016)

6. A light rod of length l has two masses m_1 and m_2 attached to its two ends. The moment of inertia of the system about an axis perpendicular to the rod and passing through the centre of mass is
(a) $\frac{m_1m_2}{m_1+m_2}l^2$ (b) $\frac{m_1+m_2}{m_1m_2}l^2$
(c) $(m_1+m_2)l^2$ (d) $\sqrt{m_1m_2}\,l^2$
(NEET-II 2016)

7. A disc and a sphere of same radius but different masses roll off on two inclined planes of the same altitude and length. Which one of the two objects gets to the bottom of the plane first?
(a) Both reach at the same time
(b) Depends on their masses
(c) Disc
(d) Sphere
(NEET-I 2016)

8. From a disc of radius R and mass M, a circular hole of diameter R, whose rim passes through the centre is cut. What is the moment of inertia of the remaining part of the disc about a perpendicular axis, passing through the centre?
(a) $11\,MR^2/32$ (b) $9\,MR^2/32$
(c) $15\,MR^2/32$ (d) $13\,MR^2/32$
(NEET-I 2016)

9. A uniform circular disc of radius 50 cm at rest is free to turn about an axis which is perpendicular to its plane and passes through its centre. It is subjected to a torque which produces a constant angular acceleration of 2.0 rad s^{-2}. Its net acceleration in m s^{-2} at the end of 2.0 s is approximately

(a) 6.0 (b) 3.0 (c) 8.0 (d) 7.0

(NEET-I 2016)

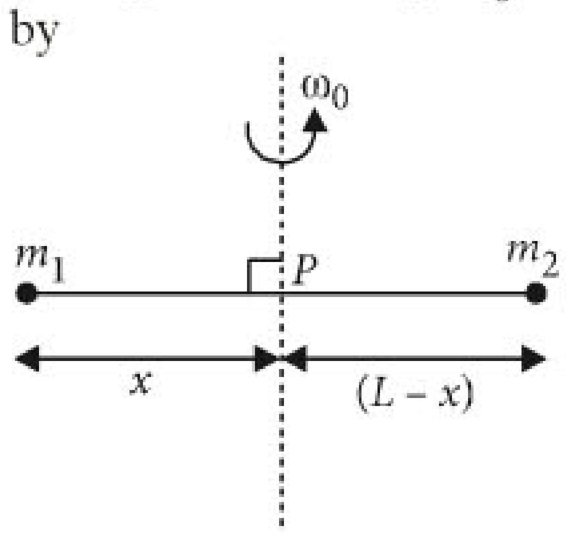
10. Point masses m_1 and m_2 are placed at the opposite ends of a rigid rod of length L, and negligible mass. The rod is to be set rotating about an axis perpendicular to it. The position of point P on this rod through which the axis should pass so that the work required to set the rod rotating with angular velocity ω_0 is minimum, is given by

(a) $x = \frac{m_2}{m_1}L$

(b) $x = \frac{m_2 L}{m_1 + m_2}$

(c) $x = \frac{m_1 L}{m_1 + m_2}$

(d) $x = \frac{m_1}{m_2}L$



(2015)

11. An automobile moves on a road with a speed of 54 km h^{-1}. The radius of its wheels is 0.45 m and the moment of inertia of the wheel about its axis of rotation is 3 kg m^2. If the vehicle is brought to rest in 15 s, the magnitude of average torque transmitted by its brakes to the wheel is

(a) 10.86 kg m^2 s^{-2} (b) 2.86 kg m^2 s^{-2}
(c) 6.66 kg m^2 s^{-2} (d) 8.58 kg m^2 s^{-2}

(2015)

12. A force $\vec{F} = \alpha\hat{i} + 3\hat{j} + 6\hat{k}$ is acting at a point $\vec{r} = 2\hat{i} - 6\hat{j} - 12\hat{k}$. The value of α for which angular momentum about origin is conserved is

(a) zero (b) 1
(c) -1 (d) 2 *(2015)*

13. A rod of weight W is supported by two parallel knife edges A and B and is in equilibrium in a horizontal position. The knives are at a distance d from each other. The centre of mass of the rod is at distance x from A. The normal reaction on A is

(a) $\frac{W(d-x)}{x}$ (b) $\frac{W(d-x)}{d}$

(c) $\frac{Wx}{d}$ (d) $\frac{Wd}{x}$

(2015 Cancelled)

