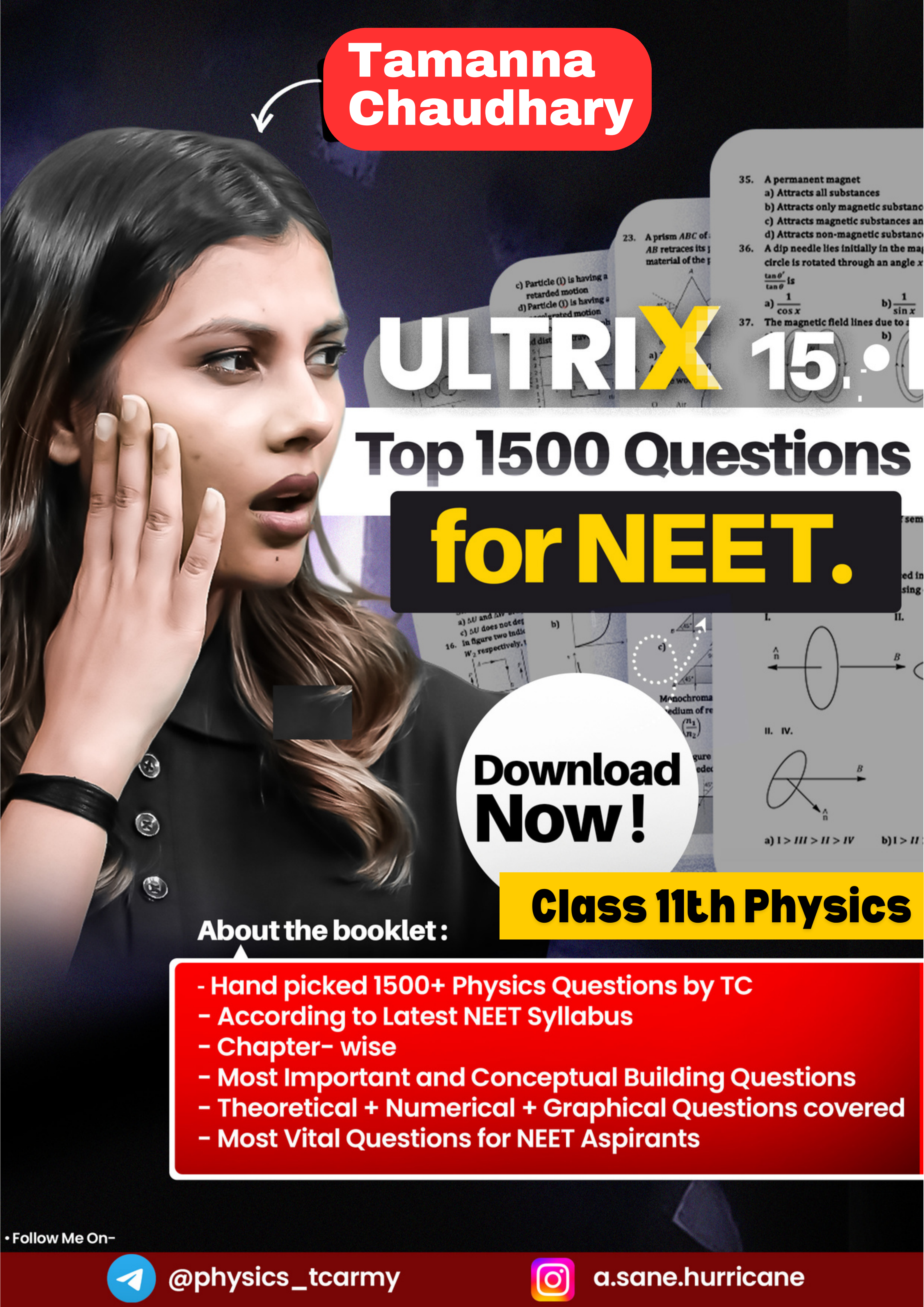

Tamanna Chaudhary
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Units and Dimensions

1. In a vernier callipers, one main scale division is $x\ cm$ and n division of the vernier scale coincide with $(n-1)$ divisions of the main scale. The least count (in cm) of the callipers is
   a) $\left(\frac{n-1}{n}\right)x$ b) $\frac{nx}{(n-1)}$ c) $\frac{x}{n}$ d) $\frac{x}{(n-1)}$
2. If the speed of light (c), acceleration due to gravity (g) and pressure (p) are taken as the fundamental quantities, then the dimension of gravitational constant is
   a) $c^2g^0p^{-2}$ b) $c^0g^2p^{-1}$ c) cg^3p^{-2} d) $c^{-1}g^0p^{-1}$
3. Dimension of R is
   a) ML^2T^{-1} b) $ML^2T^{-3}A^{-2}$ c) $ML^{-1}T^{-2}$ d) None of these
4. "Pascal-Second" has dimension of
   a) Force b) Energy
   c) Pressure d) Coefficient of viscosity
5. The unit of physical quantity obtained by the line integral of electric field is
   a) NC^{-1} b) Vm^{-1} c) JC^{-1} d) $C^2N^{-1}m^{-2}$
6. The dimensions of electric potential are
   a) $[ML^2T^{-2}Q^{-1}]$ b) $[MLT^{-2}Q^{-1}]$ c) $[ML^2T^{-1}Q]$ d) $[ML^2T^{-2}Q]$
7. The velocity v (in cm/sec) of a particle is given in terms of time t(in sec) by the relation $v = at + \frac{b}{t+c}$; the dimensions of a, b and c are
   a) $a = L^2, b = T, c = LT^2$ b) $a = LT^2, b = LT, c = L$
   c) $a = LT^2, b = L, c = T$ d) $a = L, b = LT, c = T^2$
8. A student measures the distance traversed in free fall of a body, initially at rest in each 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) $e_1 - 2e_2$
9. Which of the following is the smallest unit
   a) *Millimetre* b) *Angstrom* c) *Fermi* d) *Metre*
10. Which relation is wrong
    a) 1 *calorie* $= 4.18$ *joule* b) $1\ \text{Å} = 10^{-10}m$
    c) $1\ MeV = 1.6 \times 10^{-13} joule$ d) 1 *newton* $= 10^{-5} dyne$
11. The resistance $R = \frac{V}{i}$ where $V = 100 \pm 5$ *volts* and $i = 10 \pm 0.2$ *amperes*. What is the total error in R
    a) 5% b) 7% c) 5.2% d) $\frac{5}{2}\%$
12. A vernier calipers has 1 mm marks on the main scale. It has 20 equal divisions on the Vernier scale which match with 16 main scale divisions. For this Vernier callipers, the least count is
    a) 0.02 mm b) 0.05 mm c) 0.1 mm d) 0.2 mm

13. Given $X = (Gh/c^3)^{1/2}$, where G, h and c are gravitational constant, Planck's constant and the velocity of light respectively. Dimensions of X are the same as those of
a) Mass b) Time c) Length d) Acceleration
14. Number of base SI unit is
a) 4 b) 7 c) 3 d) 5
15. The dimensions of permittivity ε_0 are
a) $A^2T^2M^{-1}L^{-3}$ b) $A^2T^4M^{-1}L^{-3}$ c) $A^{-2}T^{-4}ML^3$ d) $A^2T^{-4}M^{-1}L^{-3}$
16. Two full turns of the circular scale of a screw gauge cover 1 mm on its main scale. The total number of divisions on the circular scale is 50. Further, it is found that the screw gauge has a zero error of -0.03 mm. While measuring the diameter of a thin wire, a student notes the main scale reading of 3 mm and the number of circular scale divisions in line with the main scale as 35. The diameter of the wire is
a) 3.32 mm b) 3.73 mm c) 3.67 mm d) 3.38 mm
17. If $x = a - b$, then the maximum percentage error in the measurement of x will be
a) $\left(\frac{\Delta a + \Delta b}{a - b}\right) \times 100\%$ b) $\left(\frac{\Delta a}{a} - \frac{\Delta b}{b}\right) \times 100\%$
c) $\left(\frac{\Delta a}{a - a} + \frac{\Delta b}{a - b}\right) \times 100\%$ d) $\left(\frac{\Delta a}{a - a} - \frac{\Delta b}{a - b}\right) \times 100\%$
18. 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%
19. Out of the following four-dimensional quantities, which one qualifies to be called a dimensional constant?
a) Acceleration due to gravity b) Surface tension of water
c) Weight of a standard kilogram mass d) The velocity of light in vacuum
20. The values of two resistors are $R_1 = (6 \pm 0.3)k\Omega$ and $R_2 = (10 \pm 0.2)k\Omega$. The percentage error in the equivalent resistance when they are connected in parallel is
a) 5.125% b) 2% c) 10.125% d) 7%
21. The dimensions of $\frac{a}{b}$ in the equation $P = \frac{a-t^2}{bx}$, where P is pressure, x is distance and t is time, are
a) MT^{-2} b) M^2LT^{-3} c) ML^3T^{-1} d) LT^{-3}
22. A screw gauge gives the following reading when used to measure the diameter of a wire.
Main scale reading: 0 mm
Circular scale reading: 52 divisions
Given that 1 mm on main scale corresponds to
100 divisions of the circular scale.
The diameter of wire from the above data is
a) 0.052 cm b) 0.026 cm c) 0.005 cm d) 0.52 cm
23. The equation of state of some gases can be expressed as $\left(P + \frac{a}{V^2}\right) = \frac{R\theta}{V}$. Where P is the pressure, V the volume, θ the absolute temperature and a and b are constants? The dimensional formula of a is
a) $[ML^5T^{-2}]$ b) $[M^{-1}L^5T^{-2}]$ c) $[ML^{-1}T^{-2}]$ d) $[ML^{-5}T^{-2}]$
24. The length of a cylinder is measured with a meter rod having least count 0.1 cm.
Its diameter is measured with vernier calipers having least count 0.01 cm. Given that length is 5.0 cm. and radius is 2.0 cm. The percentage error in the calculated value of the volume will be
a) 1% b) 2% c) 3% d) 4%
25. If $E =$ energy, $G =$ gravitational constant, $I =$ impulse and $M =$ mass, then dimensions of $\frac{GIM^2}{E^2}$ are same as that of
a) Time b) Mass c) Length d) Force

26. The least count of a stop watch is 0.2 s. The time of 20 oscillations of a pendulum is measured to be 25 s. The percentage error in the measurement of time will be
a) 8% b) 1.8% c) 0.8% d) 0.1%

27. If velocity v, acceleration A and force F are chosen a fundamental quantity, then the dimensional formula of angular momentum in terms of v, A and F would be
a) $FA^{-1}v$ b) Fv^3A^{-2} c) Fv^2A^{-1} d) $F^2v^2A^{-1}$

28. The potential energy of a particle varies with distance x from a fixed origin as $U = \left(\frac{A\sqrt{X}}{x+B}\right)$; where A and B are constants. The dimensions of AB are
a) $[\mathrm{ML^{5/2}T^{-2}}]$ b) $[\mathrm{ML^2T^{-2}}]$ c) $[\mathrm{M^{3/2}L^{3/2}T^{-2}}]$ d) $[\mathrm{ML^{7/2}T^{-2}}]$

29. A physical quantity is given by $X = M^aL^bT^c$. The percentage error in measurement of M, L and T are α, β and γ respectively. The maximum percentage error in the quantity X is
a) $a\alpha + b\beta + c\gamma$ b) $a\alpha + b\beta - c\gamma$ c) $\frac{a}{\alpha} + \frac{b}{\beta} + \frac{c}{\gamma}$ d) None of these

30. $[\mathrm{ML^{-2}T^{-2}}]$ represents dimensional formula of which of the following physical quantities?
a) Energy b) pressure c) Torque d) Pressure gradient

31. The dimensions of resistivity in terms of M, L, T and Q where Q stands for the dimensions of charge, is
a) $ML^3T^{-1}Q^{-2}$ b) $ML^3T^{-2}Q^{-1}$ c) $ML^2T^{-1}Q^{-1}$ d) $MLT^{-1}Q^{-1}$

32. Which does not have the same unit as others
a) *Watt-sec* b) *Kilowatt-hour* c) *eV* d) *J-sec*

33. The radius of a wire is 0.24 mm. Then its area of cross section by taking significant figures into consideration is
a) 0.1 mm^2 b) 0.2 mm^2 c) 0.18 mm^2 d) 0.180 mm^2

34. The expression $[\mathrm{ML^{-1}T^{-1}}]$ represents
a) Momentum b) Force
c) Pressure d) Coefficient of viscosity

35. A thin copper wire of length l *metre* increases in length by 2% when heated through 10^oC. What is the percentage increase in area when a square copper sheet of length l *metre* is heated through 10^oC
a) 4% b) 8% c) 16% d) None of the above

36. R and L represent respectively resistance and self inductance, which of the following combinations has the dimensions of frequency
a) $\frac{R}{L}$ b) $\frac{L}{R}$ c) $\sqrt{\frac{R}{L}}$ d) $\sqrt{\frac{L}{R}}$

37. Length cannot be measured by
a) *Fermi* b) *Debye* c) *Micron* d) *Light year*

38. In an experiment, we measure quantities a, b and c. Then x is calculated from the formula $x = \frac{ab^2}{c^3}$. The percentage errors in a, b, c are $\pm1\%, \pm3\%$, and $\pm2\%$ respectively. The percentage error in x can be
a) $\pm1\%$ b) $\pm4\%$ c) 7% d) $\pm13\%$

39. The time dependence of a physical quantity P is given by $P = P_0e^{at^2} - at^2$ where α is a constant and t is time. Then constant α is
a) Dimensionless b) Dimensionless of T^{-2}
c) Dimensionless of P d) Dimensionless of T^2

40. The percentage errors in the measurement of length and time period of a simple pendulum are 1% and 2% respectively. Then the maximum error in the measurement of acceleration due to gravity is
a) 8% b) 3% c) 4% d) 5%

41. One femtometer is equivalent to
a) $10^{15}\ m$ b) $10^{-15}\ m$ c) $10^{-12}\ m$ d) $10^{12}\ m$

42. Dimensional formula of Stefan's constant is
a) $[\mathrm{MT^{-3}K^{-4}}]$ b) $[\mathrm{ML^2T^{-2}K^{-4}}]$ c) $[\mathrm{ML^2T^{-2}}]$ d) $[\mathrm{MT^{-2}L^0}]$

43. In the relation $x = \cos(\omega t + kx)$, the dimensions of ω are

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

44. $newton - second$ is the unit of

a) Velocity b) Angular momentum c) Momentum d) Energy

45. The initial temperature of a liquid is $(80.0 \pm 0.1)^0$C. After it has been cooled, its temperature is $(10.0 \pm 0.1)^0$C. The fall in temperature in degree centigrade is

a) 70.0 b) 70.0 ± 0.3 c) 70.0 ± 0.2 d) 70.0 ± 0.1

46. If there is a positive error of 50% in the measurement of speed of a body, then the error in the measurement of kinetic energy is

a) 25% b) 50% c) 100% d) 125%

47. If the value of the resistance is 10.845Ω and the value of the current is 3.23 A, then the potential difference is 35.02935 V. its value in correct significant figures would be

a) 35 V b) 35.0 V c) 35.03 V d) 35.029 V

48. Which of the following sets of quantities have same dimensional formula?

a) Frequency, angular frequency and angular momentum

b) Surface tension, stress and spring constant

c) Acceleration, momentum and retardation

d) Work, energy and torque

49. The random error in the arithmetic mean of 100 observations is x; then random error in the arithmetic mean of 4000 observations would be

a) $4x$ b) $14x$ c) $2x$ d) $12x$

1 **(c)**

One main scale division, 1 M. S. D. $= x\ cm$

One vernier scale division , 1 V. S. D. $= \frac{(n-1)x}{n}$

Least count $=$ 1 M. S. D. $-$1 V. S. D.

$$= \frac{nx - nx + x}{n} = \frac{x}{n}\ cm$$

2 **(b)**

Let $[G] \propto c^x g^y p^z$

By substituting the following dimensions:

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

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

and by comparing the powers of both sides

we can get $x = 0, y = 2, z = -1$

$\therefore [G] \propto c^0 g^2 p^{-1}$

3 **(b)**

$$R = \frac{V}{I} = \left[\frac{ML^2T^{-3}A^{-1}}{A}\right] = [ML^2T^{-3}A^{-2}]$$

4 **(d)**

$NSm^{-2} = Nm^{-2} \times S =$ Pascal-second

5 **(c)**

The unit of physical quantity obtained by the line integral of electric field is JC^{-1}.

6 **(a)**

$$V = \frac{W}{Q} = [ML^2T^{-2}Q^{-1}]$$

7 **(c)**

From the principle of dimensional homogeneity $[v] = [at] \Rightarrow [a] = [LT^{-2}]$. Similarly $[b] = [L]$ and $[c] = [T]$

8 **(b)**

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

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

$$= e_1 + 2e_2$$

9 **(c)**

1 fermi $= 10^{-15}\ metre$

10 **(d)**

$1\ newton\ =\ 10^{-5}\ dyne$

11 **(b)**

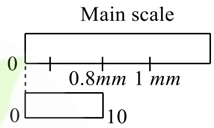
$$\therefore \left(\frac{\Delta R}{R} \times 100\right)_{\max} = \frac{\Delta V}{V} \times 100 + \frac{\Delta I}{I} \times 100$$

$$= \frac{5}{100} \times 100 + \frac{0.2}{10} \times 100 = (5 + 2)\% = 7\%$$

12 **(d)**

$20\ VSD\ = 16\ MSD$

$1\ VSD\ = 0.8\ MSD$



Least count $= MSD - VSD$

$= 1\ mm - 0.8\ mm = 0.2\ mm$

13 **(c)**

$$[X] = \left[\frac{M^{-1}L^3T^{-2} \times ML^2T^{-1}}{L^3T^{-3}}\right]^{-1/2} = [L]$$

14 **(b)**

15 **(b)**

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$$

$$\Rightarrow \varepsilon_0 = \frac{|q_1||q_2|}{[F][r^2]} = \frac{[A^2T^2]}{[MLT^{-2}][L^2]} = [A^2T^4M^{-1}L^{-3}]$$

16 **(d)**

Diameter $=$ Main scale reading

$+$ Circular scale reading $\times$ LC

$+$ Zero error

$$= 3 + 35 \times \frac{1}{2 \times 50} + 0.03 = 3.38\text{ mm}$$

17 **(a)**

Maximum absolute error is $\Delta a + \Delta b$. Now work out the relative error ad finally the percentage error.

18 **(d)**

As $v = \frac{4}{3}\pi r^3$

$$\frac{dv}{v} = 3\left(\frac{dr}{r}\right)$$

$\therefore$ Percentage error in determination of volume = 3 (Percentage error in measurement of radius) = 3(2%) = 6%

19 **(d)**

20 **(c)**

$R_{\text{parallel}} = \frac{R_1 R_2}{(R_1 + R_2)}$

$\Rightarrow \frac{\Delta R_p}{R_p} = \frac{\Delta R_1}{R_1} + \frac{\Delta R_2}{R_2} + \frac{\Delta(R_1 + R_2)}{R_1 + R_2}$

$\Rightarrow \frac{\Delta R_p}{R_p} = \frac{0.3}{6} + \frac{0.2}{10} + \frac{(0.3 + 0.2)}{10 + 6}$

$= 0.05 + 0.02 + 0.03125 = 0.10125$

$\therefore \frac{\Delta R_p}{R_p} \times 100 = 10.125$ or 10.125%

21 **(a)**

$[a] = [T^2]$ and $[b] = \frac{[a-t^2]}{[P][X]} = \frac{T^2}{[ML^{-1}T^{-2}][L]}$

$\Rightarrow [b] = [M^{-1}T^4]$

So $\left[\frac{a}{b}\right] = \frac{[T^2]}{[M^{-1}T^4]} = [MT^{-2}]$

22 **(a)**

Diameter of wire,

$$d = \text{MSR} + \text{CSR} \times \text{LC}$$

$$= 0 + 52 \times \frac{1}{100}$$

$$= 0.52 \text{ mm} = 0.052 \text{ cm.}$$

23 **(a)**

By the principle of dimensional homogenity

$[P] = \left[\frac{a}{V^2}\right] \Rightarrow [a] = [P] \times [V^2] = [ML^{-1}T^{-2}][L^6]$

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

24 **(c)**

Volume of cylinder $V = \pi r^2 l$

Percentage error in volume

$\frac{\Delta V}{V} \times 100 = \frac{2\Delta r}{r} \times 100 + \frac{\Delta l}{l} \times 100$

$= \left(2 \times \frac{0.01}{2.0} \times 100 + \frac{0.1}{5.0} \times 100\right) = (1 + 2)\%$

$$= 3\%$$

25 **(a)**

Dimensions of $E = [\text{ML}^2\text{T}^{-2}]$

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

Dimensions of $I = [\text{MLT}^{-1}]$

And dimension of $M = [\text{M}]$

$\therefore$ Dimensions of $\frac{GIM^2}{E^2}$

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

$$= [\text{T}]$$

= Dimensions of time

26 **(c)**

$\frac{0.2}{25} \times 100 = 0.8$

27 **(b)**

$L \propto v^x A^y F^z \Rightarrow L = kv^x A^y F^z$

Putting the dimensions in the above relation

$[ML^2T^{-1}] = k[LT^{-1}]^x[LT^{-2}]^y[MLT^{-2}]^z$

$\Rightarrow [ML^2T^{-2}] = k[M^z L^{x+y+z} T^{-x-2y-2z}]$

Comparing the powers of M, L and T

$z = 1$ ...(i)

$x + y + z = 2$ ...(ii)

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

On solving (i), (ii) and (iii) $x = 3, y = -2, z = 1$

So dimension of L in terms of v, A and f

$[L] = [Fv^3A^{-2}]$

28 **(d)**

Given, $U = \frac{A\sqrt{x}}{x+B}$ ... (i)

Dimensions of U = dimensions of potential energy

$$= [\text{ML}^2\text{T}^{-2}]$$

From Eq. (i),

Dimensions of B = dimensions of $x = [\text{M}^0\text{LT}^0]$

$\therefore$ Dimensions of A

$$= \frac{\text{dimensions of } U \times \text{dimensions of } (x + B)}{\text{dimension of } \sqrt{x}}$$

$$= \frac{[\text{ML}^2\text{T}^{-2}][\text{M}^0\text{LT}^0]}{[\text{M}^0\text{L}^{1/2}\text{T}^0]}$$

$$= [\text{ML}^{5/2}\text{T}^{-2}]$$

Hence, dimensions of AB

$$= [\text{ML}^{5/2}\text{T}^{-2}][\text{M}^0\text{LT}^0]$$

$$= [\text{ML}^{7/2}\text{T}^{-2}]$$

29 **(a)**
Percentage error in $X = a\alpha + b\beta + c\gamma$
30 **(d)**
$$[ML^{-2}T^{-2}] = \frac{[MLT^{-2}]}{[L][L^2]}$$
$$= \frac{\text{Force}}{\text{distance} \times \text{area}} = \frac{\text{pressure}}{\text{distance}}$$
= pressure gradient.
31 **(a)**
$\rho = \frac{RA}{l}$ $i.e.$ dimension of resistivity is $[ML^3T^{-1}Q^{-2}]$
32 **(d)**
Joule-sec is the unit of angular momentum where as other units are of energy
33 **(c)**
Area of cross section $= \frac{22}{7} \times 0.24 \times 0.24 \text{mm}^2 = 018 \text{mm}^2$
34 **(d)**
Coefficient of viscosity $= \frac{F \times r}{A \times v} = \frac{[MLT^{-2}] \times [L]}{[L^2] \times [LT^{-1}]}$
$= [ML^{-1}T^{-1}]$
35 **(a)**
Since percentage increase in length =2%
Hence, percentage increase in area if square sheet =2 × 2% = 4%
36 **(a)**
$$\frac{R}{L} = \frac{V/I}{V \times T/I} = \frac{1}{T} = \text{Frequency}$$
37 **(b)**

38 **(d)**
Percentage error in $x = 1\% + 2 \times 3\% + 3 \times 2\% = 13\%$.
The sign ± has been used because the words `maximum percentage error' have not been used.
Note percentage error is $\pm \frac{\Delta A}{A} \times 100$
Maximum percentage error is $\frac{\Delta A}{A} \times 100$
39 **(b)**
Here αt^2 is a dimensionless. Therefore, $\alpha = \frac{1}{t^2}$ and has the dimension of $[T^{-2}]$.
40 **(d)**
Time period of a simple pendulum is
$$T = 2\pi\sqrt{\frac{L}{g}} \Rightarrow g = \frac{4\pi^2 L}{T^2}$$
$$\therefore \frac{\Delta g}{g} \times 100 = \left(\frac{\Delta L}{L} + 2\frac{\Delta T}{T}\right) \times 100 = 1\% + 2 \times 2\%$$
$$= 5\%$$
41 **(b)**

42 **(b)**
By Stefan's law,
$$E = \sigma T^4$$
Where σ is the Stefan's constant
$$\sigma = \frac{E}{T^4}$$
$$[\sigma] = \frac{[E]}{T^4} = \frac{[ML^2T^{-2}]}{[K^4]}$$
$$= [ML^2T^{-2}\,K^{-4}]$$
43 **(c)**
Given, $x = \cos(\omega t + kx)$
Here, $(\omega t + kx)$ is an angle so the dimension of
$$(\omega t + kx) = [M^0L^0T^0]$$
Or dimensions of $\omega t = [M^0L^0T^0]$
Or dimensions of $\omega = \frac{[M^0L^0T^0]}{[T]}$
Or $= [M^0L^0T^{-1}]$
44 **(c)**
Impulse = change in momentum $= F \times t$
So the unit of momentum will be equal to *Newton-sec*
45 **(c)**
When quantities are subtracted, their maximum absolute errors are added up.
46 **(d)**
Kinetic energy, $E = \frac{1}{2}mv^2$
$$\therefore \frac{\Delta E}{E} \times 100 = \frac{v'^2 - v^2}{v^2} \times 100$$
$= [(1.5)^2 - 1] \times 100$
$= 125\%$
47 **(b)**
We have to retain three significant figures in the result.