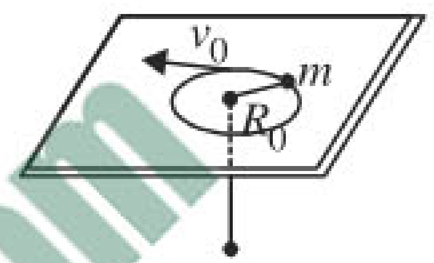
14. A mass m moves in a circle on a smooth horizontal plane with velocity v_0 at a radius R_0. The mass is attached to a string which passes through a smooth hole in the plane as shown. The tension in the string is increased gradually and finally m moves in a circle of radius $\frac{R_0}{2}$. The final value of the kinetic energy is

(a) $2mv_0^2$

(b) $\frac{1}{2}mv_0^2$

(c) mv_0^2

(d) $\frac{1}{4}mv_0^2$



(2015 Cancelled)

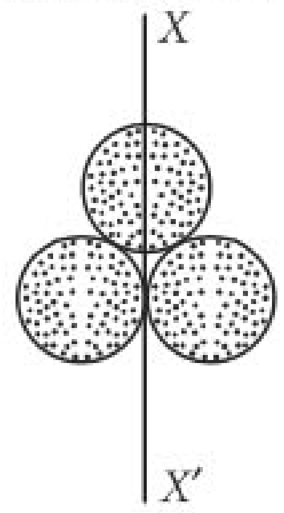
15. Three identical spherical shells, each of mass m and radius r are placed as shown in figure. Consider an axis XX' which is touching to two shells and passing through diameter of third shell. Moment of inertia of the system consisting of these three spherical shells about XX' axis is

(a) $\frac{16}{5}mr^2$

(b) $4mr^2$

(c) $\frac{11}{5}mr^2$

(d) $3mr^2$



(2015 Cancelled)

16. A solid cylinder of mass 50 kg and radius 0.5 m is free to rotate about the horizontal axis. A massless string is wound round the cylinder with one end attached to it and other hanging freely. Tension in the string required to produce an angular acceleration of 2 revolutions s^{-2} is

(a) 25 N (b) 50 N (c) 78.5 N (d) 157 N

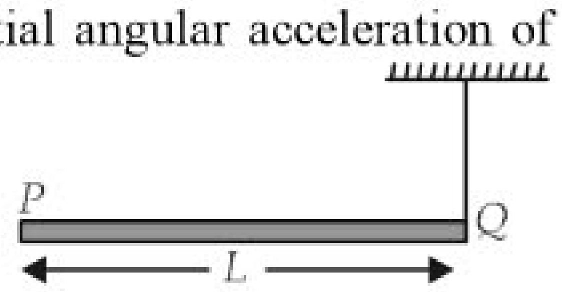
(2014)

17. The ratio of the accelerations for a solid sphere (mass m and radius R) rolling down an incline of angle θ without slipping and slipping down the incline without rolling is

(a) 5 : 7 (b) 2 : 3 (c) 2 : 5 (d) 7 : 5

(2014)

18. A rod PQ of mass M and length L is hinged at end P. The rod is kept horizontal by a massless string tied to point Q as shown in figure. When string is cut, the initial angular acceleration of the rod is



(a) $\frac{2g}{L}$

(b) $\frac{2g}{2L}$

(c) $\frac{3g}{2L}$ (d) $\frac{g}{L}$ *(NEET 2013)*

19. A small object of uniform density rolls up a curved surface with an initial velocity 'v'. It reaches upto a maximum height of $\frac{3v^2}{4g}$ with respect to the initial position. The object is
(a) hollow sphere (b) disc
(c) ring (d) solid sphere
(NEET 2013)

20. The ratio of radii of gyration of a circular ring and a circular disc, of the same mass and radius, about an axis passing through their centres and perpendicular to their planes are
(a) $1:\sqrt{2}$ (b) 3 : 2 (c) 2 : 1 (d) $\sqrt{2}:1$
(Karnataka NEET 2013)

21. Two discs are rotating about their axes, normal to the discs and passing through the centres of the discs. Disc D_1 has 2 kg mass and 0.2 m radius and initial angular velocity of 50 rad s^{-1}. Disc D_2 has 4 kg mass, 0.1 m radius and initial angular velocity of 200 rad s^{-1}. The two discs are brought in contact face to face, with their axes of rotation coincident. The final angular velocity (in rad s^{-1}) of the system is
(a) 60 (b) 100 (c) 120 (d) 40
(Karnataka NEET 2013)

22. When a mass is rotating in a plane about a fixed point, its angular momentum is directed along
(a) a line perpendicular to the plane of rotation
(b) the line making an angle of 45° to the plane of rotation
(c) the radius
(d) the tangent to the orbit *(2012)*

23. Two persons of masses 55 kg and 65 kg respectively, are at the opposite ends of a boat. The length of the boat is 3.0 m and weighs 100 kg. The 55 kg man walks up to the 65 kg man and sits with him. If the boat is in still water the center of mass of the system shifts by
(a) 3.0 m (b) 2.3 m (c) zero (d) 0.75 m
(2012)

24. A car of mass 1000 kg negotiates a banked curve of radius 90 m on a frictionless road. If the banking angle is 45°, the speed of the car is
(a) 20 m s^{-1} (b) 30 m s^{-1}
(c) 5 m s^{-1} (d) 10 m s^{-1} *(2012)*

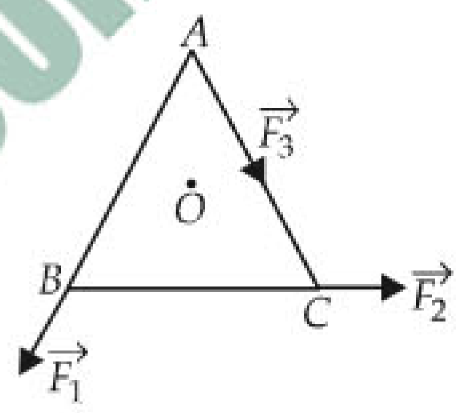
25. ABC is an equilateral triangle with O as its centre. $\vec{F}_1$, $\vec{F}_2$ and $\vec{F}_3$ represent three forces acting along the sides AB, BC and AC respectively. If the total torque about O is zero then the magnitude of $\vec{F}_3$ is

(a) $F_1 + F_2$

(b) $F_1 - F_2$

(c) $\frac{F_1 + F_2}{2}$

(d) $2(F_1 + F_2)$



(2012, 1998)

26. A car of mass m is moving on a level circular track of radius R. If μ_s represents the static friction between the road and tyres of the car, the maximum speed of the car in circular motion is given by

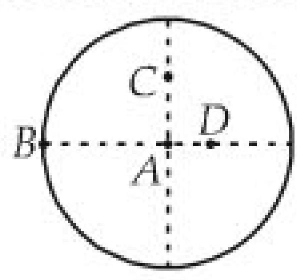
(a) $\sqrt{\mu_s mRg}$ (b) $\sqrt{\frac{Rg}{\mu_s}}$

(c) $\sqrt{\frac{mRg}{\mu_s}}$ (d) $\sqrt{\mu_s Rg}$

(Mains 2012)

27. A circular platform is mounted on a frictionless vertical axle. Its radius R = 2 m and its moment of inertia about the axle is 200 kg m^2. It is initially at rest. A 50 kg man stands on the edge of the platform and begins to walk along the edge at the speed of 1 ms^{-1} relative to the ground. Time taken by the man to complete one revolution is
(a) π s (b) $\frac{3\pi}{2}$ s (c) 2π s (d) $\frac{\pi}{2}$ s
(Mains 2012)

28. The moment of inertia of a uniform circular disc is maximum about an axis perpendicular to the disc and passing through



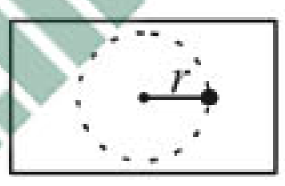
(a) B
(b) C
(c) D
(d) A *(Mains 2012)*

29. Three masses are placed on the x-axis : 300 g at origin, 500 g at $x = 40$ cm and 400 g at $x = 70$ cm. The distance of the centre of mass from the origin is
(a) 40 cm (b) 45 cm
(c) 50 cm (d) 30 cm
(Mains 2012)

30. The instantaneous angular position of a point on a rotating wheel is given by the equation $\theta(t) = 2t^3 - 6t^2$
The torque on the wheel becomes zero at
(a) $t = 1$ s (b) $t = 0.5$ s
(c) $t = 0.25$ s (d) $t = 2$ s *(2011)*