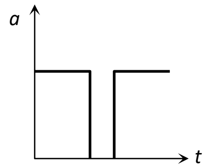
48 **(d)**
The dimensional formula of

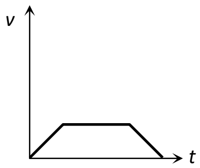
$\text{Work} = \text{Energy} = \text{Torque} = [ML^2T^{-2}]$

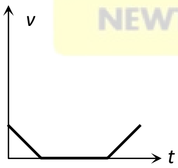
49 **(b)**

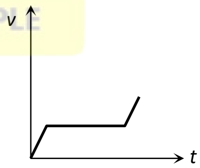
Motion on a straight line

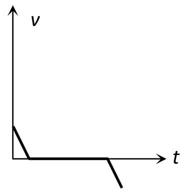
1. A car accelerates from rest at a constant rate α for some time, after which it decelerates at a constant rate β and comes to rest. If the total time elapsed is t, then the maximum velocity acquired by the car is
a) $\left(\frac{\alpha t+\beta^2}{\alpha\beta}\right)t$ b) $\left(\frac{\alpha^2-\beta^2}{\alpha\beta}\right)t$ c) $\frac{(\alpha+\beta)t}{\alpha\beta}$ d) $\frac{\alpha\beta t}{\alpha+\beta}$
2. A police jeep is chasing with velocity of 45 km/h a thief in another jeep moving with velocity 153 km/h. Police fires a bullet with muzzle velocity of 180 m/s. The velocity with which it will strike the car of the thief is
a) 150 m/s b) 27 m/s c) 450 m/s d) 250 m/s
3. Acceleration-time graph of a body is shown. The corresponding velocity-time graph of the same body is



a) 

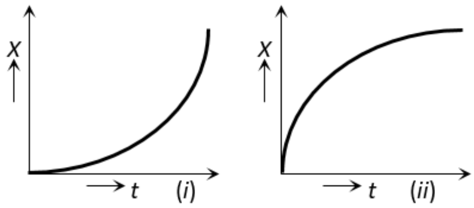
b) 

c) 

d) 

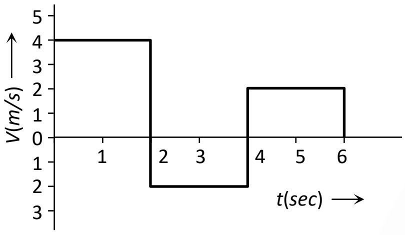
4. A person travels along a straight road for the first half time with a velocity v_1 and the next half time with a velocity v_2
The mean velocity V of the man is
a) $\frac{2}{V}=\frac{1}{v_1}+\frac{1}{v_2}$ b) $V=\frac{v_1+v_2}{2}$ c) $V=\sqrt{v_1v_2}$ d) $V=\sqrt{\frac{v_1}{v_2}}$
5. The displacement of a particle is given by $y=a+bt+ct^2-dt^4$. The initial velocity and acceleration are respectively
a) $b,-4d$ b) $-b,2c$ c) $b,2c$ d) $2c,-4d$
6. The motion of a particle is described by the equation $u=at$. The distance travelled by the particle in the first 4 seconds
a) $4a$ b) $12a$ c) $6a$ d) $8a$

7. Figures (i) and (ii) below show the displacement-time graphs of two particles moving along the x-axis. We can say that



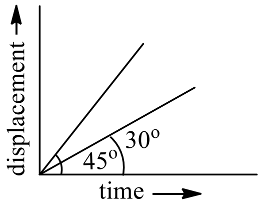
a) Both the particles are having a uniformly accelerated motion
b) Both the particles are having a uniformly retarded motion
c) Particle (i) is having a uniformly accelerated motion while particle (ii) is having a uniformly retarded motion
d) Particle (i) is having a uniformly retarded motion while particle (ii) is having a uniformly accelerated motion

8. The velocity-time graph of a body moving in a straight line is shown in the figure. The displacement and distance travelled by the body in 6 sec are respectively



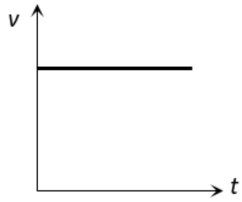
a) $8\ m, 16\ m$ b) $16\ m, 8\ m$ c) $16\ m, 16\ m$ d) $8\ m, 8\ m$

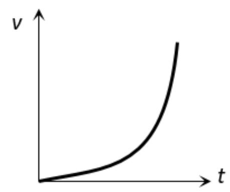
9. The displacement-time graphs of two moving particles make angles of 30° and 45° with the x-axis. The ratio of the two velocities is

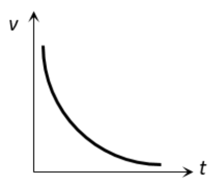


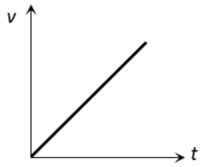
a) $\sqrt{3} : 1$ b) $1 : 1$ c) $1 : 2$ d) $1 : \sqrt{3}$

10. Which of the following velocity-time graphs represent uniform motion

a) 

b) 

c) 

d) 

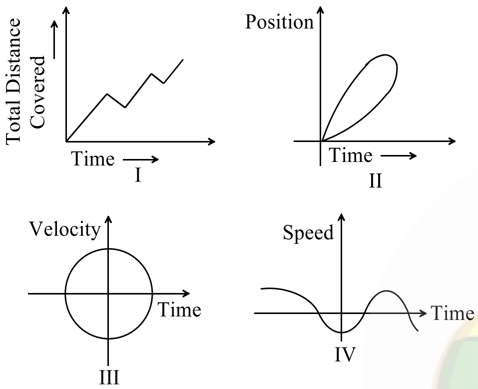
11. A balloon rises from rest with a constant acceleration $g/8$. A stone is released from it when it has risen to height h. The time taken by the stone to reach the ground is

a) $4\sqrt{\frac{h}{g}}$ b) $2\sqrt{\frac{h}{g}}$ c) $\sqrt{\frac{2h}{g}}$ d) $\sqrt{\frac{g}{h}}$

12. A train accelerates from rest at a constant rate α for distance x_1 and time t_1. After that it retards to rest at constant rate β for distance x_2 and time t_2. Then it is found that

a) $\frac{x_1}{x_2}=\frac{\alpha}{\beta}=\frac{t_1}{t_2}$ b) $\frac{x_1}{x_2}=\frac{\beta}{\alpha}=\frac{t_1}{t_2}$ c) $\frac{x_1}{x_2}=\frac{\beta}{\alpha}=\frac{t_2}{t_1}$ d) $\frac{x_1}{x_2}=\frac{\beta}{\alpha}=\frac{t_2}{t_1}$

13. Which of the following graphs can not possibly represent one dimensional motion of a particle



a) I and II b) II and III c) II and IV d) All four

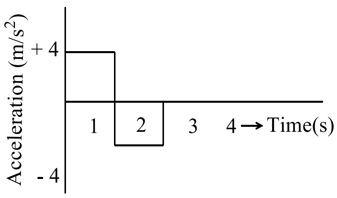
14. A stone is dropped from a height h. Simultaneously, another stone is thrown up from the ground which reaches a height 4 h. The two stones cross other after time

a) $\sqrt{\frac{h}{8g}}$ b) $\sqrt{8gh}$ c) $\sqrt{2gh}$ d) $\sqrt{\frac{h}{2g}}$

15. The numerical ratio of average velocity to average speed is

a) Always less than one b) Always equal to one
c) Always more than one d) Equal to or less than one

16. A particle starts from rest at $t=0$ and moves in a straight line with an acceleration as shown below. The velocity of the particle at $t=3s$ is



a) $2\ ms^{-1}$ b) $4\ ms^{-1}$ c) $6\ ms^{-1}$ d) $8\ ms^{-1}$

17. Two particles held at different heights a and b above the ground are allowed to fall from rest. The ratio of their velocities on reaching the ground is

a) $a : b$ b) $\sqrt{a}:\sqrt{b}$ c) $a^2:b^2$ d) $a^3:b^3$

18. If the velocity of a particle is $(10+2t^2)m/s$, then the average acceleration of the particle between $2s$ and $5s$ is

a) $2m/s^2$ b) $4m/s^2$ c) $12m/s^2$ d) $14m/s^2$

19. A body thrown vertically up to reach its maximum height in t second. The total time from the time of projection to reach a point at half of its maximum height while returning (in second) is

a) $\sqrt{2}\, t$ b) $\left(1+\frac{1}{\sqrt{2}}\right)t$ c) $\frac{3t}{2}$ d) $\frac{t}{\sqrt{2}}$

20. Select the incorrect statements from the following

S1 : Average velocity is path length divided by time interval

S2 : In general, speed is greater than the magnitude of the velocity

S3 : A particle moving in a given direction with a non-zero velocity can have zero speed

S4 : The magnitude of average velocity is the average speed

a) S2 and S3 b) S1 and S4 c) S1, S3 and S4 d) All four statements

21. A bird flies for 4 s with a velocity of $|t-2| m/s$ in a straight line, where t is time in seconds. It covers a distance of

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

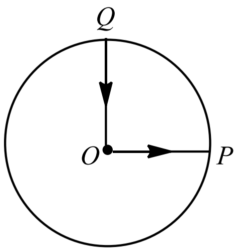
22. The acceleration 'a' in m/s^2 of a particle is given by $a = 3t^2 + 2t + 2$ where t is the time. If the particle starts out with a velocity $u = 2m/s$ at $t = 0$, then the velocity at the end of 2 $seconds$ is

a) 12 m/s b) 18 m/s c) 27 m/s d) 36 m/s

23. Water drops fall from a tap on the floor 5m below at regular intervals of time, the first drop striking the floor when the fifth drop begins to fall. The height at which the third drop will be, from ground, at the instant when first drop strikes the ground, will be (g $=10ms^{-2}$)

a) 1.25 m b) 2.15 m c) 2.73 m d) 3.75 m

24. A cyclist starts from the centre$O$ of a circular park of radius 1 km, reaches the edge P of the park, then cycles along the circumference and returns to the point O as shown in figure. If the round trip takes 10 min, the net displacement and average speed of the cyclist (in metre and kilometer per hour) are



a) 0, 1 b) $\frac{\pi+4}{2}, 0$ c) $214, \frac{\pi+4}{2}$ d) 0, 21.4

25. Two trains each 50 m long are travelling in opposite direction with velocity 10 m/s and 15 m/s. The time of crossing is

a) $2s$ b) $4s$ c) $2\sqrt{3}s$ d) $4\sqrt{3}\, s$

26. 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 second. What will be the position of this particle when it achieves maximum speed along the $+x$ direction

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

27. A body stars from rest and falls vertically from a height of 19.6m. If g $= 9.8ms^{-2}$, then the time taken by the body to fall through the last metre of its fall, is

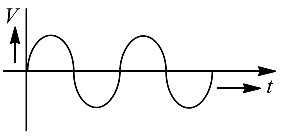
a) 2.00 s b) 0.05 s c) 0.45 s d) 1.95 s

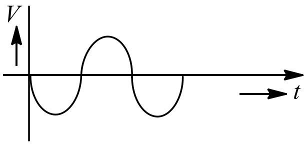
28. Acceleration of a particle changes when

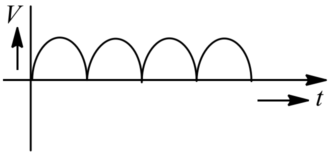
a) Direction of velocity changes b) Magnitude of velocity changes

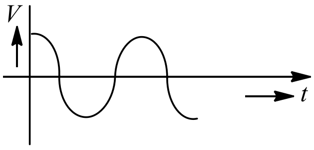
c) Both of above d) Speed changes

29. The position of a particle at any instant t is given by $x = a \cos \omega t$. The speed-time graph of the particle is

a) 

b) 

c) 

d) 

30. A body projected vertically upwards crosses a point twice in its journey at a height h just after t_1 and t_2 second. Maximum height reached by the body is

a) $\frac{g}{4}(t_1 + t_2)^2$ b) $g\left(\frac{t_1 + t_2}{4}\right)^2$ c) $2g\left(\frac{t_1 + t_2}{4}\right)^2$ d) $\frac{g}{4}(t_1 t_2)$

31. A particle moving with a uniform acceleration along a straight line covers distance a and b in successive intervals of p and q second. The acceleration of the particle is

a) $\frac{pq(p+q)}{2(bp-aq)}$ b) $\frac{2(aq-bp)}{pq(p-q)}$ c) $\frac{bp-aq}{pq(p-q)}$ d) $\frac{2(bp-aq)}{pq(p-q)}$

32. The displacement-time graphs of two particles A and B are straight lines making angles of respectively 30° and 60° with the time axis. If the velocity of A is v_A and that of B is v_B, then the value of $\frac{v_A}{v_B}$ is

a) $\frac{1}{2}$ b) $\frac{1}{\sqrt{3}}$ c) $\sqrt{3}$ d) $\frac{1}{3}$

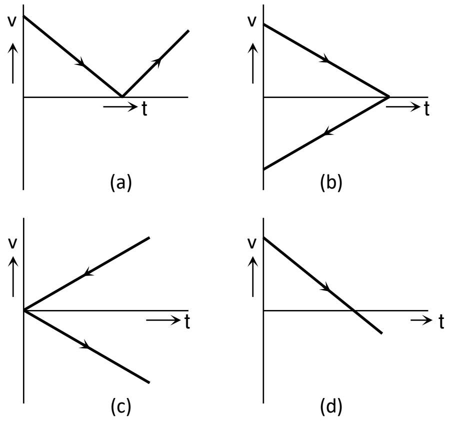
33. A small block sides without friction down an inclined plane starting from rest. Let S_n be the distance travelled from time $t = n - 1$ to $t = n$. Then $\frac{S_n}{S_{n+1}}$ is

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

34. The area under acceleration-time graph gives

a) Distance travelled
b) Change in acceleration
c) Force acting
d) Change in velocity

35. A ball is thrown vertically upwards. Which of the following graph/graphs represent velocity-time graph of the ball during its flight (air resistance is neglected)



a) A b) B c) C d) D

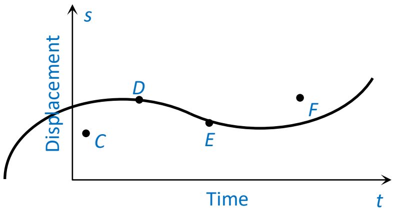
36. A body, thrown upwards with some velocity, reaches the maximum height of $20m$. Another body with double the mass thrown up, with double initial velocity will reach a maximum height of

a) 200 m b) 16 m c) 80 m d) 40 m

37. The relation between time and distance is $t = \alpha x^2 + \beta x$, where α and β are constants. The retardation is

a) $2\alpha v^3$ b) $2\beta v^3$ c) $2\alpha\beta v^3$ d) $2\beta^2 v^3$

38. The displacement-time graph of moving particle is shown below



The instantaneous velocity of the particle is negative at the point

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

39. A car accelerates from rest at a constant rate of 2ms^{-2} for sometime. Then, it retards at a constant rate of 4ms^{-2} and comes to rest. If the total time for which it remains in motion is 3s, what is the total distance travelled?

a) 2m b) 3m c) 4m d) 6m

40. The acceleration 'a' in m/s^2 of a particle is given by $a = 3t^2 + 2t + 2$ where t is the time. If the particle starts out with a velocity $u = 2m/s$ at $t = 0$, then the velocity at the end of 2 $seconds$ is

a) 12 m/s b) 18 m/s c) 27 m/s d) 36 m/s

41. The area under acceleration-time graph gives

a) Distance in travelled b) Change in acceleration

c) Force acting d) Change in velocity

42. Which of the following 4 statements is false

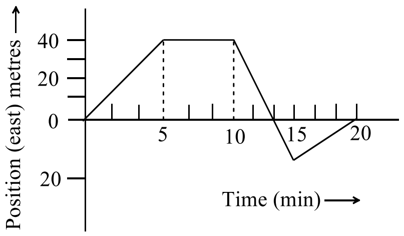
a) A body can have zero velocity and still be accelerated

b) A body can have a constant velocity and still have a varying speed

c) A body can have a constant speed and still have a varying velocity

d) The direction of the velocity of a body can change when its acceleration is constant

43. A body begins to walk eastward along a street in front of his house and the graph of his position from home is shown in the following figure. His average speed for the whole time interval is equal to

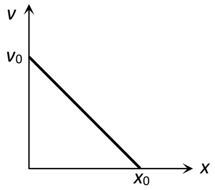


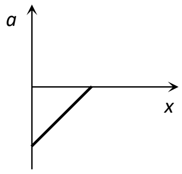
a) 8 m/min b) 6 m/min c) $\frac{8}{3}$ m/min d) 2 m/min

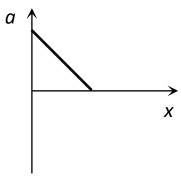
44. A particle is moving with constant acceleration from A to B in a straight line AB. If u and v are the velocities at A and B respectively then its velocity at the midpoint C will be

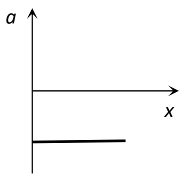
a) $\left(\frac{u^2+v^2}{2u}\right)^2$ b) $\frac{u+v}{2}$ c) $\frac{v-u}{2}$ d) $\sqrt{\frac{u^2+v^2}{2}}$

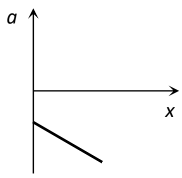
45. The given graph shows the variation of velocity with displacement. Which one of the graph given below correctly represents the variation of acceleration with displacement



a) 

b) 

c) 

d) 

46. A stone is thrown with an initial speed of $4.9\ m/s$ from a bridge in vertically upward direction. It falls down in water after 2 sec. The height of the bridge is

a) 4.9 m b) 9.8 m c) 19.8 m d) 24.7 m

47. A bus start from rest with an acceleration of 1 ms^{-2}. A man who is 48m behind the bus starts with a uniform velocity of $10ms^{-1}$. The minimum time after which the ma will catch the bus

a) 4.8 s b) 8 s c) 10 s d) 12 s

48. A body A is thrown up vertically from the ground with a velocity V_0 and another body B is simultaneously dropped from a height H. They meet at a height $\frac{H}{2}$ if V_0 is equal to

a) $\sqrt{2gH}$ b) $\sqrt{gH}$ c) $\frac{1}{2}\sqrt{gH}$ d) $\sqrt{\frac{2g}{H}}$

49. A car travels equal distances in the same direction with velocities 60kmh^{-1}, 20 km h^{-1} and 10 km h^{-1}respectively. The average velocity of the car over the whole journey of motion is

a) 8 ms^{-1} b) 7 ms^{-1} c) 6 ms^{-1} d) 5 ms^{-1}

50. Two bodies of different masses 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) $\frac{25}{16}$ b) $\frac{5}{4}$ c) $\frac{4}{5}$ d) $\frac{16}{25}$

1 **(d)**

Let the car accelerate at rate α for time t_1 then maximum velocity attained,

$v = 0 + \alpha t_1 = \alpha t_1$

Now, the car decelerates at a rate β for time $(t - t_1)$ and finally comes to rest. Then,

$0 = v - \beta(t - t_1) \Rightarrow 0 = \alpha t_1 - \beta t + \beta t_1$

$$\Rightarrow t_1 = \frac{\beta}{\alpha + \beta} t$$

$$\therefore v = \frac{\alpha\beta}{\alpha + \beta} t$$

2 **(a)**

Effective speed of bullet

= speed of bullet + speed of police jeep

$= 180\ m/s + 45\ km/h = (180 + 12.5)\ m/s$

$= 192.5\ m/s$

Speed of thief's jeep $= 153\ km/h = 42.5\ m/s$

Velocity of bullet $w.r.t.$ thief's car $= 192.5 - 42.5 = 150\ m/s$

3 **(c)**

From acceleration time graph, acceleration is constant for first part of motion so, for this part velocity of body increases uniformly with time and as $a = 0$ then the velocity becomes constant. Then again increased because of acceleration

4 **(b)**

5 **(c)**

$y = a + bt + ct^2 - dt^4$

$\therefore v = \frac{dy}{dt} = b + 2ct - 4dt^3$ and $a = \frac{dv}{dt} = 2c - 12dt^2$

Hence, at $t = 0, v_{\text{initial}} = b$ and $a_{\text{initial}} = 2c$

6 **(d)**

$$u = at, x = \int u\, dt = \int at\, dt = \frac{at^2}{2}$$

For $t = 4$ sec, $x = 8a$

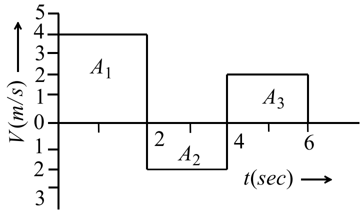
7 **(c)**

8 **(a)**

Displacement = Summation of all the area with sign

$= (A_1) + (-A_2) + (A_3)$

$= (2 \times 4) + (-2 \times 2) + (2 \times 2)$



$\therefore$ Displacement $= 8\ m$

Distance = Summation of all the areas without sign

$= |A_1| + |-A_2| + |A_3| = |8| + |-4| + |4|$

$= 8 + 4 + 4$

$\therefore$ Distance $= 16\ m$

9 **(d)**

$$\frac{\tan 30°}{\tan 45°} = \frac{1}{\sqrt{3}} + 1 = 1:\sqrt{3}$$

10 **(a)**

Slope of velocity-time graph measures acceleration. For graph (a) slope is zero. Hence $a = 0$ $i.e.$ motion is uniform

11 **(b)**

The velocity of balloon at height h, $v = \sqrt{2\left(\frac{g}{8}\right)h}$

When the stone released from this balloon, it will go upward with velocity, $= \frac{\sqrt{gh}}{2}$ (Same as that of balloon). In this condition time taken by stone to reach the ground

$$t = \frac{v}{g}\left[1 + \sqrt{1 + \frac{2gh}{v^2}}\right] = \frac{\sqrt{gh}/2}{g}\left[1 + \frac{2gh}{gh/4}\right]$$

$$= \frac{2\sqrt{gh}}{g} = 2\sqrt{\frac{h}{g}}$$

12 **(b)**

Let v be the velocity of the train after time t_1.