31. The moment of inertia of a thin uniform rod of mass M and length L about an axis passing through its midpoint and perpendicular to its length is I_0. Its moment of inertia about an axis passing through one of its ends and perpendicular to its length is
(a) $I_0 + ML^2/2$ (b) $I_0 + ML^2/4$
(c) $I_0 + 2ML^2$ (d) $I_0 + ML^2$ *(2011)*

32. A small mass attached to a string rotates on a frictionless table top as shown. If the tension in the string is increased by pulling the string causing the radius of the circular motion to decrease by a factor of 2, the kinetic energy of the mass will



(a) decrease by a factor of 2
(b) remain constant
(c) increase by a factor of 2
(d) increase by a factor of 4 *(Mains 2011)*

33. A circular disk of moment of inertia I_t is rotating in a horizontal plane, about its symmetry axis, with a constant angular speed ω_i. Another disk of moment of inertia I_b is dropped coaxially onto the rotating disk. Initially the second disk has zero angular speed. Eventually both the disks rotate with a constant angular speed ω_f. The energy lost by the initially rotating disc to friction is

(a) $\frac{1}{2}\frac{I_b^2}{(I_t + I_b)}\omega_i^2$ (b) $\frac{1}{2}\frac{I_t^2}{(I_t + I_b)}\omega_i^2$

(c) $\frac{I_b - I_t}{(I_t + I_b)}\omega_i^2$ (d) $\frac{1}{2}\frac{I_b I_t}{(I_t + I_b)}\omega_i^2$

(2010)

34. Two particles which are initially at rest, move towards each other under the action of their internal attraction. If their speeds are v and $2v$ at any instant, then the speed of centre of mass of the system will be
(a) $2v$ (b) zero (c) $1.5v$ (d) v
(2010)

35. A gramophone record is revolving with an angular velocity ω. A coin is placed at a distance r from the centre of the record. The static coefficient of friction is μ. The coin will revolve with the record if

(a) $r = \mu g \omega^2$ (b) $r < \frac{\omega^2}{\mu g}$

(c) $r \le \frac{\mu g}{\omega^2}$ (d) $r \ge \frac{\mu g}{\omega^2}$ *(2010)*

36. From a circular disc of radius R and mass $9M$, a small disc of mass M and radius $\frac{R}{3}$ is removed concentrically. The moment of inertia of the remaining disc about an axis perpendicular to the plane of the disc and passing through its centre is

(a) $\frac{40}{9}MR^2$ (b) MR^2

(c) $4MR^2$ (d) $\frac{4}{9}MR^2$

(Mains 2010)

37. A solid cylinder and a hollow cylinder, both of the same mass and same external diameter are released from the same height at the same time on an inclined plane. Both roll down without slipping. Which one will reach the bottom first?
(a) Both together only when angle of inclination of plane is 45°
(b) Both together
(c) Hollow cylinder
(d) Solid cylinder *(Mains 2010)*

38. A thin circular ring of mass M and radius r is rotating about its axis with constant angular velocity ω. Two objects each of mass m are attached gently to the opposite ends of a diameter of the ring. The ring now rotates with angular velocity given by

(a) $\frac{(M + 2m)\omega}{2m}$ (b) $\frac{2M\omega}{M + 2m}$

(c) $\frac{(M + 2m)\omega}{M}$ (d) $\frac{M\omega}{M + 2m}$

(Mains 2010, 1998)

39. A thin circular ring of mass M and radius R is rotating in a horizontal plane about an axis vertical to its plane with a constant angular velocity ω. If two objects each of mass m be attached gently to the opposite ends of a diameter of the ring, the ring will then rotate with an angular velocity

(a) $\dfrac{\omega M}{M+2m}$ (b) $\dfrac{\omega(M+2m)}{M}$

(c) $\dfrac{\omega M}{M+m}$ (d) $\dfrac{\omega(M-2m)}{M+2m}$ *(2009)*

40. If $\vec{F}$ is the force acting on a particle having position vector $\vec{r}$ and $\vec{\tau}$ be the torque of this force about the origin, then

(a) $\vec{r}\cdot\vec{\tau}>0$ and $\vec{F}\cdot\vec{\tau}<0$

(b) $\vec{r}\cdot\vec{\tau}=0$ and $\vec{F}\cdot\vec{\tau}=0$

(c) $\vec{r}\cdot\vec{\tau}=0$ and $\vec{F}\cdot\vec{\tau}\neq 0$

(d) $\vec{r}\cdot\vec{\tau}\neq 0$ and $\vec{F}\cdot\vec{\tau}=0$ *(2009)*

41. Four identical thin rods each of mass M and length l, form a square frame. Moment of inertia of this frame about an axis through the centre of the square and perpendicular to its plane is

(a) $\frac{2}{3}Ml^2$ (b) $\frac{13}{3}Ml^2$

(c) $\frac{1}{3}Ml^2$ (d) $\frac{4}{3}Ml^2$ *(2009)*

42. Two bodies of mass 1 kg and 3 kg have position vectors $\hat{i}+2\hat{j}+\hat{k}$ and $-3\hat{i}-2\hat{j}+\hat{k}$, respectively. The centre of mass of this system has a position vector

(a) $-2\hat{i}-\hat{j}+\hat{k}$ (b) $2\hat{i}-\hat{j}-2\hat{k}$

(c) $-\hat{i}+\hat{j}+\hat{k}$ (d) $-2\hat{i}+2\hat{k}$ *(2009)*

43. A thin rod of length L and mass M is bent at its midpoint into two halves so that the angle between them is 90°. The moment of inertia of the bent rod about an axis passing through the bending point and perpendicular to the plane defined by the two halves of the rod is

(a) $\dfrac{ML^2}{6}$ (b) $\dfrac{\sqrt{2}ML^2}{24}$

(c) $\dfrac{ML^2}{24}$ (d) $\dfrac{ML^2}{12}$ *(2008)*

44. The ratio of the radii of gyration of a circular disc to that of a circular ring, each of same mass and radius, around their respective axes is

(a) $\sqrt{2}:1$ (b) $\sqrt{2}:\sqrt{3}$

(c) $\sqrt{3}:\sqrt{2}$ (d) $1:\sqrt{2}$ *(2008)*

45. A particle of mass m moves in the XY plane with a velocity v along the straight line AB. If the angular momentum of the particle with respect to origin O is L_A when it is at A and L_B when it is at B, then

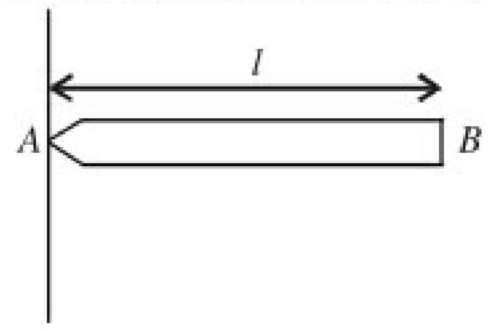
(a) $L_A = L_B$

(b) the relationship between L_A and L_B depends upon the slope of the line AB

(c) $L_A < L_B$

(d) $L_A > L_B$. *(2007)*

46. A uniform rod AB of length l and mass m is free to rotate about point A. The rod is released from rest in the horizontal position. Given that the moment of inertia of the rod about A is $ml^2/3$, the initial angular acceleration of the rod will be



(a) $\dfrac{mgl}{2}$

(b) $\dfrac{3}{2}gl$

(c) $\dfrac{3g}{2l}$ (d) $\dfrac{2g}{3l}$. *(2007, 2006)*

47. A wheel has angular acceleration of 3.0 rad/sec^2 and an initial angular speed of 2.00 rad/sec. In a time of 2 sec it has rotated through an angle (in radian) of

(a) 10 (b) 12

(c) 4 (d) 6. *(2007)*

48. The moment of inertia of a uniform circular disc of radius R and mass M about an axis touching the disc at its diameter and normal to the disc

(a) $\frac{1}{2}MR^2$ (b) MR^2

(c) $\frac{2}{5}MR^2$ (d) $\frac{3}{2}MR^2$ *(2006)*

49. A tube of length L is filled completely with an incompressible liquid of mass M and closed at both the ends. The tube is then rotated in a horizontal plane about one of its ends with a uniform angular velocity ω. The force exerted by the liquid at the other end is