Then $v = \alpha t_1 = \beta t_2; x_1 = \frac{1}{2}\alpha t_1^2$

and $x_2 = \frac{1}{2}\beta t_2^2$

$\therefore \frac{\beta}{\alpha} = \frac{t_1}{t_2}$ and $\frac{x_1}{x_2} = \frac{\alpha t_1^2}{\beta t_2^2} = \frac{\alpha}{\beta} \times \frac{\beta^2}{\alpha^2} = \frac{\beta}{\alpha}$

$\therefore \frac{x_1}{x_2} = \frac{\beta}{\alpha} = \frac{t_1}{t_2}$

13 **(d)**

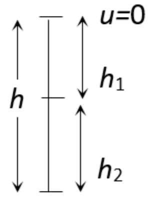
I is not possible because total distance covered by a particle increases with time

II is not possible because at a particular time, position cannot have two values

III is not possible because at a particular time, velocity cannot have two values
IV is not possible because speed can never be negative

14 **(a)**
For first stone $u = 0$ and
For second stone $\frac{u^2}{2g} 4h \Rightarrow u^2 = 8gh$
$\therefore u = \sqrt{8gh}$
Now, $h_1 = \frac{1}{2}gt^2$

$$h_2 = \sqrt{8ght - \frac{1}{2}gt^2}$$

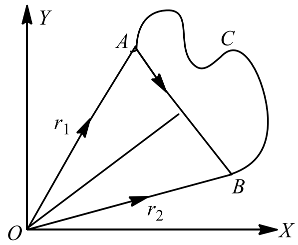


$u = \sqrt{8gh}$
Where, t = time cross each other
$\therefore h_1 + h_2 = h$

$$\Rightarrow \frac{1}{2}gt^2 + \sqrt{8ght} - \frac{1}{2}gt^2 = h \Rightarrow t = \frac{h}{\sqrt{8gh}} = \sqrt{\frac{h}{8g}}$$

15 **(d)**
The average speed

$$v_{av} = \frac{\text{length of path } ACB}{\text{time interval } (t_2 - t_1)} \quad \text{... (i)}$$



And average velocity,

$$\mathbf{v}_{av} = \frac{\text{displacement}}{\text{time interval}} = \frac{\mathbf{r}_2 - \mathbf{r}_1}{t_2 - t_1} \quad \text{... (ii)}$$

But we know that distance is always be greater than or equal to magnitude of displacement. So the average speed will always be greater than or equal to the magnitude of average velocity.

From Eqs. (i) and (ii)

$$\frac{\mathbf{v}_{av}}{v_{av}} = \frac{\text{displacement}}{\text{length of path (distance)}} \leq 1$$

16 **(b)**
Velocity of graph = Area of a-t graph
$= (4 \times 1.5) - (2 \times 1) = 4 m/s$

17 **(b)**
$v \propto \sqrt{h} \quad \therefore \frac{v_1}{v_2} = \sqrt{\frac{a}{b}}$
So, (b) is the correct choice.
The velocity acquired by a body in falling freely from rest through height h is $\sqrt{2gh}$.
$[u = 0, v = ?, 'a' = g, 'S' = h, v^2 - u^2 = 2aS]$

18 **(d)**
Average acceleration $= \frac{\text{Change in velocity}}{\text{Time taken}} = \frac{v_2 - v_1}{t_2 - t_1}$

$$= \frac{[10 + 2(5)^2] - [10 + 2(2)^2]}{3} = \frac{60 - 18}{3} 14 m/s^2$$

19 **(b)**
The ball is thrown vertically upwards, then according to equation of motion.

$$(0)^2 - u^2 = -2gh \quad \text{... (i)}$$

And

$$0 = u - gt \quad \text{... (ii)}$$

From Eqs. (i) and (ii),

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

When the ball is falling downwards after reaching the maximum height

$$s = ut' + \frac{1}{2}g(t')^2$$

$$\frac{h}{2} = (0)t' + \frac{1}{2}g(t')^2$$

$$\Rightarrow \quad t' = \sqrt{\frac{h}{g}}$$

$$t' = \frac{t}{\sqrt{2}}$$

Hence, the total time from the time of projection of reach a point at half of its maximum height while returning $= t + t'$

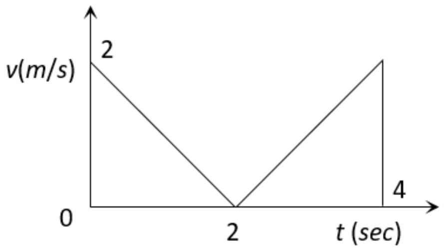
$$= t + \frac{t}{\sqrt{2}} = \left(1 + \frac{1}{\sqrt{2}}\right)t$$

20 **(c)**
Average velocity $= \frac{\text{Displacement}}{\text{Time interval}}$
A particle moving in a given direction with non-zero velocity cannot have zero speed.

In general, average speed is not equal to magnitude of average velocity. However, it can be so if the motion is along a straight line without change in direction

21 **(b)**

The velocity time graph for given problem is shown in the figure.



Distance travelled S = Area under curve $= 2 + 2 = 4m$

22 **(b)**

$$v = u + \int a dt = u + \int (3t^2 + 2t + 2)dt$$

$$= u + \frac{3t^3}{3} + \frac{2t^2}{2} + 2t = u + t^3 + t^2 + 2t$$

$$= 2 + 8 + 4 + 4 = 18\ m/s \quad (\text{As } t = 2\ sec)$$

23 **(d)**

By the time 5th water drop starts falling, the first water drop reaches the ground.

As $u = 0$, $h = \frac{1}{2}gt^2 = \frac{1}{2} \times 10 \times t^2$

or $5 = \frac{1}{2} \times 10 \times t^2$ or $t = 1$ s

Hence, the interval of each water drop $= \frac{1s}{4} =$ 0.25s.

When the 5th drop starts its journey towards ground, the third drop travels in air for $t_1 = 0.25 + 0.25 = 0.5$s

∴ Height (distance) covered by 3rd drop in air is

$$h_1 = \frac{1}{2}gt_1^2 = \frac{1}{2} \times 10 \times (0.5)^2$$

$$= 5 \times 0.25 = 1.25\text{m}$$

So, third water drop will be at a height of

$$= 5 - 1.25 = 3.75\text{m}$$

24 **(d)**

Since, the initial position of cyclist coincides with final position, so his net displacement is zero.

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

$$= \frac{OP + PQ + QO}{10} \text{km min}^{-1}$$

$$= \frac{1 + \frac{\pi}{2} \times 1 + 1}{10} \text{km min}^{-1}$$

$$= \frac{\pi + 4}{20} \times 60 \text{ kmh}^{-1} = 21.4 \text{ kmh}^{-1}$$

25 **(b)**

$$\text{Time} = \frac{\text{Total length}}{\text{Relative velocity}} = \frac{50 + 50}{10 + 15} = \frac{100}{25}$$

$$= 4\ sec$$

26 **(b)**

$x = 9t^2 - t^3; v = \frac{dx}{dt} = 18t - 3t^2$, For maximum speed

$$\frac{dv}{dt} = \frac{d}{dt}[18t - 3t^2] = 0 \Rightarrow 18 - 6t = 0 \therefore t = 3 \text{ sec}$$

i.e., Particle achieve maximum speed at $t = 3$ sec.

At this instant position of this particle, $x = 9t^2 - t^3$

$$= 9(3)^2 - (3)^3 = 81 - 27 = 54\ m$$

27 **(b)**

$$\Delta t = \sqrt{\frac{2 \times 19.6}{9.8}} s - \sqrt{\frac{2 \times 18.6}{9.8}} s = 2 - 1.95 = 0.05\text{s}$$

28 **(c)**

Because acceleration is a vector quantity

29 **(c)**

$\therefore\ x = a\cos \omega t$

$$\therefore v = \frac{dx}{dt} = -a\omega \sin \omega t$$

The instantaneous speed is given by modulus of instantaneous velocity.

∴ speed= $|u| = |-a\omega \sin \omega t|$

Hence, (c) is correct.

30 **(c)**

Time taken by the body to reach the point A is t_1 (During upward journey).

The body crosses this point again (during downward journey) after t_2, *ie*, the body takes the time $(t_2 - t_1)$ to come again at point A.

So, the time taken by the body to reach at point B (a maximum height).

$$t = t_1\left(\frac{t_2 - t_1}{2}\right)$$

[∵ Time pf ascending = Time of descending]

$$t = \frac{t_1 + t_2}{2}$$

So, maximum height $H = \frac{1}{2}\ gt^2$

$$= \frac{1}{2}g\left(\frac{t_1 + t_2}{2}\right)^2$$

$$= 2g\left(\frac{t_1 + t_2}{4}\right)^2$$

31 **(b)**

According to problem, when

$s = a, t = p$

$\because\ s = ut + \frac{1}{2}ft^2$ (here, f =acceleration)

$\therefore\ a = up + \frac{fp^2}{2}$ (i)

For $s = b, t = q$

$b = uq + \frac{fq^2}{2}$ (ii)

After solving Eqs. (i) and (ii),

$$f = \frac{2(aq - bp)}{pq(p - q)}$$

32 **(d)**

$$\frac{v_A}{v_B} = \frac{\tan 30°}{\tan 60°} = \frac{1}{\sqrt{3}} \times \frac{1}{\sqrt{3}} = \frac{1}{3}$$

33 **(c)**

$$S_n = \frac{1}{2} g \cos\theta\,(2n - 1), S_{n+1}$$

$$= \frac{1}{2} g \cos\theta\,\{2(n + 1) - 1\}$$

$$\frac{S_n}{S_{n+1}} = \frac{2n - 1}{2n + 1}$$

34 **(d)**

35 **(d)**

In the positive region the velocity decreases linearly (during rise) and in the negative region velocity increases linearly (during fall) and the direction is opposite to each other during rise and fall, hence fall is shown in the negative region

36 **(c)**

Mass does not affect maximum height

$H = \frac{u^2}{2g} \Rightarrow H \propto u^2$, So if velocity is doubled then height will become four times.i.e.$H = 20 \times 4 = 80m$

37 **(a)**

$$\frac{dt}{dx} = 2\alpha x + \beta \Rightarrow v = \frac{1}{2\alpha x + \beta}$$

$$\because a = \frac{dv}{dt} = \frac{dv}{dx}.\frac{dx}{dt}$$

$$a = v\frac{dv}{dx} = \frac{-v.2\alpha}{(2\alpha x + \beta)^2} = -2\alpha.v.v^2 = -2\alpha v^3$$

$\therefore$ Retardation $= 2\alpha v^3$

38 **(d)**

Slope of displacement time graph is negative only at point time E

39 **(d)**

Using, $v = u + at$ or $v - u = at$, we find that if $|\vec{a}|$ is, it t is the time for acceleration, then $\frac{t}{2}$ is the time for retardation

Now, $t + \frac{t}{2} = 3$ or $\frac{3t}{2} = 3$ or $t = 2s$

$S = \frac{1}{2} \times 2 \times 2 \times 2 + \frac{1}{2} \times 4 \times 1 \times 1 = (4 + 2)$m=6m

40 **(b)**

$$v = u + \int a dt = u + \int (3t^2 + 2t + 2)dt$$

$$= u + \frac{3t^3}{3} + \frac{2t^2}{2} + 2t = u + t^3 + t^2 + 2t$$

$= 2 + 8 + 4 + 4 = 18\ m/s$ (As $t = 2\ sec$)

41 **(d)**

The area under acceleration-time graph gives change in velocity.

42 **(b)**

Constant velocity means constant speed as well as same direction throughout

43 **(b)**

Average speed is the ratio of distance to time taken

Distance travelled from 0 to $5s = 40\ m$

Distance travelled from 5 to $10s = 0\ m$

Distance travelled from 10 to $15s = 60\ m$

Distance travelled from 15to $20s = 20$

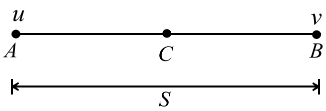
So, total distance $= 40 + 0 + 60 + 20 = 120\ m$

Total time taken $= 20\ minutes$

Hence, average speed

$$= \frac{\text{distance travelled } (m)}{\text{time (min)}} = \frac{120}{20} = 6\ m/min$$

44 **(d)**



Let S be the distance between AB and a be constant acceleration of a particle. Then

$v^2 - u^2 = 2aS$

Or $aS = \frac{v^2 - u^2}{2}$ ... (i)

Let v_c be velocity of a particle at midpoint C

$$\therefore\ v_c^2 - u^2 = 2a\left(\frac{S}{2}\right)$$

$v_c^2 = u^2 + aS = u^2 + \frac{v^2 - u^2}{2}$ [Using (i)]

$$v_c = \sqrt{\frac{u^2 + v^2}{2}}$$

45 **(a)**

Given line have positive intercept but negative slope. So its equation can be written as

$v = -mx + v_0$ ....(i) [where $m = \tan\theta = \frac{v_0}{x_0}$]

By differentiating with respect to time we get

$\frac{dv}{dt} = -m\frac{dx}{dt} = -mv$

Now substituting the value of v from eq. (i) we get

$\frac{dv}{dt} = -m[-mx + v_0] = m^2x - mv_0 \;\therefore a = m^2x - mv_0$

$i.e.$ the graph between a and x should have positive slope but negative intercept on a-axis. So graph (a) is correct

46 **(b)**

Speed of stone in a vertically upward direction is 4.9 m/s. So for vertical downward motion we will consider $u = -4.9\ m/s$

$h = ut + \frac{1}{2}gt^2 = -4.9 \times 2 + \frac{1}{2} \times 9.8 \times (2)^2 = 9.8\ m$

47 **(b)**

$10t = 48 + \frac{1}{2} \times 1 \times t^2$ or $t^2 - 20t + 96 = 0$

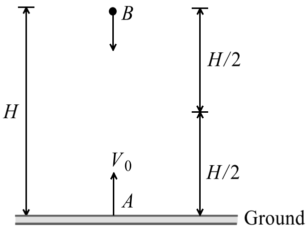
or $t^2 - 8t - 12t + 96 = 0$ or $t(t-8) - 12(t-8) = 0$

or $(t-12)(t-8) = 0$ or $t = 8$ s or 12 s

But we are interested in minimum time.

48 **(b)**

Let the two bodies A and B respectively meet at a time t, at a height $\frac{H}{2}$ from the ground



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

For a body $A, u = V_0, a = -g, S = \frac{H}{2}$

$\therefore \frac{H}{2} = V_0t - \frac{1}{2}gt^2$ ...(i)

For body $B, u = 0, a = +g, S = \frac{H}{2}$

$\therefore \frac{H}{2} = \frac{1}{2}gt^2$ ...(ii)

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

$V_0t - \frac{1}{2}gt^2 = \frac{1}{2}gt^2 \Rightarrow V_0t = gt^2$ or $t = \frac{V_0}{g}$

Substituting the value of t in equation (i), we get

$\frac{H}{2} = V_0 \times \left(\frac{V_0}{g}\right) - \frac{1}{2}g\left(\frac{V_0}{g}\right)^2 = \frac{V_0^2}{g} - \frac{1}{2}\frac{V_0^2}{g}$

$\frac{H}{2} = \frac{1}{2}\frac{V_0^2}{g}$ or $V_0^2 = gH \Rightarrow V_0 = \sqrt{gH}$

49 **(d)**

Average velocity$= \frac{3x}{\frac{x}{60}+\frac{x}{20}+\frac{x}{10}} = \frac{3x}{\frac{x+3x+6x}{60}}$

$= \frac{3x \times 60}{10x} = 18\text{kmh}^{-1}$

$= \frac{18 \times 5}{18}\text{ms}^{-1} = 5\text{ms}^{-1}$

50 **(c)**

$h = 0 + \frac{1}{2}gt^2 \Rightarrow t^2 \propto h$

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

Motion on a plane

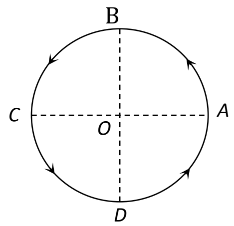
1. A particle moves in circle of radius 25 cm at the rate of two revolutions per second. The acceleration of particle is
   a) $2\pi^2 \text{ms}^{-2}$ b) $4\pi^2 \text{ms}^{-2}$ c) $8\pi^2 \text{ms}^{-2}$ d) $\pi^2 \text{ms}^{-2}$
2. A body of mass 5 kg is moving in a circle of radius 1 m with an angular velocity of 2 $radian$/sec. The centripetal force is
   a) 10 N b) 20 N c) 30 N d) 40 N
3. The velocity of projection of an oblique projectile is $\vec{\mathbf{v}} = 3\hat{\mathbf{i}} + 2\hat{\mathbf{j}}$ (in ms^{-1}). The speed of the projectile at the highest point of the trajectory is
   a) 3 ms^{-1} b) 2 ms^{-1} c) 1 ms^{-1} d) Zero
4. A stone is projected from the ground with velocity 50 ms^{-1} and angle of 30°. It crosses a wall after 3 s. How far beyond the wall the stone will strike the ground?
   a) 80.5 m b) 85.6 m c) 86.6 m d) 75.2 m
5. 

   Figure shows a body of mass m moving with a uniform speed v along a circle of radius r. The change in velocity in going from A to B is
   a) $v\sqrt{2}$ b) $v/\sqrt{2}$ c) v d) zero
6. The equation of trajectory of a projectile is $y = 10x - \left(\frac{5}{9}\right)x^2$. if we assume $g = 10\text{ms}^{-2}$, the range of projectile (in metre) is
   a) 36 b) 24 c) 18 d) 9
7. In a projectile motion, velocity at maximum height is
   a) $\frac{u\cos\theta}{2}$ b) $u\cos\theta$ c) $\frac{u\sin\theta}{2}$ d) None of these
8. At what point of a projectile motion acceleration and velocity and velocity are perpendicular to each other
   a) At the point of projection b) At the point of drop
   c) At the topmost point d) Any where in between the point of projection and topmost point
9. The ratio of the angular speed of minutes hand and hour hand of a watch is
   a) 6 : 1 b) 12 : 1 c) 1 : 6 d) 1 : 12

10. A stone of mass m is tied to a string of length l and rotated in a circle with a constant speed v. If the string is released, the stone flies

a) Radially outwards
b) Radially inwards
c) Tangentially outwards
d) With an acceleration mv^2/l

11. When a simple pendulum is rotated in a vertical plane with constant angular velocity, centripetal force is

a) Maximum at highest point
b) Maximum at lowest point
c) Same at all lower point
d) Zero

13. Two particles of equal masses are revolving in circular paths of radii r_1 and r_2 respectively with the same speed. The ratio of their centripetal forces is

a) $\frac{r_2}{r_1}$
b) $\sqrt{\frac{r_2}{r_1}}$
c) $\left(\frac{r_1}{r_2}\right)^2$
d) $\left(\frac{r_2}{r_1}\right)^2$

14. The horizontal and vertical displacement x and y of a projectile at a given time t are given by $x = 6t$ metre and $y = 8t - 5t^2$ metre. The range of the projectile in metre is

a) 9.6
b) 10.6
c) 19.2
d) 38.4

15. A man projects a coin upwards from the gate of a uniformly moving train. The path of coin for the man will be

a) Parabolic
b) Inclined straight line
c) Vertical straight line
d) Horizontal straight line

16. A cannon on a level plane is aimed at an angle θ above the horizontal and a shell is fired with a muzzle velocity v_0 towards a vertical cliff a distance D away. Then the height from the bottom at which the shell strikes the side walls of the cliff is

a) $D \sin\theta - \frac{gD^2}{2v_0^2 \sin^2\theta}$
b) $D \cos\theta - \frac{gD^2}{2v_0^2 \cos^2\theta}$
c) $D \tan\theta - \frac{gD^2}{2v_0^2 \cos^2\theta}$
d) $D \tan\theta - \frac{gD^2}{2v_0^2 \sin^2\theta}$

17. Which one of the following statements is not correct in uniform circular motion

a) The speed of the particle remains constant
b) The acceleration always points towards the center
c) The angular speed remains constant
d) The velocity remains constant

18. An aeroplane flying horizontally with a speed of 360 kmh^{-1} releases a bomb at a height of 490 m from the ground. When will the bomb strike the ground?

a) 8 s
b) 6 s
c) 7 s
d) 10 s

19. A ball is projected from a certain point on the surface of a planet at a certain angel with the horizontal surface. The horizontal and vertical displacement x and y vary with time t in second as $x = 10\sqrt{3}t$ and $y = 10t - t^2$

The maximum height attained by the ball is

a) 100 m
b) 75 m
c) 50 m
d) 25 m

20. The equation of motion of a projectile are given by $x = 36\ t\ metre$ and $2y = 96\ t - 9.8\ t^2\ metre$. The angle of projection is

a) $\sin^{-1}\left(\frac{4}{5}\right)$
b) $\sin^{-1}\left(\frac{3}{5}\right)$
c) $\sin^{-1}\left(\frac{4}{3}\right)$
d) $\sin^{-1}\left(\frac{3}{4}\right)$

21. A stone projected with a velocity u at an angle θ with the horizontal reaches maximum height H_1. When it is projected with velocity u at an angle $\left(\frac{\pi}{2} - \theta\right)$ with the horizontal, it reaches maximum height H_2. The relation between the horizontal range R of the projectile, H_1 and H_2 is

a) $R = 4\sqrt{H_1 H_2}$ b) $R = 4(H_1 - H_2)$ c) $R = 4(H_1 + H_2)$ d) $R = \frac{H_1^2}{H_2^2}$

22. The range of particle when launched at an angle $15°$ with the horizontal is 1.5 km. What is the range of projectile when launched at an angle of $45°$ to the horizontal?

a) 3.0 km b) 1.5 km c) 6.0 km d) 0.75 km

23. A body of mass m is projected with a speed u making an angle α with the horizontal. The change in momentum suffered by the body along he y-axis between the starting point and the highest point of its path will be

a) $mu \cos \alpha$ b) $mu \sin \alpha$ c) $3\, mu \sin \alpha$ d) mu

24. Two bodies are projected from ground with equal speeds 20 m/sec from the same position in same vertical plane to have equal range but at different angle above the horizontal. If one of the angle is $30°$ the sum of their maximum heights is (assume $g = 10 m/s^2$)

a) 400 m b) 20 m c) 30 m d) 40 m

25. The equation of motion of a projectile is $y = 12x - \frac{3}{4}x^2$. The horizontal component of velocity is 3ms^{-1}. What is the range of the projectile?

a) 18 m b) 16 m c) 12 m d) 21.6 m

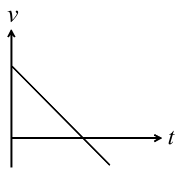
26. A ball is projected with velocity u at an angle α with horizontal plane. Its speed when it makes an angle β with the horizontal is

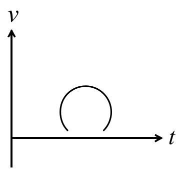
a) $u \cos \alpha$ b) $\frac{u}{\cos \beta}$ c) $u \cos \alpha \cos \beta$ d) $\frac{u \cos \alpha}{\cos \beta}$

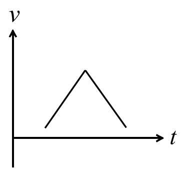
27. For an object thrown at $45°$ to horizontal, the maximum height (H) and horizontal range (R) are related as

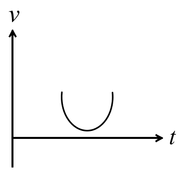
a) $R = 16H$ b) $R = 8H$ c) $R = 4H$ d) $R = 2H$

28. A particle is thrown above, the correct $v - t$ graph will be

a) 

b) 

c) 

d) 

29. Two bodies are projected with the same velocity. If one is projected at an angle of $30°$ and the other at an angle of $60°$ to the horizontal, the ratio of the maximum heights reached is

a) 3 : 1 b) 1 : 3 c) 1 : 2 d) 2 : 1

30. The distance r from the origin of a particle moving in $x - y$ plane varies with time as $r = 2t$ and the angle made by the radius vector with positive x-axis is $\theta = 4t$. Here, t is in second, r in metre and θ in radian. The speed of the particle at $t = 1$ s is

a) 10 ms^{-1} b) 16 ms^{-1} c) 10 ms^{-1} d) 12 ms^{-1}

31. In uniform circular motion, the velocity vector and acceleration vector are

a) Perpendicular to each other b) Same direction
c) Opposite direction d) Not related to each other