(a) $\frac{ML^2\omega^2}{2}$ (b) $\frac{ML\omega^2}{2}$

(c) $\frac{ML^2\omega}{2}$ (d) $ML\omega^2$ *(2006)*

50. The moment of inertia of a uniform circular disc of radius R and mass M about an axis passing from the edge of the disc and normal to the disc is

(a) MR^2 (b) $\frac{1}{2}MR^2$

(c) $\frac{3}{2}MR^2$ (d) $\frac{7}{2}MR^2$. *(2005)*

51. A drum of radius R and mass M, rolls down without slipping along an inclined plane of angle θ. The frictional force

(a) dissipates energy as heat

(b) decreases the rotational motion

(c) decreases the rotational and translational motion

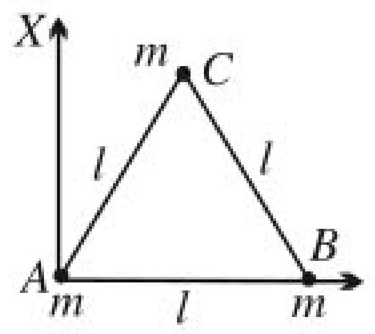
(d) converts translational energy to rotational energy. *(2005)*

52. Two bodies have their moments of inertia I and $2I$ respectively about their axis of rotation. If their kinetic energies of rotation are equal, their angular velocity will be in the ratio

(a) 2 : 1 (b) 1 : 2

(c) $\sqrt{2}$: 1 (d) 1 : $\sqrt{2}$ *(2005)*

53. Three particles, each of mass m gram, are situated at the vertices of an equilateral triangle ABC of side l cm (as shown in the figure). The moment of inertia of the system about a line AX perpendicular to AB and in the plane of ABC, in gram-cm² units will be



(a) $\frac{3}{4}ml^2$

(b) $2ml^2$

(c) $\frac{5}{4}ml^2$ (d) $\frac{3}{2}ml^2$ *(2004)*

54. Consider a system of two particles having masses m_1 and m_2. If the particle of mass m_1 is pushed towards the mass centre of particles through a distance d, by what distance would be particle of mass m_2 move so as to keep the mass centre of particles at the original position ?

(a) $\frac{m_1}{m_1+m_2}d$ (b) $\frac{m_1}{m_2}d$

(c) d (d) $\frac{m_2}{m_1}d$ *(2004)*

55. A wheel having moment of inertia 2 kg m² about its vertical axis, rotates at the rate of 60 rpm about this axis. The torque which can stop the wheel's rotation in one minute would be

(a) $\frac{2\pi}{15}$ N m (b) $\frac{\pi}{12}$ N m

(c) $\frac{\pi}{15}$ N m (d) $\frac{\pi}{18}$ N m *(2004)*

56. A round disc of moment of inertia I_2 about its axis perpendicular to its plane and passing through its centre is placed over another disc of moment of inertia I_1 rotating with an angular velocity ω about the same axis. The final angular velocity of the combination of discs is

(a) $\frac{I_2\omega}{I_1+I_2}$ (b) ω

(c) $\frac{I_1\omega}{I_1+I_2}$ (d) $\frac{(I_1+I_2)\omega}{I_1}$ *(2004)*

57. The ratio of the radii of gyration of a circular disc about a tangential axis in the plane of the disc and of a circular ring of the same radius about a tangential axis in the plane of the ring is

(a) 2 : 3 (b) 2 : 1

(c) $\sqrt{5}:\sqrt{6}$ (d) $1:\sqrt{2}$ *(2004)*

58. A stone is tied to a string of length l and is whirled in a vertical circle with the other end of the string as the centre. At a certain instant of time, the stone is at its lowest position and has a speed u. The magnitude of the change in velocity as it reaches a position where the string is horizontal (g being acceleration due to gravity) is

(a) $\sqrt{2(u^2-gl)}$ (b) $\sqrt{u^2-gl}$

(c) $u-\sqrt{u^2-2gl}$ (d) $\sqrt{2gl}$ *(2003)*

59. A ball rolls without slipping. The radius of gyration of the ball about an axis passing through its centre of mass is K. If radius of the ball be R, then the fraction of total energy associated with its rotational energy will be

(a) $\frac{K^2+R^2}{R^2}$ (b) $\frac{K^2}{R^2}$

(c) $\frac{K^2}{K^2+R^2}$ (d) $\frac{R^2}{K^2+R^2}$ *(2003)*

60. A solid cylinder of mass M and radius R rolls without slipping down an inclined plane of length L and height h. What is the speed of its centre of mass when the cylinder reaches its bottom ?