32. A bullet is fired horizontally with a velocity of 80 ms^{-1}. During the first second,

a) It falls 9.8 m b) It falls $\frac{80}{9.8}$ m c) It does not fall at all d) It falls 4.9 m

33. A cricketer hits a ball with a velocity 25 m/s at 60° above the horizontal. How far above the ground it passes over a fielder 50 m from the bat (assume the ball is struck very close th the ground)

a) 8.2 m b) 9.0 m c) 11.6 m d) 12.7 m

34. A ball is projected from the ground at a speed of $10ms^{-1}$ making an angle of 30° with the horizontal. Another ball is simultaneously released from a point on the vertical line along the maximum height of the projectile. Both the balls collide at the maximum height of first ball. The initial height of the second ball is ($g = 10ms^{-2}$)

a) $6.25m$ b) $2.5m$ c) $3.75m$ d) $5m$

35. A ball is thrown up at an angle with the horizontal. Then the total change of momentum by the instant it returns to ground is

a) Acceleration due to gravity × total time of flight

b) Weight of the ball × half the time of flight

c) Weight of the ball × total time of flight

d) Weight of the ball × horizontal range

36. An aeroplane moving horizontally at a speed of 200 m/s and at a height of 8.0×10^3 m is to drop a bomb on a target. At what horizontal distance from the target should the bomb be released

a) 7.234 km b) 8.081 km c) 8.714 km d) 9.124 km

37. A particle is projected with certain velocity at two different angels of projections with respect to horizontal plane so as to have same range R on a horizontal plane. If t_1 and t_2 are the time taken for the two paths, the which one of the following relations is correct?

a) $t_1t_2 = \frac{2R}{g}$ b) $t_1t_2 = \frac{R}{g}$ c) $t_1t_2 = \frac{R}{2g}$ d) $t_1t_2 = \frac{4R}{g}$

38. The equation of a projectile is $y = \sqrt{3}x - \frac{gx^2}{2}$. The angle of projection is given by

a) $\tan\theta = \frac{1}{\sqrt{3}}$ b) $\tan\theta = \sqrt{3}$ c) $\frac{\pi}{2}$ d) Zero

39. If a body is projected with an angle θ to the horizontal then

a) its velocity is always perpendicular to its acceleration

b) its velocity becomes zero as its maximum height

c) its velocity makes zero angle with the horizontal at its maximum height

d) the body just before hitting the ground, the direction of velocity coincides with the acceleration

40. A stone is projected with a velocity $20\sqrt{2}ms^{-1}$ at an angle of 45° to the horizontal. The average velocity of stone during its motion from starting point to its maximum height is ($g = 10ms^{-2}$)

a) $5\sqrt{5}\ ms^{-1}$ b) $10\sqrt{5}\ ms^{-1}$ c) $20\ ms^{-1}$ d) $20\sqrt{5}\ ms^{-1}$

41. 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°

42. If a_r and a_t represent radial and tangential accelerations, the motion of a particle will be uniformly circular if

a) $a_r = 0$ and $a_t = 0$ b) $a_r = 0$ but $a_t \neq 0$ c) $a_r \neq 0$ but $a_t = 0$ d) $a_r \neq 0$ and $a_t \neq 0$

43. For a projectile, the ratio of maximum height reached to the square of flight time is ($g = 10\ ms^{-2}$)

a) 5 : 4 b) 5 : 2 c) 5 : 1 d) 10 : 1

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 duration of time t.The ratio of the angular speed of the first to the second car is

a) $m_1 : m_2$ b) $r_1 : r_2$ c) 1 : 1 d) $m_1 : r_1 : m_2 r_2$

45. A particle is moving in a horizontal circle with constant speed. It has constant

a) Velocity b) Acceleration c) Kinetic energy d) Displacement

46. The height y and the distance x along the horizontal plane of a projectile on a certain planet (with no surrounding atmosphere) are given by $y = 8t - 5t^2$ metre and $x = 6t$ metre, where t is in second. The velocity with which the projectile is projected, is

a) 14 ms^{-1} b) 10 ms^{-1} c) 8 ms^{-1} d) 6 ms^{-1}

47. An aeroplane is flying with a uniform speed of 100 m/s along a circular path of radius 100 m. The angular speed of the aeroplane will be

a) 1 rad/sec b) 2 rad/sec c) 3 rad/sec d) 4 rad/sec

48. A particle comes round a circle of radius 1 m once. The time taken by it is 10 sec. The average velocity of motion is

a) 0.2 $\pi m/s$ b) 2 $\pi m/s$ c) 2 m/s d) Zero

49. A particle is projected from horizontal making an angle 60° with initial velocity $40\mathrm{ms}^{-1}$. The time taken by the particle to make angel 45° from horizontal, is

a) 15 s b) 2.0 s c) 20 s d) 1.5 s

50. When a projectile is projected at a certain angle with the horizontal, its horizontal range is R and time of flight is T_1. When the same projectile is throwing with the same speed at some other angle with the horizontal, its horizontal range is R and time of flight is T_2. The product of T_1 and T_2 is

a) $\frac{R}{g}$ b) $\frac{2R}{g}$ c) $\frac{3R}{g}$ d) $\frac{4R}{g}$

1 **(b)**

Acceleration of the particle is

$a = r\omega^2 = r(2\pi n)^2$

$= 0.25 \times (2\pi \times 2)^2$

$= 16\pi^2 \times 0.25$

$= 4\pi^2 \text{ ms}^{-2}$

2 **(b)**

Centripetal force $= mr\omega^2 = 5 \times 1 \times (2)^2 = 20\ N$

3 **(a)**

At the highest point, velocity is horizontal

4 ©

$$T = \frac{2 \times 50 \times \frac{1}{2}}{10} = 5 \text{ s}$$

Horizontal distance travelled in last 2 s

$= 50 \times \cos 30° \times 2$ m

$= 100 \times \frac{2}{\sqrt{3}}\text{m} = 50\sqrt{3}\text{m} = 86.6$ m

5 **(a)**

$$|\overrightarrow{\Delta v}| = 2v\sin(\theta/2) = 2v\sin\left(\frac{90}{2}\right) = 2v\sin 45$$

$$= v\sqrt{2}$$

6 ©

Equation of projectile

$$y = x - \left(\frac{5}{9}\right)x^2$$

Standard equation

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

On comparing, we get

$\tan\theta = 10$

and $\frac{g}{2u^2\cos^2\theta} = \frac{5}{9}$

or $10u^2\cos^2\theta = 9g$
$g = 10\ ms^{-2}$
$\therefore\ u^2\cos^2\theta = 9$

range of projecticle $R = \dfrac{2u^2\tan\theta\cdot\cos\theta}{g}$

$= \dfrac{2u^2\tan\theta\cdot\cos\theta}{g}$

$(\because \sin\theta = \tan\theta\cdot\cos\theta)$

$\dfrac{2(u^2\cos^2\theta)\cdot\tan\theta}{g}$

$= \dfrac{2\times 9\times 10}{10} = 18\ \text{m}$

7 **(b)**
Only horizontal component of velocity $(u\cos\theta)$

8 **(c)**

9 **(b)**
Angular speed of minute hand,
$\omega_m = \frac{2\pi}{60\times 60}$ rad s^{-1}
Angular speed of hour hand,
$\omega_h = \frac{2\pi}{12\times 60\times 60}$ rad s^{-1}
$\therefore\ \dfrac{\omega_m}{\omega_h} = 12$

10 **(c)**
When a stone tied at the end of string is rotated in a circle, the velocity of the stone at an instant acts tangentially outwards the circle. When the string is released, the stone files off tangentially outwards *ie*, in the direction of velocity

11 **(c)**
In a vertical circular motion, centripetal force remains same at all points on circular path and always directed towards the © of circular path

13 **(a)**
$F = \frac{mv^2}{r}$. If m and v are constants then $F \propto \frac{1}{r}$
$\therefore\ \dfrac{F_1}{F_2} = \left(\dfrac{r_2}{r_1}\right)$

14 **(a)**
$x = (u\cos\theta)t = 6t$
$y = (u\sin\theta)\,t - \dfrac{1}{2}gt^2 = 8t - 5t^2$
Therefore, $u\sin\theta = 8$
$u\cos\theta = 6$

Range. $R = \dfrac{u^2 2\sin 2\theta}{g}$

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

$= \dfrac{2(u\sin\theta)\,(\cos\theta)}{g}$

$= \dfrac{2(8)(6)}{10} = 9.6\ \text{m}$

15 ©
Because horizontal velocity is same for coin and the observer. So relative horizontal displacement will be zero

16 ©
Equation of trajectory for oblique projectile motion
$y = x\tan\theta - \dfrac{gx^2}{2u^2\cos^2\theta}$
Substituting $x = D$ and $u = v_0$
$h = D\tan\theta - \dfrac{gD^2}{2u_0^2\cos^2\theta}$

17 **(d)**

18 **(d)**
$t = \sqrt{\dfrac{2\times 490}{9.8}} = \sqrt{\dfrac{2\times 49\times 100}{98}} = \sqrt{100}\ \text{s}$
$= 10\ \text{s}$

19 **(d)**
$v_y = \dfrac{d}{dt}(y) = \dfrac{d}{dt}(10t) - \dfrac{d}{dt}(t^2) = 10 - 2t$
At maximum height, $v_y = 0$
$\therefore\ 10 - 2t = 0$ or $2t = 10$ or $t = 5\ \text{s}$
$\therefore\ y = (10\times 5 - 5\times 5)\ \text{m} = 25\ \text{m}$

20 **(a)**
$x = 36t\ \therefore v_x = \dfrac{dx}{dt} = 36\ m/s$
$y = 48t - 4.9t^2\ \therefore v_y = 48 - 9.8t$
at $t = 0$ $v_x = 36$ and $v_y = 48\ m/s$

So, angle of projection $\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{4}{3}\right)$

Or $\theta = \sin^{-1}(4/5)$

21 **(a)**

$H_1 = \frac{u^2 \sin^2 \theta}{2g}$ and $H_2 = \frac{u^2 \sin^2(90-\theta)}{2g} = \frac{u^2 \cos^2 \theta}{2g}$

$$H_1 H_2 = \frac{u^2 \sin^2 \theta}{2g} \times \frac{u^2 \cos^2 \theta}{2g} = \frac{(u^2 \sin 2\theta)^2}{16g^2}$$

$$= \frac{R^2}{16}$$

$\therefore R = 4\sqrt{H_1 H_2}$

22 **(a)**

The horizontal range $R_x = \dfrac{u^2 \sin 2\theta}{g}$

When projected at angle of 15°

$$R_{x1} = \frac{u^2}{g}\sin(2 \times 15) = \frac{u^2}{2g} = 1.5\text{km}$$

When projected at angle of 45°

$$R_{x1} = \frac{u^2}{g}\sin(2 \times 45°)\frac{u^2}{g}$$

$$= \frac{2u^2}{2g} = 2 \times 1.5 = 3.0 \text{ km}$$

23 **(b)**

At the highest point, velocity along y-axis is zero. Therefore, change in linear momentum $= m(u \sin \alpha - 0) = mu \sin \alpha$

24 **(b)**

$$H_1 + H_2 = \frac{u^2}{2g}(\sin^2 30° + \sin^2 60°)$$

$$= \frac{20^2}{2 \times 10}\left(\frac{1}{4} + \frac{3}{4}\right) = 20\ m$$

25 **(b)**

Given, $y = 12x - \frac{3}{4}x^2$

$u_x = 3\text{ ms}^{-1}$

$$v_y = \frac{dy}{dt} = 12\frac{dx}{dt} - \frac{3}{2}x\frac{dx}{dt}$$

At $x = 0, v_y = u_y = 12\frac{dx}{dt} = 12u_x = 12 \times 3 = 36\text{ ms}^{-1}$

$$a_y = \frac{d}{dt}\left(\frac{dy}{dt}\right) = 12\frac{d^2x}{dt^2} - \frac{3}{2}\left(\frac{dx}{dt} + x\frac{d^2x}{dt^2}\right)$$

But $\frac{d^2x}{dt^2} = a_x = 0$, hence

$$a_y = -\frac{3}{2}\frac{dx}{dt} = -\frac{3}{2}u_x = -\frac{3}{2} \times 3 - \frac{9}{2}\text{ms}^{-2}$$

Range $R = \frac{2u_x u_y}{a_y} = \frac{2 \times 3 \times 12}{9/2} = 16\text{m}$

26 **(d)**

$v \cos \beta = u \cos \alpha$

$$v = \frac{u \cos \alpha}{\cos \beta}$$

27 **©**

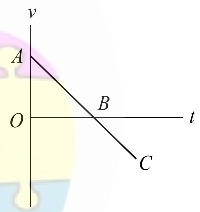
For $\theta = 45°$

$$H_{\max} = \frac{u^2 \sin^2 45°}{2g} = \frac{u^2}{4g} \quad \left[\because \sin 45° = \frac{1}{\sqrt{2}}\right]$$

$$R = \frac{u^2 \sin 90°}{g} = \frac{u^2}{g};\ \therefore \frac{R}{H} = \frac{u^2}{g} \times \frac{4g}{u^2} = 4 \Rightarrow R = 4H$$

28 **(a)**

Taking initial position as origin and direction of motion ($i.e.$, vertically up) as positive. As the particle is thrown with initial velocity, at highest point its velocity is zero and then it returns back to its reference position. This situation is best depicted in figure of option (a)



In figure, AB part denotes upward motion and BC part denotes downward motion

29 **(b)**

As $H = \frac{u^2 \sin^2 \theta}{2g}$ $\therefore \frac{H_1}{H_2} = \frac{\sin^2 \theta_1}{\sin \theta_2} = \frac{\sin^2 30°}{\sin^2 60} = \frac{1/4}{3/4} = \frac{1}{3}$

30 **(b)**

Here, $r = 2t, \theta = 4t$

$l = r\theta = (2t)(4t) = 8t^2$

$$v = \frac{dl}{dt} = \frac{d}{dt}(8t)^2 = 16t$$

$= 16 \times 1 = 16\text{ ms}^{-1}$

31 **(a)**

Because velocity is always tangential and centripetal acceleration is radial.

32 **(d)**

$$s = 0 \times 1 + \frac{1}{2} \times 9.8 \times 1 \times 1 = 4.9\text{ m}$$

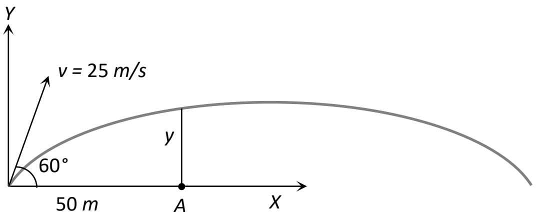
33 **(a)**

Horizontal component of velocity

$v_x = 25 \cos 60° = 12.5\ m/s$

Vertical component of velocity

$v_y = 25\sin 60° = 12.5\sqrt{3}\ m/s$



Tim to over 50 m distance $t = \frac{50}{12.5} = 4\ sec$

The vertical height y is given by

$$y = v_y t - \frac{1}{2}gt^2 = 12.5\sqrt{3} \times 4 - \frac{1}{2} \times 9.8 \times 16$$
$$= 8.2\ m$$

34 **(b)**

Maximum height of projectile, $h_0 = \frac{u^2 \sin^2\theta}{2g}$

$$\therefore h_0 = \frac{(10)^2 \times \sin^2 30°}{2 \times 10} = \frac{5}{4} = 1.25\ m$$

Time for attaining maximum height , $t = \frac{u\sin\theta}{g}$

$$\therefore t = \frac{10 \times \sin 30°}{10} = 0.5\ \text{sec}$$

$\therefore$ Distance of vertical fall in 0.5 sec, $S = \frac{1}{2}gt^2$

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

$\therefore$ Height of second ball $= 1.25 + 1.25 = 2.50m$

35 **(c)**

Change in momentum of the ball $= mv\sin\theta - (-mv\sin\theta)$

$$= 2mv\sin\theta = 2mgv\frac{\sin\theta}{g} = mg \times \frac{2v\sin\theta}{g}$$

= weight of the ball × total time of flight

36 **(b)**

Horizontal distance travelled by the bomb

$S = u \times t$

$$= 200 \times \sqrt{\frac{2h}{g}} = 200 \times \sqrt{\frac{2 \times 8 \times 10^3}{9.8}}$$
$$= 8.081\ km$$

37 **(a)**

If the horizontal range is the same then the angle of projection of an object is θ or $(90° - \theta)$ with the horizontal direction. So, the angle of projection of first particle is θ and the other particle is $(90° - \theta)$

$$t_1 = \frac{2u\sin\theta}{g}$$
$$t_2 = \frac{2u\sin\theta(90° - \theta)}{g}$$
$$t_2 = \frac{2u\cos\theta}{g}$$
$$\because\ t_1 t_2 = \frac{2u\sin\theta}{g} \cdot \frac{2u\cos\theta}{g}$$
$$t_1 t_2 = \frac{2u^2\sin 2\theta}{g^2}$$
$$\text{or}\quad t_1 t_2 = \frac{2R}{g} \quad \left(\because R = \frac{u^2\sin 2\theta}{g}\right)$$

38 **(b)**

Computing the given equation with

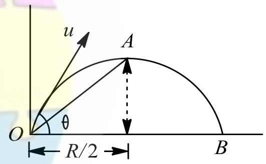
$y = x\tan\theta - \frac{gx^2}{2v^2\cos^2\theta}$, we get

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

39 **(c)**

40 **(b)**

Refer figure are when projectile is at A, then



$$OC = \frac{R}{2} = \frac{1}{2}\frac{u^2}{g}\sin 2\theta$$
$$= \frac{1}{2} \times \frac{(20\sqrt{2})^2}{10}\sin 2 \times 45°$$
$$= 40\ \text{m}$$
$$AC = H = \frac{u^2\sin^2\theta}{2g} = \frac{(20\sqrt{2})^2}{2 \times 10}\sin^2 45°$$

$\therefore$ Displacement, $OA = \sqrt{OC^2 + CA^2} = \sqrt{40^2 + 20^2}$

Time of projectile from O to A

$$= \frac{1}{2}\left(\frac{2u\sin\theta}{g}\right) = \frac{u\sin\theta}{2g} = \frac{(20\sqrt{2})\sin 45°}{10}$$
$$= 2\text{s}$$

$$\therefore\ \text{Average velocity} = \frac{\text{displacement}}{\text{time}}$$
$$= \frac{\sqrt{40^2 + 20^2}}{2} = 10\sqrt{5}\ \text{ms}^{-1}$$

41 **(a)**

$$v' = v_0\cos\theta$$
$$\frac{v_0}{2} = v_0\cos\theta$$

$\cos\theta = \frac{1}{2}$

$\theta = 60°$

42 **(c)**

In uniform circular motion tangential acceleration remains zero but magnitude of radial acceleration remains constant.

43 **(a)**

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

So $\frac{H}{T^2} = \frac{u^2\sin^2\theta/2g}{4u^2\sin^2\theta/g^2} = \frac{g}{8} = \frac{5}{4}$

44 **(c)**

As time periods are equal therefore ration of angular speeds will be one. $\omega = \frac{2\pi}{T}$

45 **(c)**

$\text{K. E.} = \frac{1}{2}mv^2$. Which is scalar, so it remains constant

46 **(b)**

$x = (u\cos\theta)t = 6$

$u\cos\theta = \frac{x}{t} = 6$

$y = (u\sin\theta)t = -\frac{1}{2}gt^2$

$y = 8t - 5t^2 \Longrightarrow u\sin\theta = 8$

$u = 10\text{m/s}$

47 **(a)**

$\omega = \frac{v}{r} = \frac{100}{100} = 1\, rad/s$

48 **(d)**

In complete revolution total displacement is zero so average velocity is zero

49 **(d)**

At 45°, $v_x = v_y$

or $u_x = u_y - \text{gt}$

$\therefore\ t = \frac{u_y - u_x}{\text{g}}$

$= \frac{40(\sin 60° - \sin 30°)}{9.8} = 1.5\text{ s}$

50 **(b)**

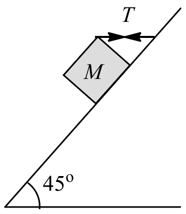
The two angles of projection are clearly θ and (90° − θ)

$T_1 = \frac{2v\sin\theta}{\text{g}}$ and $T_2 = \frac{2v\sin(90° - \theta)}{\text{g}}$

$T_1T_2 = \frac{2(v)^2(2\sin\theta\cos\theta)}{\text{g}\times\text{g}} = \frac{2R}{\text{g}}$

Laws of Motion

1. A block of mass 15 kg is resting on a rough inclined plane as shown in figure. The block is tied by a horizontal string which has a tension of 50 N. The coefficient of friction between the surfaces of contact is $(g = 10\ ms^{-2})$



a) 1/2 b) 3/4 c) 2/3 d) 1/4

2. Consider the following statement. When jumping from some height, you should bend your knees as you come to rest instead of keeping your legs stiff. Which of the following relations can be useful in explaining the statement?

a) $\Delta \mathbf{p}_1 = -\Delta \mathbf{p}_2$ b) $\Delta E = -\Delta(\mathrm{PE} + \mathrm{KE}) = 0$

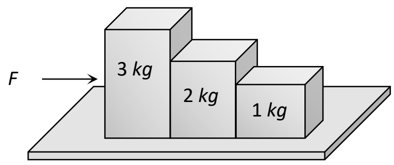
c) $\mathbf{F}\,\Delta t = m\Delta \mathbf{v}$ d) $\Delta \mathbf{x} \propto \Delta \mathbf{F}$

Where symbols have their usual meaning

3. A body takes time t to reach the bottom of an inclined plane of angle θ with the horizontal. If the plane is made rough, time taken now is $2t$. The coefficient of the friction of the rough surface is

a) $\frac{3}{4}\tan\theta$ b) $\frac{2}{3}\tan\theta$ c) $\frac{1}{4}\tan\theta$ d) $\frac{1}{2}\tan\theta$

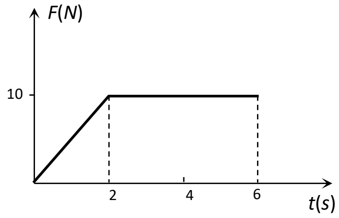
4. Consider the following statements about the blocks shown in the diagram that are being pushed by a constant force on a frictionless table



A. All blocks move with the same acceleration
B. The net force on each block is the same
Which of these statements are/is correct

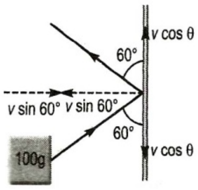
a) A only b) B only c) Both A and B d) Neither A nor B

5. A body of mass $3kg$ is acted on by a force which varies as shown in the graph below. The momentum acquired is given by



a) Zero　　b) 5 N-s　　c) 30 N-s　　d) 50 N-s

6. A mass of 100 g strikes the wall with speed 5 ms^{-1} at an angle as shown in figure and it rebounds with the same speed. If the contact time is 2×10^{-3} s, what is the force applied?



a) $250\sqrt{3}$ N to right　　b) 250 N to right　　c) $250\sqrt{3}$ N to left　　d) 250 N to left

7. A partly hanging uniform chain of length chain of length L is resting on a rough horizontal table. l is the maximum possible length that can hang in equilibrium. The coefficient of friction between the chain and table is

a) $\frac{l}{L-l}$　　b) $\frac{L}{l}$　　c) $\frac{l}{L}$　　d) $\frac{lL}{L+l}$

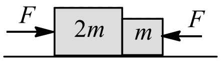
8. Which of the following quantities measured from different inertial reference frames are same?

a) Force　　b) Velocity　　c) Displacement　　d) Kinetic energy

9. A uniform metal chain is placed on a rough table such that one end of it hangs down over the edge of the table. When one-third of its length hangs over the edge, the chain starts sliding. Then, the coefficient of static friction is

a) 3/4　　b) 1/4　　c) 2/3　　d) 1/2

10. Two blocks are in contact on a frictionless table. One has mass m and other $2m$. A force f is applied on $2m$ as shown in figure. Next the same force F is applied from the right on m. In the two cases respectively, the force of contact between the two blocks will be



a) 2 : 1　　b) 1 : 3　　c) 1 : 2　　d) 3 : 1

11. To avoid slipping while walking on ice, one should take smaller steps because of the

a) Friction of ice is large　　b) Larger normal reaction

c) Friction of ice is small　　d) Smaller normal reaction

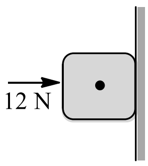
12. An iron nail is dropped from a height h from the level of a sand bed. If it penetrates through a distance x in the sand before coming to rest, then average force exerted by the sand on nail is

a) $mg\left(\frac{h}{x}+1\right)$　　b) $mg\left(\frac{x}{h}+1\right)$　　c) $mg\left(\frac{h}{x}-1\right)$　　d) $mg\left(\frac{x}{h}-1\right)$

13. A body is moving along a rough horizontal surface with an initial velocity 6 m/s. If the body comes to rest after travelling $9m$, then the coefficient of sliding friction will be

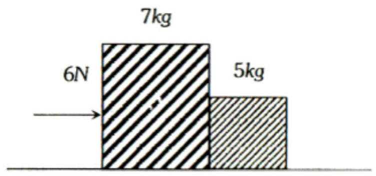
a) 0.4　　b) 0.2　　c) 0.6　　d) 0.8

14. A block of weight 5N is pushed against a vertical wall by a force 12N. The coefficient of friction between the wall and block is 0.6. The magnitude of the force exerted by the wall on the block is



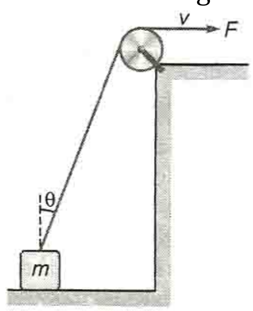
a) 12 N　　b) 5 N　　c) 7.2 N　　d) 13 N

15. Two block of masses 7 kg and 5 kg are placed in contact with each other on a smooth surface. If a force of 6 N is applied on the heavier mass, the force on the lighter mass is



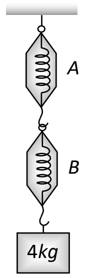
a) 3.5 N b) 2.5 N c) 7 N d) 5 N

16. A block is dragged on a smooth horizontal plane with the help of a light rope which moves with a velocity v as shown in figure. The horizontal velocity of the block is



a) v b) $v \sin \theta$ c) $\dfrac{v}{\sin \theta}$ d) $\dfrac{v}{\cos \theta}$

17. A block of mass 4 kg is suspended through two light spring balances A and B. Then A and B, Then A and B will read respectively



a) 4 kg and zero kg b) Zero kg and 4 kg c) 4 kg and 4 kg d) 2 kg and 2 kg

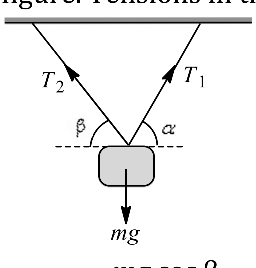
18. A particle is moving with a constant speed along a straight line path. A force is not required to

a) Increase its speed b) Decrease the momentum
c) Change in direction d) Keep it moving with uniform velocity

19. The linear momentum of a particle varies with time t as $p = a + bt + ct^2$
Which of the following statements is correct?

a) Force varies with time in a quadratic manner
b) Force is time-dependent
c) The velocity of the particle is proportional to time
d) The displacement of the particle is proportional to t

20. A body of mass m is suspended by two strings making angle α and β with the horizontal as shown in figure. Tensions in the two strings are



a) $T_1 = \dfrac{mg \cos \beta}{\sin(\alpha + \beta)} = T_2$ b) $T_1 = \dfrac{mg \sin \beta}{\sin(\alpha + \beta)} = T_2$

c) $T_1 = \dfrac{mg \cos \beta}{\sin(\alpha + \beta)}; T_2 = \dfrac{mg \cos \alpha}{\sin(\alpha + \beta)}$ d) None of the above

21. Three solids of masses m_1, m_2 and m_3 are connected with weightless string in succession and are placed on a frictionless table. If the mass m_3 is dragged with a force T, the tension in the string between m_2 and m_3 is

a) $\frac{m_2}{m_1+m_2+m_3}T$ b) $\frac{m_3}{m_1+m_2+m_3}T$ c) $\frac{m_1+m_2}{m_1+m_2+m_3}T$ d) $\frac{m_2+m_3}{m_1+m_2+m_3}T$

22. A body of mass M at rest explodes into three pieces, two of which of mass $M/4$ each are thrown off in perpendicular directions with velocities of 3 m/s and 4 m/s respectively. The third piece will be thrown off with a velocity of

a) 1.5 m/s b) 2.0 m/s c) 2.5 m/s d) 3.0 m/s

23. A nucleus disintegrates into two nuclear parts which have their velocities in the ratio 2 : 1. The ratio of their nuclear sizes will be

a) $2^{1/3}:1$ b) $1:3^{1/2}$ c) $3^{1/2}:1$ d) $1:2^{1/3}$

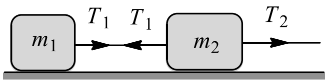
24. A man wants to slide down a rope. The breaking load for the rope $\frac{2}{3}$rd of the weight of the man. With what minimum acceleration should fireman slide down?

a) $\frac{g}{4}$ b) $\frac{g}{3}$ c) $\frac{2g}{3}$ d) $\frac{g}{6}$

25. The rate of mass of the gas emitted from rear of a rocket is initially 0.1 kg/sec. If the speed of the gas relative to the rocket is 50 m/sec and mass of the rocket is 2 kg, then the acceleration of the rocket in m/sec^2 is

a) 5 b) 5.2 c) 2.5 d) 25

26. Refer to the system shown in figure. The ratio of tension T_1 and T_2 is



a) $\frac{m_1}{m_1+m_2}$ b) $\frac{m_2}{m_1+m_2}$ c) $\frac{m_1}{m_2}$ d) $\frac{m_2}{m_1}$

27. A block is kept on an inclined plane of inclination θ and length l. The velocity of particle at the bottom of incline is (the coefficient of friction is μ)

a) $\sqrt{2gl(\mu\cos\theta-\sin\theta)}$ b) $\sqrt{2gl(\sin\theta-\mu\cos\theta)}$

c) $\sqrt{2gl(\sin\theta+\mu\cos\theta)}$ d) $\sqrt{2gl(\cos\theta-\mu\sin\theta)}$

28. A gun fires bullet each of mass 1 g with velocity of 10 $\mathrm{ms^{-1}}$ by exerting a constant force of 5 g weight. Then the number of bullets fired per second is

(Take $g = 10\ \mathrm{ms^{-2}}$)

a) 50 b) 5 c) 10 d) 25

29. A block at rest slides down a smooth inclined plane which makes an angle 60° with the vertical and it reaches the ground in t_1 seconds. Another block is dropped vertically from the same point and reaches the ground in t_2 seconds.

Then the ratio of $t_1:t_2$ is

a) 1: 2 b) 2: 1 c) 1: 3 d) $1:\sqrt{2}$

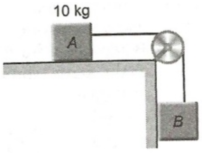
30. When two surfaces are coated with a lubricant, then they

a) Stick to each other b) Slide upon each other c) Roll upon each other d) None of these

31. A rope of length L is pulled by a constant force F. What is the tension in the rope at a distance x from the end where the force is applied

a) $\frac{FL}{x}$ b) $\frac{F(L-x)}{L}$ c) $\frac{FL}{L-x}$ d) $\frac{Fx}{L-x}$

32. If the mass of $A = 10$ kg, coefficient of static friction $= 0.22$, coefficient of kinetic friction $= 0.2$, then minimum mass of B to start motion is



a) 2 kg b) 2.2 kg c) 4.8 kg d) 3.4 kg

33. Impulse is

a) A scalar b) Equal to change in the momentum of a body
c) Equal to rate of change of momentum of a body d) A force

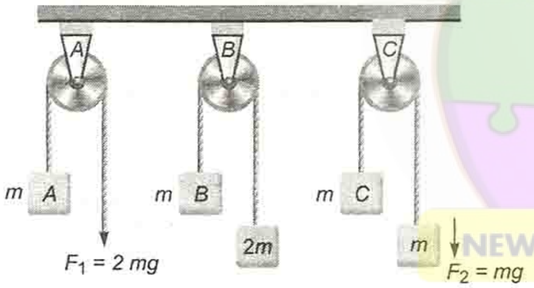
34. A bullet is fired from a gun. The force on the bullet is given by $F = 600 - 2 \times 10^5 t$, where F is in *newtons* and t in seconds. The force on the bullet becomes zero as soon as it leaves the barrel. What is the average impulse imparted to the bullet

a) 9 Ns b) Zero c) 0.9 Ns d) 1.8 Ns

35. A given object taken n times as much time to slide down a 45° rough incline as it takes to slide down a perfectly smooth 45° incline. The coefficient of kinetic friction between the object and the incline is given by

a) $\left(1 - \frac{1}{n^2}\right)$ b) $\frac{1}{1 - n^2}$ c) $\sqrt{\left(1 - \frac{1}{n^2}\right)}$ d) $\sqrt{\frac{1}{1 - n^2}}$

36. In figure, the blocks A, B and C each of mass m have acceleration a_1, a_2 and a_3 respectively. F_1 and F_2 are external forces of magnitude 2 mg and mg respectively.
Then



a) $a_1 = a_2 = a_3$ b) $a_1 > a_3 > a_2$ c) $a_1 = a_2, a_2 = a_3$ d) $a_1 = a_2, a_1 = a_3$

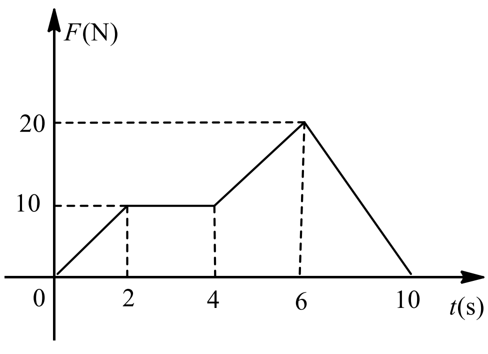
37. Formula for true force is

a) $F = ma$ b) $F = \frac{mdv}{dt}$ c) $F = \frac{dmv}{dt}$ d) $F = \frac{md^2x}{dt^2}$

38. A body of mass m collides against a wall with a velocity v and rebounds with the same speed. Its change of momentum is

a) 2 mv b) mv c) $-mv$ d) Zero

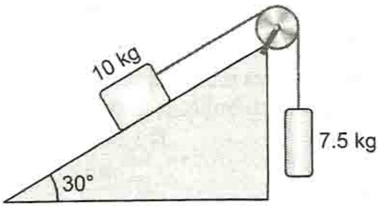
39. A particle of mass 2 kg is initially at rest. A force acts on it whose magnitude changes with time. The force-time graph is shown below



The velocity of the particle after 10 s is

a) 20 ms^{-1} b) 10 ms^{-1} c) 75 ms^{-1} d) 50 ms^{-1}

40. The acceleration of the system shown in figure is

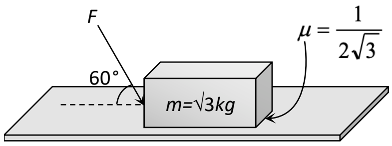


a) $\frac{3.5}{17.5}$g b) $\frac{7.5}{17.5}$g c) $\frac{14.5}{17.5}$g d) $\frac{\text{g}}{7}$

41. If μ_s, μ_k and μ_r are coefficients of static friction, sliding friction and rolling friction, then

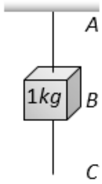
a) $\mu_s < \mu_k < \mu_r$ b) $\mu_k < \mu_r < \mu_s$ c) $\mu_r < \mu_k < \mu_s$ d) $\mu_r < \mu_k < \mu_s$

42. What is the maximum value of the force F such that the block shown in the arrangement, does not move



a) 20 N b) 10 N c) 12 N d) 15 N

43. A mass of 1 kg is suspended by a string A. Another string C is connected to its lower end (see figure). If a sudden jerk is given to C, then

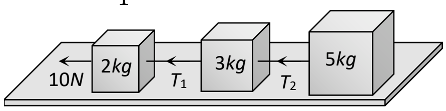


a) The portion AB of the string will break b) The portion BC of the string will break
c) None of the strings will break d) The mass will start rotating

44. Swimming is possible on account of

a) First law of motion b) Second law of motion
c) Third law of motion d) Newton's law of gravitation

45. Three blocks of masses 2 kg, 3 kg and 5 kg are connected to each other with light string and are then placed on a frictionless surface as shown in the figure. The system is pulled by a force $F = 10\ N$, then tension $T_1 =$



a) 1 N b) 5 N c) 8 N d) 10 N

46. The time period of a simple pendulum measured inside a stationary lift is found to be T. If the lift starts accelerating upwards with an acceleration $g/3$, the time period is

a) $T\sqrt{3}$ b) $T\sqrt{3}/2$ c) $T/\sqrt{3}$ d) $T/3$

47. Two masses M and $M/2$ are joined together by means of light inextensible string passed over a frictionless pulley as shown in the figure. When the bigger mass is released, the small one will ascend with an acceleration of

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

48. When a body is stationary

a) There is no force acting on it
b) The force acting on it is not in contact with it
c) The combination of forces acting on it balances each other
d) The body is in vacuum

49. A rocket of mass 100 kg burns 0.1 kg of fuel per sec. If velocity of exhaust gas is 1 km/sec, then it lifts with an acceleration of

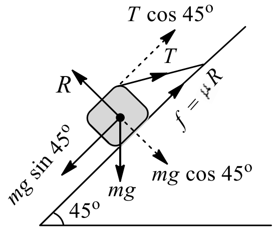
a) 1000 ms^{-2}
b) 100 ms^{-2}
c) 10 ms^{-2}
d) 1 ms^{-2}

50. An object placed on an inclined plane starts sliding when the angle of incline becomes 30°. The coefficient of static friction between the object and the plane is

a) $\frac{1}{\sqrt{3}}$
b) $\sqrt{3}$
c) $\frac{1}{2}$
d) $\frac{\sqrt{3}}{2}$

1 **(a)**

Figure shows free body diagram of the block



For equilibrium, along the place

$\mu R + T\cos 45° = mg\sin 45°$

$\mu R + \frac{T}{\sqrt{2}} = \frac{mg}{\sqrt{2}}$ ...(i)

For equilibrium, in direction perpendicular to inclined plane,

$R = T\sin 45° = mg\cos 45°$

$= \dfrac{T}{\sqrt{2}} + \dfrac{mg}{\sqrt{2}}$

Put in Eq. (i), $\frac{\mu}{\sqrt{2}}(T + mg) = -\frac{1}{\sqrt{2}}(mg - T)$

$\mu(50+15\times 10) = (15\times 10 - 50)$

$\mu = \dfrac{100}{200} = \dfrac{1}{2}$

2 **(c)**

Change of momentum $\mathbf{F}\,\Delta t = m\Delta\mathbf{v}$

$\Rightarrow \quad \mathbf{F} = \dfrac{m\Delta\mathbf{v}}{t}$

By doing so time of change in momentum increases and impulsive force on knees decreases.

3 **(a)**

$$\mu = \tan\theta\left(1 - \frac{1}{n^2}\right) = \tan\theta\left(1 - \frac{1}{2^2}\right) = \frac{3}{4}\tan\theta$$

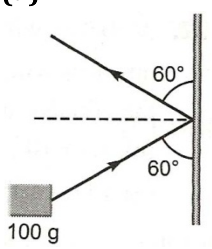
4 **(a)**

5 **(d)**

Momentum acquired = Area of force -time graph

$= \frac{1}{2}\times(2)\times(10) + 4\times 10 = 10 + 40 = 50\ N\text{-}s$

6 **(a)**



Change in the velocity $= v\sin\theta - (-v\sin\theta) = 2\sin\theta$

Change in the momentum

$\Delta p = 2\,m\,v\sin\theta$

$\therefore$ Force applied $F = \dfrac{\Delta p}{\Delta t}$

$= \dfrac{2\times 100\times 10^{-3}\times 5\sin\theta\, 60°}{2\times 10^{-3}}$

$= 100\times 5\times\dfrac{\sqrt{3}}{2}$

$= 250\sqrt{3}$ N (To the right)

7 **(a)**

If μ is the mass/length, then

Weight of hanging length $= \mu l g$

Weight of chain on table $= \mu(L - l)g$

$R = \mu(L - l)g$

$f = \mu_s R = \mu_s\mu(L - l)g$

Equating, $\mu_s\mu(L - l)g = \mu l g$ or $\mu_s = \frac{l}{L-l}$

8 **(d)**

Kinetic energy being a scalar quantity, hence measured from different inertial frame gives the same value, while the other three being vector quantities their values vary.

9 **(d)**

Coefficent of friction $\mu = \dfrac{F}{R}$

$= \dfrac{mg/3}{2mg/3} = \dfrac{1}{2}$

10 **(c)**

When force F is applied on $2m$ from left, contact force,

$F_1 = \dfrac{m}{m + 2m}F = \dfrac{F}{3}$

When force F is applied on m from right, contact force

$F_2 = \dfrac{2m}{m + 2m}F = \dfrac{2F}{3}$

$\therefore F_1 : F_2 = 1 : 2$

11 **(c)**

12 **(a)**

The nail has fallen through a total vertical distance of $(h + x)$. Hence loss in tis potential energy $= mg(h + x)$. If average retarding force exerted by sand on nail is f, then work done $W = -Fx$

For equilibrium,

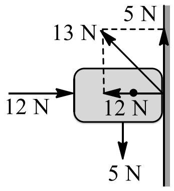
$mg(h + x) = Fx$ or $F = mg\frac{h+x}{x} = mg\left(\frac{h}{x} + 1\right)$

13 **(b)**

We know $s = \frac{u^2}{2\mu g}$ $\therefore$ $\mu = \frac{u^2}{2gs} = \frac{(6)^2}{2\times10\times9} = 0.2$

14 **(d)**

Wall applies 2 forces of the block (i) normal reaction, $R = 12$ N, and (ii) frictional force, $f_2 = mg = 5$ N tangentially upward



$\therefore$ Total force exerted by wall on block

$F = \sqrt{N^2 + f_s^2} = \sqrt{(12)^2 + (5)^2} = 13$N

15 **(b)**

Newton second law

$F = ma \Rightarrow 6 = (7+5)a \,;\, a = \frac{1}{2}\frac{m}{s^2}; F' \to 5\,kg$

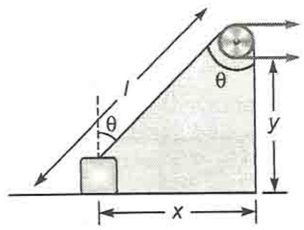
Now, $F' = 5 \times \frac{1}{2} = 2.5\,N$

16 **(c)**

From geometry $l^2 = x^2 + y^2$ but y is constant, hence differentiating, we have, $2l\frac{dl}{dt} = 2x\frac{dx}{dt}$

But $\frac{dl}{dt} = v$. Hence horizontal velocity of block,

$v_x = \frac{dx}{dt}$



$\Rightarrow$ $lv = x.v_x$ or $v_x = \frac{l.v}{x} = \frac{v}{\sin\theta}$

17 **(c)**

As the spring balances are massless therefore the reading of both balance should be equal

18 **(d)**

Particle will move with uniform velocity due to inertia

19 **(b)**

$F = \frac{d}{dt}(p)$

$F = \frac{d}{dt}(a + bt + ct^2)$ or $F = b + 2ct$

Clearly, the force is time-dependent

20 **(c)**

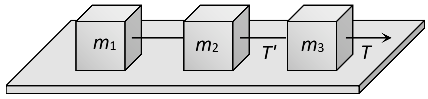
Applying Lami's theorem

$$\frac{T_1}{\sin(90° + \beta)} = \frac{T_2}{\sin(90° + \alpha)}$$
$$= \frac{mg}{\sin[180° - (\alpha + \beta)]}$$

or $\frac{T_1}{\cos\beta} = \frac{T_2}{\cos\alpha} = \frac{mg}{\sin(\alpha+\beta)}$

$\therefore$ $T_1 = \frac{mg\cos\beta}{\sin(\alpha+\beta)}; T_2 = \frac{mg\cos\alpha}{\sin(\alpha+\beta)}$

21 **(c)**



$T' = (m_1 + m_2) \times \frac{T}{m_1 + m_2 + m_3}$

22 **(c)**

Momentum of one piece $= \frac{M}{4} \times 3$

Momentum of the other piece $= \frac{M}{4} \times 4$

$\therefore$ Resultant momentum $= \sqrt{\frac{9M^2}{16} + M^2} = \frac{5M}{4}$

The third piece should also have the same momentum

Let its velocity be v, then

$\frac{5M}{4} = \frac{M}{2} \times v \Rightarrow v = \frac{5}{2} = 2.5\,m/sec$

23 **(d)**

law of conservation of momentum gives

$m_1 v_1 = m_2 v_2$

$\Longrightarrow \frac{m_1}{m_2} = \frac{v_2}{v_1}$

But, $m = \frac{4}{3}\pi r^3 \rho$

or $m \propto r^3$

$\therefore$ $\frac{m_1}{m_2} = \frac{r_1^3}{r_2^3} = \frac{v_2}{v_1}$

$\Longrightarrow \frac{r_1}{r_2} = \left(\frac{1}{2}\right)^{1/3}$

$\therefore$ $r_1 : r_2 = 1 : 2^{1/3}$

24 **(b)**

Tension is rope, $T <$ Breaking load, $\frac{2}{3}mg$

$\therefore m(g - a) < \frac{2}{3}mg$ or $a > \frac{g}{3}$

25 **(c)**

$\frac{dM}{dt} = 0.1kg/s, v_{gas} = 50\,m/s,$

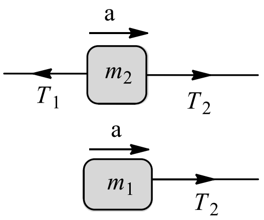
Mass of the rocket $= 2\,kg. Mv =$ constant

$-v\frac{dM}{dt} + M\frac{dv}{dt} = 0 \therefore \frac{dv}{dt} = \frac{1}{M}v\frac{dM}{dt}$

$\Rightarrow$ Acceleration $= \frac{1}{2} \times 50 \times 0.1 = 2.5\,m/s^2$

26 **(a)**

$T_2 - T_1 = m_2 a$



Dividing, $\frac{T_2-T_1}{T_1}=\frac{m_2}{m_1}$

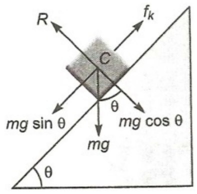
or $\frac{T_2}{T_1}=\frac{m_2}{m_1}+1=\frac{m_2+m_1}{m_1}$

or $\frac{T_2}{T_1}=\frac{m_1}{m_1+m_2}$

27 **(b)**

The various forces acting on the block are as shown

From Newton's law



$mg\sin\theta - f = ma$ ….(i)

Where f is frictional force and a the acceleration downwards.

Since, there is no motion perpendicular to surface, we have

$R - mg\cos\theta = 0$

$\Longrightarrow\quad R = mg\cos\theta$ ….(ii)

Also, $f=\mu R=\mu\, mg\cos\theta$

Putting the value in Eq. (i) we get

$mg\sin\theta - \mu\, mg\cos\theta = ma$

$\Longrightarrow\quad a = g\sin\theta - \mu\, g\cos\theta$

Now, velocity at bottom

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

Since, $v = 0$

$\therefore u=\sqrt{2as}$

Given, $\quad s = l, \quad a = g\sin\theta - g\mu\cos\theta$

$\therefore\quad u=\sqrt{2l(g\sin\theta - g\mu\cos\theta)}$

$u=\sqrt{2gl(\sin\theta-\mu\cos\theta)}$

28 **(b)**

Mass of each bullet$(m)=1\text{ g}=0.001\text{ kg}$

Velocity of bullet $(v)=10\text{ ms}^{-1}$

Applied force $(F)=5$ g-wt.