(a) $\sqrt{2gh}$ (b) $\sqrt{\frac{3}{4}gh}$

(c) $\sqrt{\frac{4}{3}gh}$ (d) $\sqrt{4gh}$

(2003, 1989)

61. A thin circular ring of mass M and radius r is rotating about its axis with a constant angular velocity ω. Four objects each of mass m, are kept gently to the opposite ends of two perpendicular diameters of the ring. The angular velocity of the ring will be

(a) $\frac{M\omega}{4m}$ (b) $\frac{M\omega}{M+4m}$

(c) $\frac{(M+4m)\omega}{M}$ (d) $\frac{(M-4m)\omega}{M+4m}$ *(2003)*

62. A rod of length is 3 m and its mass acting per unit length is directly proportional to distance x from one of its end then its centre of gravity from that end will be at

(a) 1.5 m (b) 2 m

(c) 2.5 m (d) 3.0 m. *(2002)*

63. A point P consider at contact point of a wheel on ground which rolls on ground without slipping then value of displacement of point P when wheel completes half of rotation (If radius of wheel is 1 m)

(a) 2 m (b) $\sqrt{\pi^2+4}$ m

(c) π m (d) $\sqrt{\pi^2+2}$ m. *(2002)*

64. A solid sphere of radius R is placed on smooth horizontal surface. A horizontal force F is applied at height h from the lowest point. For the maximum acceleration of centre of mass, which is correct?

(a) $h = R$

(b) $h = 2R$

(c) $h = 0$

(d) no relation between h and R. *(2002)*

65. A disc is rotating with angular speed ω. If a child sits on it, what is conserved

(a) linear momentum

(b) angular momentum

(c) kinetic energy

(d) potential energy. *(2002)*

66. A circular disc is to be made by using iron and aluminium so that it acquired maximum moment of inertia about geometrical axis. It is possible with

(a) aluminium at interior and iron surround to it

(b) iron at interior and aluminium surround to it

(c) using iron and aluminium layers in alternate order

(d) sheet of iron is used at both external surface and aluminium sheet as internal layers. *(2002)*

67. A disc is rolling, the velocity of its centre of mass is v_{cm}. Which one will be correct?

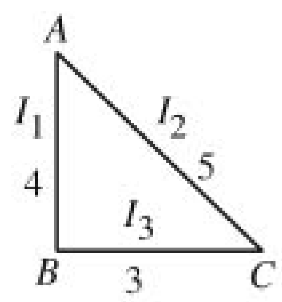
(a) the velocity of highest point is 2 v_{cm} and point of contact is zero

(b) the velocity of highest point is v_{cm} and point of contact is v_{cm}

(c) the velocity of highest point is $2v_{cm}$ and point of contact is v_{cm}

(d) the velocity of highest point is $2v_{cm}$ and point of contact is $2v_{cm}$. *(2001)*

68. For the adjoining diagram, the correct relation between I_1, I_2, and I_3 is, (I - moment of inertia)



(a) $I_1 > I_2$

(b) $I_2 > I_1$

(c) $I_3 > I_1$

(d) $I_3 > I_2$. *(2000)*

69. For a hollow cylinder and a solid cylinder rolling without slipping on an inclined plane, then which of these reaches earlier

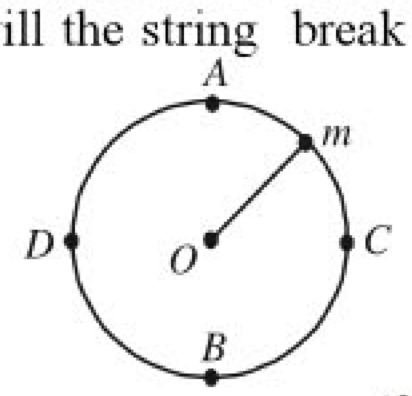
(a) solid cylinder

(b) hollow cylinder

(c) both simultaneously

(d) can't say anything. *(2000)*

70. As shown in the figure at point O a mass is performing vertical circular motion. The average velocity of the particle is increased, then at which point will the string break



(a) A

(b) B

(c) C

(d) D. *(2000)*