$=\frac{5}{1000}\times 10\text{ N}$

$=0.05\text{ N}$

Let n bullets are fired per second, then

Force= rate of change of linear momentum

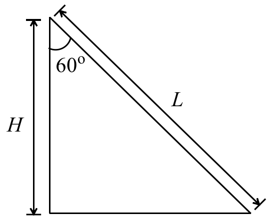
$ie, \quad F = n\times mv$

$\therefore$ Number of bullets fired per second

$n=\frac{F}{mv}$

$=\frac{0.05}{0.001\times 10}=5$

29 **(b)**



Let L be the length and H be height of the inclined plane respectively

Acceleration of the block slide down the smooth incline plane is

$a = g\cos 60°$

$\therefore L=\frac{1}{2}g\cos 60°\, t_1^2\quad [\because u=0]$ ...(i)

Acceleration of another block dropped vertically down from the same inclined plane is

$a = g$

$\therefore H=\frac{1}{2}at_2^2=\frac{1}{2}gt_2^2\quad[\because u=0]$

From figure,

$\cos 60°=\frac{H}{L}\Rightarrow H=L\cos 60°$

$\therefore L\cos 60°=\frac{1}{2}gt_2^2$ ...(ii)

Divide (i) by (ii), we get

$\frac{t_1^2\cos 60°}{t_2^2}=\frac{1}{\cos 60°}$

$\frac{t_1^2}{t_2^2}=\frac{1}{\cos^2 60°}=\frac{4}{1}\Rightarrow\frac{t_1}{t_2}=\frac{2}{1}$

30 **(b)**

Surfaces always slide over each other

31 **(b)**

32 **(b)**

Let the minimum mass of B is M_B.

Force applied by it $F=M_Bg$

Friction force on block A

$f=\mu\, M_Ag$

For motion to start

$M_Bg=\mu\, M_Ag$

$M_B=0.22\times 10$

$=2.2$ kg

33 **(b)**

Impulse is given by the product of force and time. Form Newton's second law

$F = ma = m\dfrac{\Delta v}{\Delta t}$

$\Rightarrow \quad F\Delta t = m\Delta v$

= change in the momentum of the body.

34 **(c)**

$F = 600 - 2 \times 10^5 t = 0 \Rightarrow t = 3 \times 10^{-3}$ sec

Impulse $I = \int_0^t F\,dt = \int_0^{3\times10^{-3}} (600 - 2 \times 10^5 t)dt$

$= [600t - 10^5 t^2]_0^{3\times10^{-3}} = 0.9\ N \times \text{sec}$

35 **(a)**

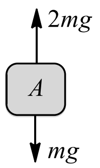
$\mu = \tan\theta\left(1 - \dfrac{1}{n^2}\right) = 1 - \dfrac{1}{n^2}$ [As $\theta = 45°$]

36 **(b)**

For A, $T = f = 2mg$

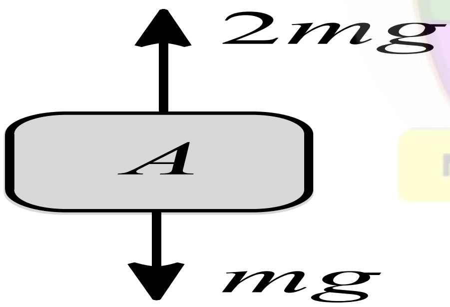
$2mg - mg = ma_1$

$\therefore\ a_1 = g$



For B,

From force diagram shown in figure,



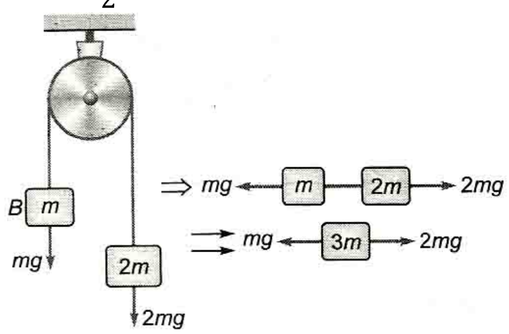
$2mg - mg = 3ma_2$

$a_2 = \dfrac{g}{3}$

For C,

$\therefore\ 2mg - mg = 2ma_3$

$\therefore\ a_3 = \dfrac{g}{2}$



So, $a_1 > a_3 > a_2$

37 **(a)**

According to Newton's second law :

Force = rate of change of linear momentum

38 **(a)**

$\Delta P = p_i - p_f = mv - (-mv) = 2\,mv$

39 **(d)**

Are under the $F - t$ cure=change in momentum

or $\dfrac{1}{2} \times 2 \times (10) + 2 \times 10 + \dfrac{1}{2}(10 + 20) \times 2$

$+ \dfrac{1}{2} \times 4 \times 20 = m(v - u)$

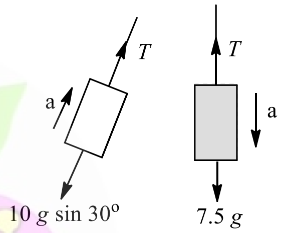
or $10 + 20 + 30 + 40 = 2(v - 0)$

or $100 = 2v$

or $v = 50\ \text{ms}^{-1}$

40 **(d)**

Refer to the free-body diagrams



$T - 10g \sin 30° = 10a$ or $T - 5g = 10a$

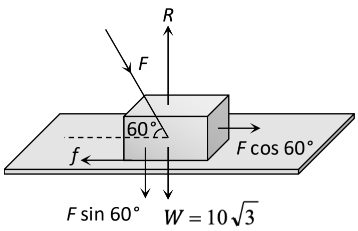
Again , $7.5 - T = 7.5\alpha$

Adding, $2.5g = 17.5\alpha$

or $\alpha = \frac{25g}{175} = \frac{g}{7}$

41 **(c)**

42 **(a)**



$f = \mu R \Rightarrow F\cos 60° = \mu(W + F\sin 60°)$

Substituting $\mu = \frac{1}{2\sqrt{3}}$ & $W = 10\sqrt{3}$

We get $F = 20\ N$

43 **(b)**

When a sudden jerk is given to C, an impulsive tension exceeding the breaking tension develops in C first, which breaks before this impulse can reach A as a wave through block

44 **(c)**

Swimming is a result of pushing water in the opposite direction of the motion

45 ©

$T_1 = \left(\dfrac{m_2 + m_3}{m_1 + m_2 + m_3}\right)g = \dfrac{3 + 5}{2 + 3 + 5} \times 10 = 8\ N$

46 **(b)**

$T = 2\pi\sqrt{\frac{l}{g}}$ and $T' = 2\pi\sqrt{\frac{l}{4g/3}}$

[As $g' = g + a = g + \frac{g}{3} = \frac{4g}{3}$]

$\therefore T' = \frac{\sqrt{3}}{2}T$

47 **(a)**

Acceleration, $a = \frac{M_1 - M_2}{M_1 + M_2}g$

$= \frac{M - \frac{M}{2}}{M + \frac{M}{2}}g = \frac{\frac{M}{2}}{\frac{3M}{2}}g = \frac{g}{3}$

48 **(c)**

49 **(d)**

$\frac{dm}{dt} = 0.1\ kg$ / sec; Mass of the rocket = $100\ kg$

$v = 1\ km/\text{sec} = 1000\ m/\text{sec}$

$F = \frac{d(mv)}{dt} = m\frac{dv}{dt} - v\frac{dm}{dt} = 0$ as the mass is decreasing

$100a - 1000 \times 0.1 = 0$

$a = +1\ m/s^2$

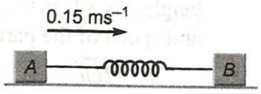
50 **(a)**

Work, Energy and Power

RED ZONE

1. The decrease in the potential energy of a ball of mass 20 kg which falls from a height of 50 cm is
   a) 968 J b) 98 J c) 1980 J d) None of these
2. The potential energy of a certain spring when stretched through a distance 'S' is 10 $joule$. The amount of work (in joule) that must be done on this spring to stretch it through an additional distance 'S' will be
   a) 30 b) 40 c) 10 d) 20
3. If the kinetic energy of a body is increased 2 times , its momentum will
   a) Half b) Remain unchanged c) Be doubled d) increase $\sqrt{2}$ times
4. Two putty balls of equal mass moving with equal velocity in mutually perpendicular directions, stick together after collision. If the balls were initially moving with a velocity of $45\sqrt{2}\ ms^{-1}$ each, the velocity of their combined after collision is
   a) $45\sqrt{2}\ ms^{-1}$ b) $45\ ms^{-1}$ c) $90\ ms^{-1}$ d) $22.5\sqrt{2}\ ms^{-1}$
5. A man does a given amount of work in 10 s. Another man does the same amount of work in 20 s. The ratio of the output power of first man to the second man is
   a) 1 b) $\frac{1}{2}$ c) $\frac{2}{1}$ d) None of these
6. The force constant of a wire is k and that of another wire is $2k$. When both the wires are stretched through same distance, then the work done
   a) $W_2 = 2W_1^2$ b) $W_2 = 2W_1$ c) $W_2 = W_1$ d) $W_2 = 0.5W_1$
7. A body at rest breaks into two pieces with unequal mass
   a) Both of them have equal speeds
   b) Both of them move along a same line with unequal speeds
   c) Sum of their momentum is non zero
   d) They move along different lines with different speeds
8. A mass of 50 kg is raised through a certain height by a machine whose efficiency is 90%, the energy is 5000 J. If the mass is now released, its KE on hitting the ground shall be
   a) 5000 J b) 4500 J c) 4000 J d) 5500 J
9. A body of mass 2 kg is projected at 20 m/s at an angle of 60° above the horizontal. Power on the block due to the gravitational force at its highest point is
   a) 200 W b) $100\sqrt{3}\ W$ c) 50 W d) Zero
10. 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) 800 W b) 400 W c) 200 W d) 100 W

11. Two rectangular blocks A and B of masses 2kg and 3 kg respectively are connected by spring of spring constant 10.8 Nm^{-1} and are placed on a frictionless horizontal surface. The block A was given an initial velocity of 0.15 ms^{-1} in the direction shown in the figure. The maximum compression of the spring during the motion is



a) 0.01 m b) 0.02 m c) 0.05 m d) 0.03 m

12. A force of $5N$, making an angle θ with the horizontal, acting on an object displaces it by $0.4m$ along the horizontal direction. If the object gains kinetic energy of $1J$, the horizontal component of the force is

a) 1.5 N b) 2.5 N c) 3.5 N d) 4.5 N

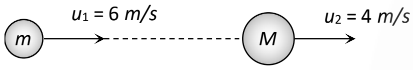
13. The bodies of masses 1 kg and 5 kg are dropped gently from the top of a tower. At a point 20 cm from the ground, both the bodies will have the same

a) Momentum b) Kinetic energy c) Velocity d) Total energy

14. A bomb at rest explodes into 3 parts of the same mass.
The momentum of the 2 parts is $-2p\hat{\imath}$ and $p\hat{\jmath}$. The momentum of the third part will have a magnitude of

a) p b) $\sqrt{3p}$ c) $p\sqrt{5}$ d) zero

15. A particle of mass m moving with horizontal speed 6 m/sec as shown in figure. If $m << M$ than for one dimensional elastic collision, the speed of lighter particle after collision will be



a) $2m/sec$ in original direction b) $2m/sec$ opposite to the original direction
c) $4m/sec$ opposite to the original direction d) $4m/sec$ in original direction

16. Consider elastic collision of a particle of mass m moving with a velocity u with another particle of the same mass at rest. After the collision the projectile and the stuck particle move in directions making angles θ_1 and θ_2 respectively with the initial direction of motion.
The sum of the angles $\theta_1 + \theta_2$

a) 45° b) 90° c) 135° d) 180°

17. A car weighing 1400 kg Is moving at a speed of 54 kmh^{-1} up a hill when the motor stops. If it is just able to reach the destination which is at a height of 10 m above the point, then the work done against friction (negative of the work done by the friction) is [Take $g = 10\mathrm{ms}^{-2}$]

a) 10 kJ b) 15 kJ c) 17.5 kJ d) 25 kJ

18. A bomb is kept stationary at a point. It suddenly explodes into two fragments of masses $1g$ and $3g$. The total K.E. of the fragments is $6.4 \times 10^4\ J$. What is the K.E. of the smaller fragment

a) $2.5 \times 10^4\ J$ b) $3.5 \times 10^4\ J$ c) $4.8 \times 10^4\ J$ d) $5.2 \times 10^4\ J$

19. If the heart pushes 1 cc of blood in 1 s under pressure $20000Nm^{-2}$,the power of heart is

a) 0.02 W b) 400 W c) 5×10^{-10}W d) 0.2 W

20. A uniform chain of length L and mass M is lying on a smooth table and one third of its length is hanging vertically down over the edge of the table. If g is acceleration due to gravity, the work required to pull the hanging part on to the table is

a) MgL b) $MgL/3$ c) $MgL/9$ d) $MgL/18$

21. A mass m is attached to the end of a rod of length l. The mass goes around a vertical circular path with the other end hinged at the centre. What should be the minimum velocity of mass at the bottom of the circle, so that the mass complete the circle?

a) $\sqrt{4gl}$ b) $\sqrt{3gl}$ c) $\sqrt{5gl}$ d) $\sqrt{gl}$

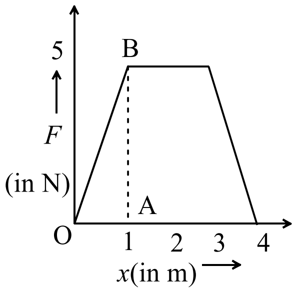
22. A bullet of mass a and velocity b is fired into a large block of mass c. The final velocity of the system is

a) $\dfrac{c}{a+b}.b$ b) $\dfrac{a}{a+c}.b$ c) $\dfrac{a+b}{c}.a$ d) $\dfrac{a+c}{a}.b$

23. A bomb of mass M at rest explodes into two fragments of masses m_1 and m_2. The total energy released in the explosion is E. If E_1 and E_2 represent the energies carried by masses m_1 and m_2 respectively, then which of the following is correct?

a) $E_1 = \frac{m_2}{M}E$ b) $E_1 = \frac{m_1}{m_2}E$ c) $E_1 = \frac{m_1}{M}E$ d) $E_1 = \frac{m_2}{m_1}E$

24. The force F acting on a particle moving in a straight line is shown in figure. What is the work done by the force on the particle in the 1st meter of the trajectory



a) 5 J b) 10 J c) 15 J d) 2.5 J

25. A position dependent force $F = 7 - 2x + 3x^2$ *newton* acts on a small body of mass 2 kg and displaces it from $x = 0$ to $x = 5m$. The work done in *joules* is

a) 70 b) 270 c) 35 d) 135

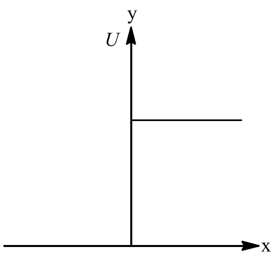
26. A body of mass 10 kg is moving on a horizontal surface by applying a force of 10 N in forward direction. If body moves with constant velocity, the work done by force of fiction for a displacement of 2m is

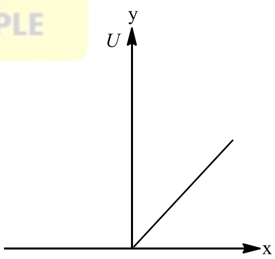
a) -20 J b) 10 J c) 20 J d) -5 J

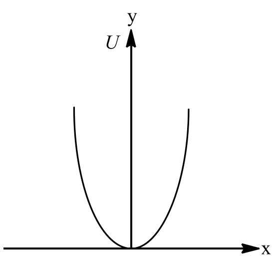
27. Which of the following statements is wrong?

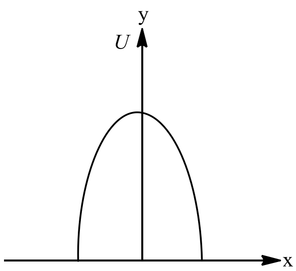
a) KE of a body is independent of the direction of motion
b) In an elastic collision of two bodies ,the momentum and energy of each body is conserved
c) If two protons are brought towards each other the PE of the system decreases.
d) A body cannot have energy without momentum.

28. Which of the following graphs show variation of potential energy (U) with position x.

a)


b)


c)


d)


29. A ball is released from certain height. It loses 50% of its kinetic energy on striking the ground. It will attain a height again equal to

a) One fourth the initial height
b) Half the initial height
c) Three fourth initial height
d) None of these

30. A particle is projected at 60° to the horizontal with a kinetic energy K. The kinetic energy at the highest point is

a) K
b) Zero
c) $\frac{K}{4}$
d) $\frac{K}{2}$

31. A 10 kg object collides with stationary 5 kg object and after collision they stick together and move forward with velocity 4 ms^{-1}.what is the velocity with which the 10 kg object hit the second one?

a) 4 ms^{-1}
b) 6 ms^{-1}
c) 10 ms^{-1}
d) 12 ms^{-1}

32. A force $F = Ay^2 + By + C$ acts on a body in the y-direction. The work done by this force during a displacement from $y = -a$ to $y = a$ is

a) $\frac{2Aa^3}{3}$
b) $\frac{2Aa^3}{3} + 2Ca$
c) $\frac{2Aa^3}{3} + \frac{Ba^2}{2} + Ca$
d) None of these

33. A 2 kg block slides on a horizontal floor with a speed of 4 m/s. It strikes a uncompressed spring, and compresses it till the block is motionless. The kinetic friction force is 15 N and spring constant is 10,000 N/m. The spring compresses by

a) 5.5 cm
b) 2.5 cm
c) 11.0 cm
d) 8.5 cm

34. Quantity/Quantities remaining constant in a collision is/are

a) Momentum, kinetic energy and temperature
b) Momentum but not kinetic energy and temperature
c) Kinetic energy and temperature but not momentum
d) None of the above

35. A force $\mathbf{F} = (2\hat{\mathbf{i}} + 4\,\hat{\mathbf{j}})$N displaces the body by $\boldsymbol{s} = (3\hat{\boldsymbol{j}} + 5\hat{\boldsymbol{k}})$m in 2 s. Power generated will be

a) 11 W
b) 6 W
c) 22 W
d) 12 W

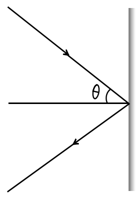
36. A man, by working a hand pump fixed to a well, pumps out 10 m^3 water in 1 s. If the water in the well is 10 m below the ground level, then the work done by the man is ($\mathrm{g} = 10\mathrm{ms}^{-2}$)

a) 10^3J
b) 10^4J
c) 10^5J
d) 10^6J

37. A body of mass m_1 is moving with a velocity V. It collides with another stationary body of mass m_2. They get embedded. At the point of collision, the velocity of the system

a) Increases
b) Decreases but does not become zero
c) Remains same
d) Become zero

38. An intense stream of water of cross-sectional area A strikes a wall at an angle θ with the normal to the wall and returns back elastically. If the density of water is ρ and its velocity is v, then the force exerted in the wall will be

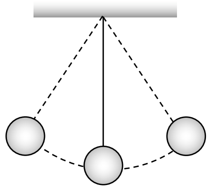


a) $2Av\rho\cos\theta$
b) $2Av^2\rho\cos\theta$
c) $2Av^2\rho$
d) $2Av\rho$

39. Two solid rubber balls A and B having masses 200 and 400 g respectively are moving in opposite directions with velocity of A equal to 0.3 m/s. After collision the two balls come to rest, then the velocity of B is

a) 0.15 m/sec
b) 1.5 m/sec
c) -0.15 m/sec
d) None of the above

40. What is the velocity of the bob of a simple pendulum at its mean position, if it is able to rise to vertical height of 10 cm (Take $g = 9.8\ m/s^2$)



a) 0.6 m/s b) 1.4 m/s c) 1.8 m/s d) 2.2 m/s

41. Which of the following statements are incorrect?
(i)If there were no friction, Work need to be done to move a body up an inclined plane is zero.
(ii)If there were no friction, moving vehicles could not be stopped even by locking the brakes.
(iii)As the angle of inclination is increased, the normal reaction on the body placed on it increases.
(iv)A duster weighing 0.5 kg is pressed against a vertical board with a force of 11 N. If the coefficient of friction is 0.5, the work done in rubbing it upward through a distance of 10 cm is 0.55J.
a) (i)and(ii) b) (i),(ii),(iv) c) (i),(iii),and(iv) d) All of these

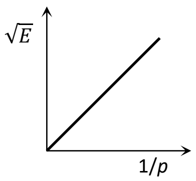
42. A ^{238}U nucleus decays by emitting an alpha particle of speed $v\ ms^{-1}$. The recoil speed of the residual nucleus is (in ms^{-1})
a) $-4v/234$ b) $v/4$ c) $-4v/238$ d) $4v/238$

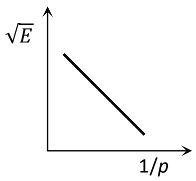
43. A particle is released from a height s. At certain height its kinetic energy is three times its potential energy. The height and speed of the particle at that instant are respectively
a) $\frac{s}{4}, \frac{3gs}{2}$ b) $\frac{s}{4}, \frac{\sqrt{3gs}}{2}$ c) $\frac{s}{2}, \frac{\sqrt{3gs}}{2}$ d) $\frac{s}{4}, \frac{\sqrt{3gs}}{2}$

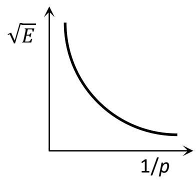
44. A light and a heavy body have equal kinetic energy. Which one has a greater momentum
a) The light body
b) The heavy body
c) Both have equal momentum
d) It is not possible to say anything without additional information

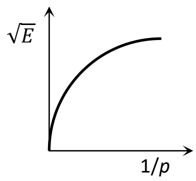
45. A bomb of mass 30 kg at rest explodes into two pieces of masses 18 kg and 12kg.The velocity of 18 kg mass is 6 ms^{-1}.The kinetic energy of the other mass is
a) 256 J b) 486 J c) 524 J d) 324 J

46. The graph between $\sqrt{E}$ and $1/p$ is (E = kinetic energy and p = momentum)

a) 

b) 

c) 

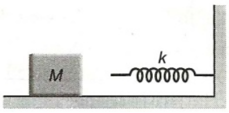
d) 

47. A bag (mass M) hangs by a long thread and a bullet (mass m) comes horizontally with velocity v and gets caught in the bag. Then for the combined (bag + bullet) system
a) Momentum is $\frac{mvM}{M+m}$
b) Kinetic energy is $\frac{mv^2}{2}$
c) Momentum is $\frac{mv(M+m)}{M}$
d) Kinetic energy is $\frac{m^2v^2}{2(M+m)}$

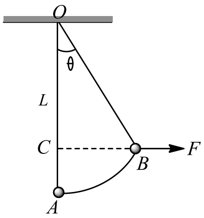
48. The kinetic energy k of a particle moving along a circle of radius R depends upon the distance s as $k = as^2$. The force acting on the particle is
a) $2a\frac{s^2}{R}$ b) $2as\left[1+\frac{s^2}{R^2}\right]^{1/2}$ c) $2as$ d) $2a$

49. A body of mass m moving with velocity v collides head on another body of mass $2m$ which is initially at rest. The ratio of KE of colliding body before and after collision body before and after collision will be
a) 1:1 b) 2:1 c) 4:1 d) 9:1

50. 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, 2
b) 0, 1
c) 1, 1
d) 1, 0.5
51. When a force is applied on a moving body, its motion is retarded. Then the work done is
a) Positive
b) Negative
c) Zero
d) Positive and negative
52. Four particles given, have same momentum. Which has maximum kinetic energy
a) Proton
b) Electron
c) Deutron
d) α- particles
53. The block of mass M moving on the frictionless horizontal surface collides with the spring of spring constant k and compresses it by length L. The maximum momentum of the block after collides is



a) $\sqrt{MkL}$
b) $\frac{kL^2}{2M}$
c) Zero
d) $\frac{ML^2}{k}$
54. In which case does the potential energy decrease
a) On compressing a spring
b) On stretching a spring
c) On moving a body against gravitational force
d) On the rising of an air bubble in water
55. An object of mass m is tied to a string of length L and a variable horizontal force is applied on it which starts at zero and gradually increases until the string makes an angel θ with the vertical. Work done by the force F is



a) $mgL(1-\sin\theta)$
b) mgL
c) $mgL(1-\cos\theta)$
d) $mgL(1+\cos\theta)$
56. A ball of mass m falls vertically to the ground from a height h_1 and rebound to a height h_2. The change in momentum of the ball on striking the ground is
a) $mg(h_1-h_2)$
b) $mg(\sqrt{2gh_1}+\sqrt{2gh_2})$
c) $m\sqrt{2g(h_1+h_2)}$
d) $m\sqrt{2g}(h_1+h_2)$
57. A mass of 10 g moving with a velocity of 100 cm/s strikes a pendulum bob of mass 10 g. The two masses stick together. The maximum height reached by the system now is ($g=10\ m/s^2$)
a) Zero
b) 5 cm
c) 2.5 cm
d) 1.25 cm
58. A sphere of mass m moving with a constant velocity u hits another stationary sphere of the same mass. If e is the coefficient of restitution, then the ratio of the velocity of two spheres after collision will be
a) $\frac{1-e}{1+e}$
b) $\frac{1+e}{1-e}$
c) $\frac{e+1}{e-1}$
d) $\frac{e-1}{e+1}t^2$
59. A particle falls from a height h upon a fixed horizontal plane and rebounds. If e is the coefficient of restitution, the total distance travelled before rebounding has stopped is
a) $h\left(\frac{1+e^2}{1-e^2}\right)$
b) $h\left(\frac{1-e^2}{1+e^2}\right)$
c) $\frac{h}{2}\left(\frac{1-e^2}{1+e^2}\right)$
d) $\frac{h}{2}\left(\frac{1+e^2}{1-e^2}\right)$

60. **Statement I** Two particles moving in the same direction do not lose all their energy in a completely inelastic collision.
Statement II Principle of conservation of momentum holds true for all kinds of collisions.
a) Statement I is true, statement II is true, statement II is the correct explanation of statement I.
b) Statement I is true Statement II is true, Statement II is not correct explanation of statement I.
c) Statement I is false, Statement II is true.
d) Statement I is true, Statement II is false.

61. Two springs A and B are identical but A is harder than $B(k_A > k_B)$. Let W_A and W_B represent the work done when the springs are stretched through the same distance and W'_A and W'_B are the work done when these are stretched by equal forces, then which of the following is true

a) $W_A > W_B$ and $W'_A = W'_B$
b) $W_A > W_B$ and $W'_A < W'_B$
c) $W_A > W_B$ and $W'_A > W'_B$
d) $W_A < W_B$ and $W'_A < W'_B$

62. A rubber ball is dropped from a height of 5 m on a planet, where the acceleration due to gravity is not known. On bouncing it rises to 1.8 m. The ball loses its velocity on bouncing by a factor of

a) $\frac{16}{25}$
b) $\frac{2}{5}$
c) $\frac{3}{5}$
d) $\frac{9}{25}$

63. A bullet is fired from a rifle. If the riffle recoils freely, then the kinetic energy of the rifle is

a) Less than that of the bullet
b) More than that of the bullet
c) Same as that of the bullet
d) Equal or less than that of the bullet

64. In an inelastic collision, what is conserved

a) Kinetic energy
b) Momentum
c) Both (a) and (b)
d) Neither (a) nor (b)

65. A 2.0 kg block is dropped from a height of 40 cm onto a spring of spring constant $k = 1960\ \text{Nm}^{-1}$. Find the maximum distance the spring is compressed

a) 0.080 m
b) 0.20 m
c) 0.40 m
d) 0.10 m

66. The energy which an e^- acquires when accelerated through a potential difference of 1 volt is called

a) 1 $Joule$
b) 1 eV
c) 1 Erg
d) 1 $Watt$

67. Identify the wrong statement

a) A body can have momentum without energy
b) A body can have energy without momentum
c) The momentum is conserved in an elastic collision
d) Kinetic energy is not conserved in an inelastic collision

68. A force acts on a 30 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 seconds is

a) 5.28 J
b) 450 mJ
c) 190 mJ
d) 530 mJ

69. A bucket tied to a string is lowered at a constant acceleration of $\frac{g}{4}$. If the mass of the bucket is m and is lowered by a distance d, the work done by the string will be

a) $\frac{mgd}{4}$
b) $-\frac{3}{4}mgd$
c) $-\frac{4}{3}mgd$
d) $\frac{4}{3}mgd$

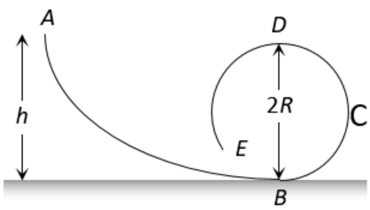
70. A body of mass 3 kg acted upon by a constant force is displaced by S metre, given by relation $S = \frac{1}{3}t^2$, where t is in second. Work done by the force in 2 seconds is

a) $\frac{8}{3}$ J
b) $\frac{19}{5}$ J
c) $\frac{5}{19}$ J
d) $\frac{3}{8}$ J

71. A ball is dropped from a height h on a floor of coefficient of restitution e.The total distance covered by the ball just before second hit is

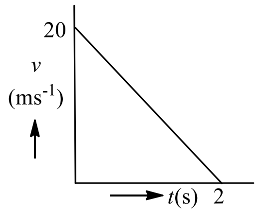
a) $h(1 - 2e^2)$
b) $h(1 + 2e^2)$
c) $h(1 + e^2)$
d) he^2

72. A frictionless track $ABCDE$ ends in a circular loop of radius R. A body slides down the track from point A which is it a height $h = 5\ cm$. Maximum value of R for the body to successfully complete the loop is



a) 5 cm
b) $\frac{15}{4}$ cm
c) $\frac{10}{3}$ cm
d) 2 cm

73. Velocity-time graph of a particle of mass 2 kg moving in a straight line is as shown in figure. Work done by all forces on the particle is

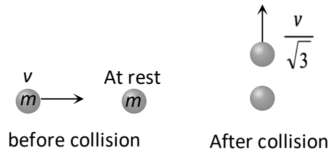


a) 400 J   b) −400 J   c) −200 J   d) 200 J

74. From an automatic gun a man fires 360 bullet per minute with a speed of 360 $km/hour$. If each weighs 20 g, the power of the gun is

a) 600 W b) 300 W c) 150 W d) 75 W

75. A mass 'm' moves with a velocity 'v' and collides inelastically with another identical mass. After collision the Ist mass moves with velocity $\frac{v}{\sqrt{3}}$ in a direction perpendicular to the initial direction of motion. Find the speed of the 2nd mass after collision



a) $\frac{2}{\sqrt{3}}v$ b) $\frac{v}{\sqrt{3}}$ c) v d) $\sqrt{3}\,v$

76. An object of mass m is attached to light string which passes through a hollow tube. The object is set into rotation in a horizontal circle of radius , r_1.If the string is pulled shortening the radius to r_2,the ratio of new kinetic energy to the original kinetic energy is

a) $\left(\frac{r_2}{r_1}\right)^2$ b) $\left(\frac{r_1}{r_2}\right)^2$ c) $\frac{r_1}{r_2}$ d) $\frac{r_2}{r_1}$

77. A uniform chain of length L and mass M overhangs a horizontal table with its two-third part on the table. The friction coefficient between the table and the chain is μ. The work done by the friction during the period the chain slips off the table is

a) $-\frac{1}{4}\ \mu MgL$ b) $-\frac{2}{9}\ \mu MgL$ c) $-\frac{4}{9}\ \mu MgL$ d) $-\frac{6}{7}\ \mu MgL$

78. A body moving with velocity v has momentum and kinetic energy numerically equal. What is the value of v

a) 2 m/s b) $\sqrt{2}$ m/s c) 1 m/s d) 0.2 m/s

79. Power supplied to a particle of mass 2 kg varies with time as $P = \frac{3t^2}{2}$ watt. Here t is in second. If the velocity of particle at $t = 0$ is $v = 0$, the velocity of particle at time $t = 2$ s will be

a) 1 ms^{-1} b) 4 ms^{-1} c) 2 ms^{-1} d) $2\sqrt{2}$ ms^{-1}

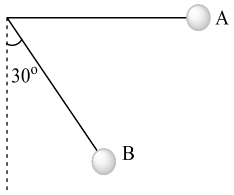
80. The area of the acceleration-displacement curve of a body gives

a) Impulse   b) Change in momentum per unit mass
c) Change in KE per unit mass   d) Total change in energy

81. A shell is fired from a cannon with velocity v m/sec at an angle θ with the horizontal direction. At the highest point in its path it explodes into two pieces of equal mass. One of the pieces retraces its path to the cannon and the speed in m/sec of the other piece immediately after the explosion is

a) $3v\cos\theta$ b) $2v\cos\theta$ c) $\frac{3}{2}v\cos\theta$ d) $\frac{\sqrt{3}}{2}v\cos\theta$

82. A simple pendulum is released from A as shown. If m and l represent the mass of the bob and length of the pendulum, the gain in kinetic energy at B is



a) $\frac{mgl}{2}$ b) $\frac{mgl}{\sqrt{2}}$ c) $\frac{\sqrt{3}}{2}mgl$ d) $\frac{\sqrt{2}}{3}mgl$

83. 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 ($g = 10\ m/s^2$)

a) 20 J b) 30 J c) 40 J d) 10 J

84. A bullet when fired at a target with velocity of 100 ms^{-1} penetrates 1 m into it. If the bullet is fired at a similar target with a thickness 0.5m, then it will emerge from it with a velocity of

a) $50\sqrt{2}$ m/s b) $\frac{50}{\sqrt{2}}$ m/s c) 50 m/s d) 10 m/s

85. 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) $+4\ m/s$ for both b) $-3\ m/s$ and $+5\ m/s$ c) $-4\ m/s$ and $+4\ m/s$ d) $-5\ m/s$ and $+3\ m/s$

86. When two bodies collide elastically, then

a) Kinetic energy of the system alone is conserved

b) Only momentum is conserved

c) Both energy and momentum are conserved

d) Neither energy nor momentum is conserved

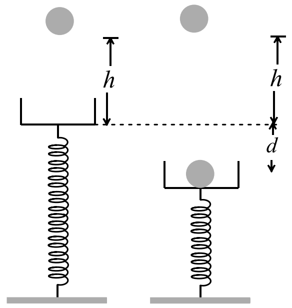
87. Two balls at same temperature collide. What is conserved

a) Temperature b) Velocity c) Kinetic energy d) Momentum

88. The power of a water jet flowing through an orifice of radius r with velocity v is

a) Zero b) $500\ \pi r^2\ v^2$ c) $500\ \pi r^2\ v^3$ d) $\pi r^4 v$

89. 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



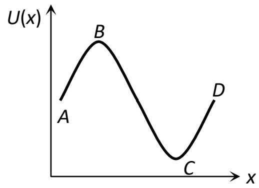
a) $mg + (h + d) + \frac{1}{2}Kd^2$ b) $mg(h + d) - \frac{1}{2}Kd^2$

c) $mg(h - d) - \frac{1}{2}Kd^2$ d) $mg(h - d) + \frac{1}{2}Kd^2$

90. A particle moves in a straight line with retardation proportional to its displacement. Its loss of kinetic energy for any displacement $x$is proportional to

a) x^2 b) e^x c) x d) $\log_e x$

91. The potential energy of a particle varies with distance x as shown in the graph.
The force acting on the particle is zero at



a) C b) B c) B and C d) A and D

92. A rod of mass m and length l is made to stand at an angle of 60^0 with the vertical. Potential energy of the rod in this position is

a) mgl b) $\frac{mgl}{2}$ c) $\frac{mgl}{3}$ d) $\frac{mgl}{4}$

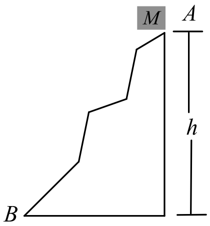
93. Two trolleys of mass m and $3m$ are connected by a spring. They were compressed and released once, they move off in opposite direction and comes to rest after covering distances S_1 and S_2 respectively. Assuming the coefficient of friction to be uniform, the ratio of distances $S_1 : S_2$ is

a) 1 : 9 b) 1 : 3 c) 3 : 1 d) 9 : 1

94. The kinetic energy of a body becomes four times its initial value. The new momentum will be

a) Same as the initial value b) Twice the initial value
c) Thrice the initial value d) Half of its initial value

95. In the given curved road, if particle is released from A then



a) Kinetic energy at B must be mgh b) Kinetic energy at B may be zero
c) Kinetic energy at B must be less than mgh d) Kinetic energy at B must not be equal to zero

96. A stationary particle explodes into two particle 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_1/m_2 b) 1 c) $m_1 v_2/m_2 v_1$ d) m_2/m_1

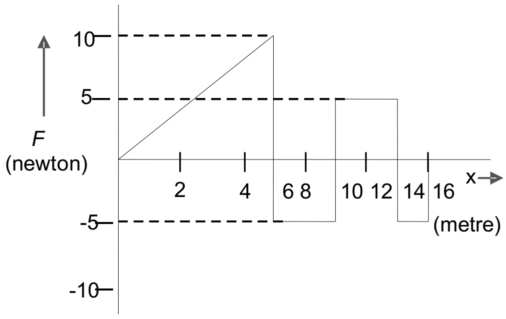
97. Two bodies moving towards each other collide and move away in opposite directions. There is some rise in temperature of bodies because a part of the kinetic energy is converted into

a) Heat energy b) Electrical energy c) Nuclear energy d) Mechanical energy

98. An open knife edge of mass 'm' is dropped from a height 'h' on a wooden floor. If the blade penetrates upto the depth 'd' into the wood, the average resistance offered by the wood edge is

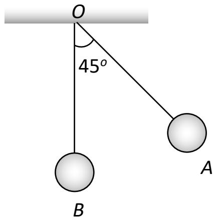
a) mg b) $mg\left(1-\frac{h}{d}\right)$ c) $mg\left(1+\frac{h}{d}\right)$ d) $mg\left(1+\frac{h}{d}\right)^2$

99. A particle is acted upon by a force F which varies with position x as shown in figure. If the particle at $x = 0$ has kinetic energy of 25 J, then the kinetic energy of the particle at $x = 16\ m$ is



a) 45 J b) 30 J c) 70 J d) 135J

100. The bob A simple pendulum is released when the string makes an angle of 45° with the vertical. It hits another bob B of the same material and same mass kept at rest on the table. If the collision is elastic



a) Both A and B rise to the same height

b) Both A and B come to rest at B

c) Both A and B move with the same velocity of A

d) A comes to rest and B moves with the velocity of A

: HINTS AND SOLUTIONS :

1 **(b)**

$\Delta U = mgh = 20 \times 9.8 \times 0.5 = 98\,J$

2 **(a)**

$\frac{1}{2}kS^2 = 10\,J$ [Given in the problem]

$\frac{1}{2}k[(2S)^2 - (S)^2] = 3 \times \frac{1}{2}kS^2 = 3 \times 10 = 30\,J$

3 **(d)**

Kinetic energy of particle ,$k = \frac{p_1^2}{2m}$

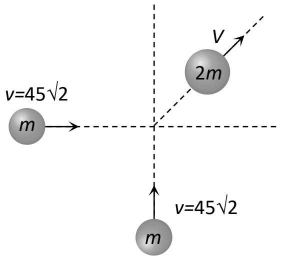
$p_1^2 = 2mk'$

When kinetic energy =2k

$p_2^2 = 2m \times 2k, p_2^2 = 2p_1^2, p_2 = \sqrt{2p_1}$

4 **(b)**

Initial momentum



$\vec{P} = m45\sqrt{2}\,\hat{\imath} + m45\sqrt{2}\,\hat{\jmath}$

$\Rightarrow |\vec{P}| = m \times 90$

Final momentum $2m \times V$

By conservation of momentum

$2m \times V = m \times 90$

$\therefore V = 45\,m/s$

5 **(c)**

Given ,$t_1 = 10s, \quad t_2 = 20, \quad w_1 = w_2$

power=$\frac{work\ done}{time}$

or $\frac{p_1}{p_2} = \frac{w_1/t_1}{w_2/t_2}$

$\therefore \quad \frac{p_1}{p_2} = \frac{t_2}{t_1} = \frac{2}{1}$

6 **(b)**

$W = \frac{1}{2}kx^2$

If both wires are stretched through same distance then

$W \propto k$. As $k_2 = 2k_1$ so $W_2 = 2W_1$

7 **(b)**

8 **(b)**

Because the efficiency of machine is 90%, hence, potential energy gained by the mass

$= \frac{90}{100} \times$ energy spend $= \frac{90}{100} \times 5000 = 4500$ J

When the mass is released now, gain in KE on hitting the ground

= Loss of potential energy

= 4500 J

9 **(d)**

$P = v\cos\theta = mg\,v\cos 90° = 0$

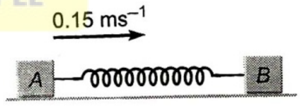
10 **(a)**

Power $= Fv = v\left(\frac{m}{t}\right)v = v^2(\rho A v)$

$= \rho A v^3 = (100)(2)^3 = 800\,W$

11 **(c)**

As the block A moves with velocity with velocity $0.15\ ms^{-1}$, it compresses the spring Which pushes B towards right. A goes on compressing the spring till the velocity acquired by B becomes equal to the velocity of A, i.e. 0.15 ms^{-1}. Let this velocity be v. Now, spring is in a state of maximum compression. Let x be the maximum compression at this stage.



According to the law of conservation of linear momentum, we get

$m_A u = (m_A + m_B)v$

Or $v = \frac{m_A u}{m_A + m_B}$

$\frac{2 \times 0.15}{2+3} = 0.06ms^{-1}$

According to the law of conservation of energy

$\frac{1}{2}m_A u^2 = \frac{1}{2}(m_A + m_B)V^2 + \frac{1}{2}kx^2$

$\frac{1}{2}m_A u^2 - \frac{1}{2}(m_A + m_B)v^2 = \frac{1}{2}kx^2$

$\frac{1}{2} \times 2 \times (0.15)^2 - \frac{1}{2}(2+3)(0.06)^2 = \frac{1}{2}kx^2$

$0.0225 - 0.009 = \frac{1}{2}kx^2$

$or\ 0.0135 = \frac{1}{2}kx^2$

Or $x = \sqrt{\frac{0.0027}{k}} = \sqrt{\frac{0.0027}{10.8}} = 0.05m$

12 **(b)**

Work done on the body = K.E. gained by the body

$Fs\cos\theta = 1 \Rightarrow F\cos\theta = \frac{1}{s} = \frac{1}{0.4} = 2.5N$

13 **(c)**

Velocity of fall is independent of the mass of the falling body

14 **(c)**

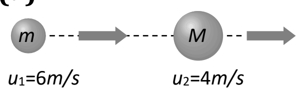
Momentum of the third part will be equal to the resultant of momentum of two parts.

$p_3 = \sqrt{p_1^2 + p_2^2}$

$p_3 = \sqrt{(-2p)^2 + p^2}$

$p_3 = p\sqrt{5}$

15 **(a)**



$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \frac{2m_2u_2}{m_1 + m_2}$

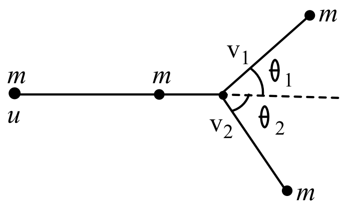
Substituting $m_1 = 0, v_1 = -u_1 + 2u_2$

$\Rightarrow v_1 = -6 + 2(4) = 2\ m/s$

$i.e.$ the lighter particle will move in original direction with the speed of 2 m/s

16 **(b)**

Let particle with mass m, move with velocity u,and $v_1$and $v_2$be velocity after collision. Since , elastic collision is one in which the momentum is conserved , we have



$\therefore mu = mv_1\cos\theta_1 + mv_2\cos\theta_2$ .....(i)

In perpendicular direction

$0 = mv_1\sin\theta_2 - mv_2\sin\theta_2$ .....(ii)

Also elastic collision occurs only if there is no conversion of kinetic energy into other from, Hence

$\frac{1}{2}mu^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2$

$u_2 = v_1^2 + v_2^2$ ....(iii)

Squaring Esq.(i)and (ii)and adding we get

$m^2u^2 = m^2(v_1\cos\theta_1 + v_2\cos\theta_2)^2$
$+m^2(v_1\sin\theta_1 - v_2\sin\theta_2)^2$

$u^2 = v_1^2 + v_2^2 + 2v_1v_2\cos\theta_1\cos\theta_2$
$- 2v_1v_2\sin\theta_1\sin\theta_2$

$u^2 = v_1^2 + v_2^2 + 2v_1v_2\cos(\theta_1 + \theta_2)$

Using Eq.(iii),we get

$2v_1v_2\cos(\theta_1 + \theta_2) = 0$

since $v_1v_2 \neq 0$

Hence $\cos(\theta_1 + \theta_2) = 0$

Or $\theta_1 + \theta_2 = 90°$

When two identical particles collide elastically and obliquely,

One being at rest, then they fly off in mutually perpendicular directions.

17 **(c)**

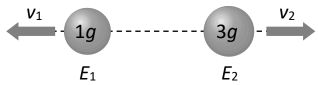
$1400 \times 10 \times 10 + W = \frac{1}{2} \times 15 \times 15$

or $W = 700 \times 15 \times 15 - 1400 \times 10 \times 10$

or $W = 700(225 - 200)$ J

or $W = 700 \times 25$ J $= 75.5$ kJ

18 **(c)**



As the momentum of both fragments are equal therefore

$\frac{E_1}{E_2} = \frac{m_2}{m_1} = \frac{3}{1}$ $i.e., E_1 = 3E_2$ ...(i)

According to problem $E_1 + E_2 = 6.4 \times 10^4\ J$ ...(ii)

By solving equation (i) and (ii), we get

$E_1 = 4.8 \times 10^4\ J$ and $E_2 = 1.6\ \times 10^4\ J$

19 **(a)**

Given, pressure=20000Nm^{-2}

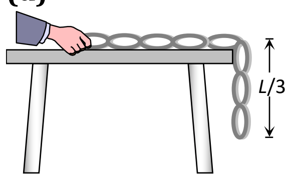
Volume=1$cc = 10^{-6}\ m^3$

∵Power=pressure×volume per second

$\therefore$ *Power* $= 20000 \times 10^{-6}$

$p = 0.02\ w$

20 **(d)**



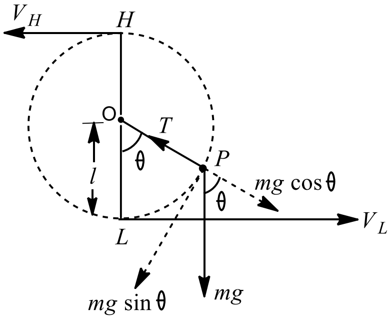
$W = \frac{MgL}{2n^2} = \frac{MgL}{2(3)^2} = \frac{MgL}{18}$ [$n = 3$ Given]

21 **(c)**

When a particle is moved in a circle under the action of a torque then such motion is non-uniform circular motion.

Applying principle of conservation of energy, total mechanical energy at L

=total mechanical energy at H



$\therefore \frac{1}{2}mv_L^2 = \frac{1}{2}mv_H^2 + MG(2l)$

But $v_H^2 = gl$

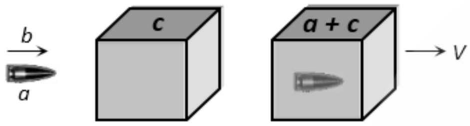
$\therefore \frac{1}{2}mv_L^2 = \frac{1}{2}m(gl) + 2mgl$

Or $v_L^2 = 5gl$

Or $v_L = \sqrt{5gl}$

Hence for looping the vertical loop, the minimum velocity at the lowest point L IS $\sqrt{5gl}$.

22 **(b)**



Initially bullet moves with velocity b and after collision bullet get embedded in block and both move together with common velocity

By the conservation of momentum

$\Rightarrow a \times b + 0 = (a+c)V \Rightarrow V = \frac{ab}{a+c}$

23 **(a)**

24 **(d)**

Work done (W) = Area under curve of F-x graph

= Area of triangle $OAB = \frac{1}{2} \times 5 \times 1 = 2.5$ J

25 **(d)**

$$W = \int_0^5 F dx = \int_0^5 (7 - 2x + 3x^2)dx$$

$$= [7x - x^2 + x^3]_0^5$$

$= 35 - 25 + 125 = 135\, J$

26 **(a)**

Since body moves with constant velocity, so. Net force on the body is zero.

Here, $N = mg, F = f$

$\therefore W = \vec{\mathbf{F}}.\vec{\mathbf{s}} = fs\cos 180''$

$= fs = -10 \times 2 = -20$ J

27 **(c)**

If momentum is Zero ie, if p=0,then kinetic energy

$K = \frac{p^2}{2m} = 0$

But potential energy cannot be zero, thus a body can have energy without momentum.

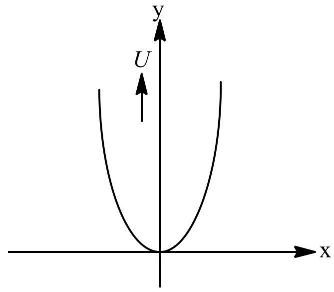
28 **(c)**

The variation of potential energy(U)

With distance(x)is

$$U = \frac{1}{2}kx^2$$

Hence, parabolic graph is obtained.



29 **(b)**

Because 50% loss in kinetic energy will affect its potential energy and due to this ball will attain only half of the initial height

30 **(c)**

Kinetic energy at highest point

$(\text{KE})_H = \frac{1}{2}mv^2\cos 2\theta$

$= K\cos^2\theta$

$= K(\cos 60°)^2$

$= \frac{K}{4}$

31 **(b)**

$m_1u_1 + m_2u_2 = (m_1 + m_2)v$

$\therefore \quad 10 \times u_1 + 5 \times 0 = (10+5) \times 4$

Or $\quad u_1 = \frac{15\times4}{10} = 6ms^{-1}$

32 **(b)**

$W = \int Fdy$

$= \int_{-a}^{+a} (Ay^2 + By + C)dy$

$= \left[\frac{Ay^3}{3} + \frac{By^2}{2} + Cy\right]_{-a}^{+a}$

$= \left[\frac{Aa^3}{3} + \frac{Ba^2}{2} + Ca\right] - \left[-\frac{Aa^3}{3} + \frac{Ba^2}{2} - Ca\right]$

$= \frac{2Aa^3}{3} + 2Ca$

33 **(a)**

$\frac{1}{2}mv^2 - f_kx = \frac{1}{2}kx^2$

$\frac{1}{2} \times 2 \times 16 - 15x = \frac{1}{2} \times 10^4 \times x^2$

$\therefore x = 5.5\, cm$

34 **(b)**

35 **(b)**

Work done is given by

$F \cdot s = (2\hat{\imath} + 4\hat{\jmath}) \cdot (3\hat{\jmath} + 5\hat{k})$

=12j

Now, power$=\frac{work}{time} = \frac{12}{2} = 6w$

36 **(d)**

Mass to be lifted $= 10 \times 10^2$kg

[$\therefore$ density of water $= 10^3$kgm^{-3}]

Height, $h = 10$ m

Work done $= 10^4 \times 10 \times 10 = 10^6$J

37 **(b)**

By momentum conservation before and after collision

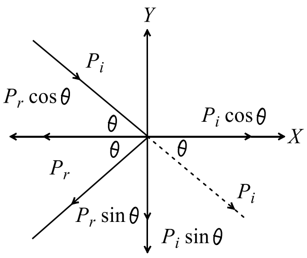
$$m_1V + m_2 \times 0 = (m_1 + m_2)v \Rightarrow v = \frac{m_1}{m_1 + m_2}V$$

$i.e.$ Velocity of system is less than V

38 **(b)**

Linear momentum of water striking per second to the wall $P_1 = mv = Av\rho\ v = Av^2\ \rho$, similarly linear momentum of reflected water per second

$P_r = Av^2\rho$



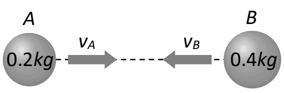
Now making components of momentum along x-axes and y-axes. Change in momentum of water per second

$= P_i \cos\theta + P_r \cos\theta$

$= 2Av^2\ \rho\cos\theta$

By definition of force, force exerted on the Wall $= 2Av^2\ \rho\cos\theta$

39 **(c)**



Initial linear momentum of system $= m_A\vec{v}_A + m_B\vec{v}_B$

$= 0.2 \times 0.3 + 0.4 \times v_B$

Finally both balls come to rest

$\therefore$ final linear momentum $= 0$

By the law of conservation of linear momentum

$0.2 \times 0.3 + 0.4 \times v_B = 0$

$$\therefore v_B = -\frac{0.2 \times 0.3}{0.4} = -0.15\ m/s$$

40 **(b)**

$v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 0.1} = \sqrt{1.96} = 1.4\ m/s$

41 **(c)**

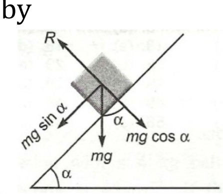
The explanation are given below

(i)If a body is moved up in inclined plane, then the work done against friction force is zero as there is no friction. But a work has to be done against the gravity. So, this statement is incorrect.

(ii)If there were no friction, moving vehicles could not be stopped by locking the brakes. Vehicles are stopped by air friction only.

So , This Statement is correct.

(iii) In this situation the normal reaction is given by

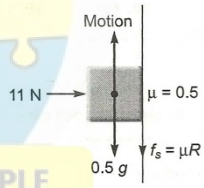


$R = mg\cos\alpha$ ... (i)

If α increase then the value of $\cos\alpha$ also decreases.

So, this Statement is incorrect.

(iv)When the duster is rubbing upward then an external force is applied and its value is



F'=0.5g+μR

$\therefore\ F' = 0.5g + 0.5 \times 11$

Or $F' = (0.5 \times 10 + 5.5)$N (Here R=11 N)

Or $F' = 10.5$N

Hence, work done in rubbing the duster through a distance of 10 cm.

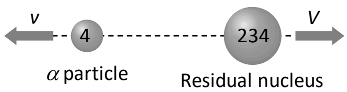
$W = F' \times d$

$$\Rightarrow \quad W = 10.5 \times \frac{10}{100}\text{J}$$

Or $F' = 10.5$J

42 **(a)**

Initially ^{238}U nucleus was at rest and after decay its part moves in opposite direction



According to conservation of momentum

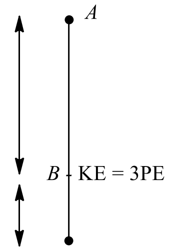
$$4v + 234V = 238 \times 0 \Rightarrow V = -\frac{4v}{234}$$

43 **(d)**

Velocity at B when dropped from A

where $AC = s$

$v^2 = u^2 + 2g(s-x)$ ....(i)
$v^2 = 2g(s-x)$ ....(ii)
Potential energy at $B = mgx$
$\therefore$ Kinetic energy $=\ 3 \times$ potential energy
$\frac{1}{2}m \times 2g(s-x) = 3 \times mgx$
or $(s-x) = 3x$
or $s = 4x$ or $x = \frac{s}{4}$
From Eq. (i)
$v^2 = 2g(s-x)$
$= 2g\left(s - \frac{s}{4}\right)$
$= \frac{2g \times 3s}{4} = \frac{3gs}{2}$
$\therefore\ x = \frac{s}{4}$ and $v = \sqrt{\frac{3gs}{2}}$

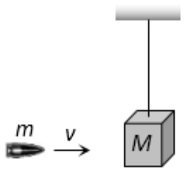


44 **(b)**
$P = \sqrt{2mE}$ if E are equal then $P \propto \sqrt{m}$
i.e., heavier body will possess greater momentum

45 **(b)**
The linear momentum of exploding part will remain conserved.
Applying conservation of linear momentum, We write,
$m_1 u_1 = m_2 u_2$
Here,$m_1 = 18$kg, $m_2 = 12$kg
$u_1 = 6ms^{-1}, u_2 = ?$
$\therefore 18 \times 6 = 12\ u_2$
$\Rightarrow\ u_2 = \frac{18 \times 6}{12}\ \ 9ms^{-1}$
Thus, kinetic energy of 12 kg mass
$k_2 = \frac{1}{2}m_2 u_2^2$
$= \frac{1}{2} \times 12 \times (9)^2$
$= 6 \times 81$
$= 486$ J

46 **(c)**
$P = \sqrt{2mE}$ it is clear that $P \propto \sqrt{E}$
So the graph between P and $\sqrt{E}$ will be straight line
But graph between $\frac{1}{P}$ and $\sqrt{E}$ will be hyperbola

47 **(d)**

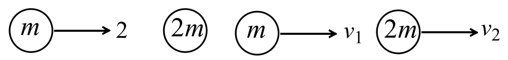


Initial momentum $= mv$
Final momentum $= (m+M)V$
By conservation of momentum $mv = (m+M)V$
$\therefore$ Velocity of (bag + bullet) system $V = \frac{mv}{M+m}$
$\therefore$ Kinetic energy $= \frac{1}{2}\ (m+M)V^2$
$= \frac{1}{2}(m+M)\left(\frac{mv}{M+m}\right)^2 = \frac{1}{2}\frac{m^2v^2}{M+m}$

48 **(b)**
Here $k = \frac{1}{2}mv^2 = as^2$
$\therefore\ mv^2 = 2as^2$
Differentiating w.r.t. time t
$2mv\frac{dv}{dt} = 4as\frac{ds}{dt} = 4asv, m\frac{dv}{dt} = 2as$
This is the tangential force, $F_t = 2as$
Centripetal force $F_c = \frac{mv^2}{R} = \frac{2as^2}{R}$
$\therefore$ Force acting on the particle
$F = \sqrt{F_t^2 + F_c^2} = \sqrt{(2as)^2 + \left(\frac{2as}{R}\right)^2}$
$= 2as\sqrt{1 + s^2/R^2}$

49 **(d)**
KE of colliding body before collision$=\frac{1}{2}mv^2$
After collision its velocity becomes
$V' = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)v = \frac{m}{3m}v = \frac{v}{3}$
KE after collision$=\frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{v}{3}\right)^2$
$= \frac{1}{2}\frac{mv^2}{9}$
Ratio of kinetic energy$=\frac{KE_{before}}{KE_{after}}$
$= \frac{\frac{1}{2}mv^2}{\frac{1}{2}\frac{mv^2}{9}} = \frac{9}{1}$

50 **(b)**



Initial condition   Final condition

By conservation of linear momentum
$2m = mv_1 + 2mv_2 \Rightarrow v_1 + 2v_2 = 2$
By definition of e, $e = \frac{1}{2} = \frac{v_2 - v_1}{2 - 0}$
$\Rightarrow v_2 - v_1 = 1 \Rightarrow v_1 = 0$ and $v_2 = 1ms^{-1}$

51 **(b)**

The angle between the displacement and the applied retarded force is 180^0

$\therefore$Work done$=Fs\cos 180° - Fs$

$= -$Ve

52 **(b)**

$E = \frac{P^2}{2m}$ $\therefore E \propto \frac{1}{m}$ [If $P =$ constant]

i.e., the lightest particle will possess maximum kinetic energy and in the given option mass of electron is minimum

53 **(a)**

Momentum would be maximum when KE would be maximum and this is the case when total elastic PE is converted KE.

According to conservation of energy

$\frac{1}{2}kL^2 = \frac{1}{2}Mv^2$

Or $kL^2 = \frac{(Mv)^2}{M}$

$MKL^2 = p^2$ $\quad\quad (p = Mv)$

$\therefore p = L\sqrt{MK}$

54 **(d)**

In compression or extension of a spring work is done against restoring force

In moving a body against gravity work is done against gravitational force of attraction

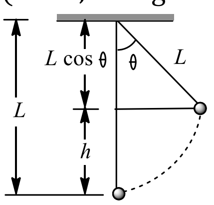
It means in all three cases potential energy of the system increases

But when the bubble rises in the direction of upthrust force then system works so the potential energy of the system decreases

55 **(c)**

$W = \Delta K$ or $W_T + W_g + W_F = 0$

(Since, change in kinetic energy is zero)



Here, $W_T =$ work done by tension $= 0$

$W_g =$ work done by fore of gravity

$= -mgh$

$= -mgL(1 - \cos\theta)$

$\therefore$ $W_F = -W_g = mgL(1 - \cos\theta)$

56 **(b)**

When ball falls vertically downward from height $h_1$its velocity $\vec{v}_1 = \sqrt{2gh_1}$

And its velocity after collision $\vec{v}_2 = \sqrt{2gh_2}$

Change in momentum

$\Delta\vec{P} = m(\vec{v}_2 - \vec{v}_1) = m(\sqrt{2gh_1} + \sqrt{2gh_2})$

[Because $\vec{v}_1$ and $\vec{v}_2$ are opposite in direction]

57 **(d)**

Initially mass 10 gm moves with velocity 100 cm/s

$\therefore$ Initial momentum $= 10 \times 100 = 1000 \frac{gm\times cm}{sec}$

After collision system moves with velocity v_{sys}. then

Final momentum $= (10 + 10) \times v_{\text{sys.}}$

By applying in conservation of momentum

$1000 = 20 \times v_{\text{sys.}}$

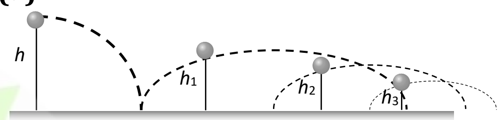
$\Rightarrow v_{\text{sys.}} = 50\ cm/s$

If system rises upto height h then

$$h = \frac{v_{\text{sys.}}^2}{2g} = \frac{50 \times 50}{2 \times 1000} = \frac{2.5}{2} = 1.25\ cm$$

58 **(a)**

59 **(a)**



Particle falls from height h then formula for height covered by it in nth rebound is given by

$h_n = he^{2n}$

Where $e =$ coefficient of restitution, $n =$ No. of rebound

Total distance travelled by particle before rebounding has stopped

$H = h + 2h_1 + 2h_2 + 2h_3 + 2h_4 + \cdots$

$= h + 2he^2 + 2he^4 + 2he^6 + 2he^8 + \cdots$

$= h + 2h(e^2 + e^4 + e^6 + e^8 + \cdots)$

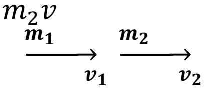
$$= h + 2h\left[\frac{E^2}{1 - e^2}\right] = h\left[1 + \frac{2e^2}{1 - e^2}\right] = h\left(\frac{1 + e^2}{1 - e^2}\right)$$

60 **(d)**

If it is a completely inelastic collision then

$m_1v_1 + m_2v_2 = m_1v + m_2v$

$v = \frac{m_1v_1 + m_2v_2}{m_1 + m_2}$



$$\text{KE} = \frac{p_1^2}{2m_1} + \frac{p_2^2}{2m_2}$$

As p_1 *and* p_2 both simultaneously cannot be zero therefore total KE cannot lost.

61 **(b)**

$k_A > k_B, x$ is the same

$\therefore \frac{1}{2}k_Ax^2 > \frac{1}{2}k_Bx^2 \Rightarrow W_A > W_B$

Forces are the same

$k_Ax_A = k_Bx_B$, As $k_A > k_B, x_A < x_B$

$W_A' = \frac{1}{2}(k_Ax_A)x_A$ and $W_B' = \frac{1}{2}(k_Bx_B)x_B$

$\therefore W_A' < W_B'; \therefore W_A > W_B$ but $W_A' < W_B'$

62 **(b)**

Potential energy=Kinetic energy

Ie, $mgh = \frac{1}{2}mv^2$

Or $v = \sqrt{2gh}$

If h_1 and h_2 are initial and final heights, then

$v_1 = \sqrt{2gh_1}, \; v_2 = \sqrt{2gh_2}$

Loss in velocity

$\Delta v = v_1 - v_2 = \sqrt{2gh_1} - \sqrt{2gh_2}$

∴Fractional loss in velocity $=\frac{\Delta v}{v_1}$

$$= \frac{\sqrt{2gh_1} - \sqrt{2gh_2}}{\sqrt{2gh_1}}$$

$$\frac{\Delta v}{v_1} = 1 - \sqrt{\frac{h_2}{h_1}}$$

$$= 1 - \sqrt{\frac{1.8}{5}}$$

$$= 1 - \sqrt{0.36} = 1 - 0.6 = 0.4 = \frac{2}{5}$$

63 **(a)**

$E = \frac{p^2}{2m}$. If $P =$ constant then $E \propto \frac{1}{m}$

i.e., kinetic energy of heavier body will be less. As the mass of gun is more than bullet therefore it possess less kinetic energy

64 **(b)**

65 **(d)**

Let m be the mass of the block, h the height from which it is dropped, and x the compression o the spring. Since, energy is conserved, so

Final gravitational potential energy

$=$ final spring potential energy

or $mg(h+x) = \frac{1}{2}kx^2$

or $mg(h+x) + \frac{1}{2}kx^2 = 0$

or $kx^2 - 2mg(h+x) = 0$

$kx^2 - 2mgx - 2mgh = 0$

This is a quadratic equation for x. Its solution is

$$x = \frac{mg \pm \sqrt{(mg)^2 + 2mghk}}{k}$$

Now, $mg = 2 \times 9.8 = 19.6$ N

and $hk = 0.40 \times 1960 = 784$ N

$$\therefore \quad x = \frac{19.6 \pm \sqrt{(19.6)^2 + 2(19.6)(784)}}{1960}$$

$= 0.10$ m or -0.080 m

Since, x must be positive (a compression) we accept the positive solution and reject the negative solution. Hence, $x = 0.10$ m

66 **(b)**

67 **(a)**

If a body has momentum, it must have kinetic energy also, (a) is the wrong statement

If the energy is totally potential, it need not have momentum (b) is correct (c) and (d) are also correct

68 **(a)**

$$v = \frac{dx}{dt} = 3 - 8t + 3t^2$$

$\therefore v_0 = 3\, m/s$ and $v_4 = 19\, m/s$

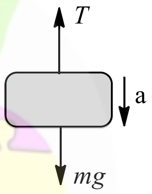
$W = \frac{1}{2}m(v_4^2 - v_0^2)$ [According to work energy theorem]

$$= \frac{1}{2} \times 0.03 \times (19^2 - 3^2) = 5.28\, J$$

69 **(b)**

From force diagram as shown in figure

$mg - T = ma$



$$T = mg - ma = mg - \frac{mg}{4} = \frac{3mg}{4}$$

$\therefore \; W_T =$ work done by tension

$$= \vec{\mathbf{T}}.\vec{\mathbf{s}} = Ts\cos 180° = -\frac{3mgd}{4}$$

70 **(a)**

Given that, $S = \frac{1}{3}t^2$

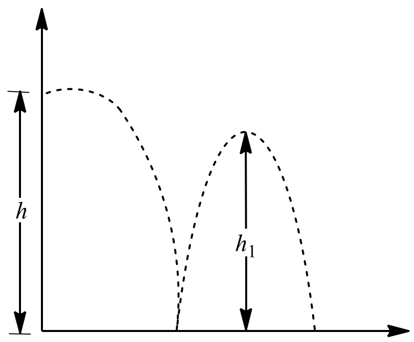
$$v = \frac{dS}{dt} = \frac{2}{3}t; \; a = \frac{d^2S}{dt^2} = \frac{2}{3}$$

$$F = ma = 3 \times \frac{2}{3} = 2\text{N}; \quad \text{Work} = 2 \times \frac{1}{3}t^2$$

At t=2

Work $= 2 \times \frac{1}{3} \times 2 \times 2 = \frac{8}{3}$J

71 **(b)**



Total distance travelled by the ball before its second hit is

$H = h + 2h_1$

$= h[1 + 2e^2]$ $\quad (\because h_1 = he^2)$

72 **(d)**

Condition for vertical looping

$h = \frac{5}{2}r = 5cm \;\therefore r = 2\ cm$

73 **(b)**

Initial velocity of particle, $v_i = 20\ \text{ms}^{-1}$

Final velocity of the particle, $v_f = 0$

According to work-energy theorem,

$W_{\text{net}} = \Delta\text{KE} = K_f - K_i$

$= \frac{1}{2}m(v_f^2 - v_i^2)$

$= \frac{1}{2} \times 2(0^2 - 20^2)$

$= -400\ \text{J}$

74 **(a)**

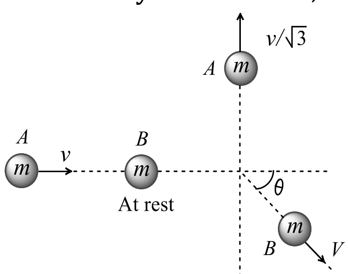
Power of gun $= \frac{\text{Total K.E.of fired bullet}}{\text{time}}$

$= \frac{n \times \frac{1}{2}mv^2}{t} = \frac{360}{60} \times \frac{1}{2} \times 2 \times 10^{-2} \times (100)^2$

$= 600\ W$

75 **(a)**

Let mass A moves with velocity v and collides inelastically with mass B, which is at rest



According to problem mass A moves in a perpendicular direction and let the mass B moves at angle θ with the horizontal with velocity v

Initial horizontal momentum of system (before collision) $= mv$ ....(i)

Final horizontal momentum of system (after collision) $= mV\cos\theta$ ....(ii)

From the conservation of horizontal linear momentum

$mv = mV\cos\theta \Rightarrow v = V\cos\theta$ ...(iii)

Initial vertical momentum of system (before collision) is zero

Final vertical momentum of system $\frac{mv}{\sqrt{3}} - mV\sin\theta$

From the conservation of vertical linear momentum

$\frac{mv}{\sqrt{3}} - mV\sin\theta = 0 \Rightarrow \frac{v}{\sqrt{3}} = V\sin\theta$ ...(iv)

By solving (iii) and (iv)

$v^2 + \frac{v^2}{3} = V^2(\sin^2\theta + \cos^2\theta)$

$\Rightarrow \frac{4v^2}{3} = V^2 \Rightarrow V = \frac{2}{\sqrt{3}}v$

76 **(b)**

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

ie, $\quad K \propto r^2$

The ratio of new kinetic energy to the original KE is given

$\frac{K_2}{K_1} = \left(\frac{r_2}{r_1}\right)^2$

77 **(b)**

$dW = -\mu\left[\frac{M}{L}\right]gl\,dl$

$W = \int_0^{\frac{2L}{3}} -\frac{\mu Mg}{L}l\,dl$

or $W = -\frac{\mu Mg}{L}\left|\frac{l^2}{2}\right|_0^{\frac{2L}{3}}$

or $W = -\frac{\mu Mg}{L}\left|\frac{4L^2}{9} - 0\right|$

or $W = -\frac{2}{9}\mu MgL$

78 **(a)**

$P = E \Rightarrow mv = \frac{1}{2}\,mv^2 \Rightarrow v = 2\,m/s$

79 **(c)**

From work-energy theorem

Δ KE $= W_{\text{net}}$

or $K_f - K_i = \int Pd$

or $\frac{1}{2}mv^2 = \int_0^2 \left(\frac{3}{2}t^2\right)dt$

$v^2 = \left[\frac{t^3}{2}\right]_0^2$

$v = 2\ \text{ms}^{-1}$

80 **(c)**

Area of acceleration–displacement curve gives change in KE per unit mass

$\frac{1}{2}m(v^2 - u^2) = F.S = \frac{mdv}{dt} \times s$

$\therefore \frac{\text{change in } KE}{\text{Mass}} = \frac{dv}{dt} \times s$

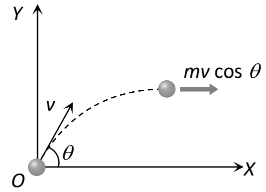
81 **(a)**

Shell is fired with velocity v at an angle θ with the horizontal

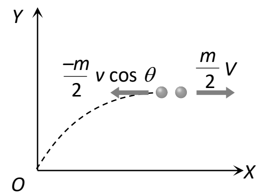
So its velocity at the highest point

$=$ horizontal component of velocity $= v\cos\theta$

So momentum of shell before explosion $=$ $mv\cos\theta$



When it breaks into two equal pieces one piece retraces its path to the canon, then other part moves with velocity V



So momentum of two pieces after explosion

$$= \frac{m}{2}(-v\cos\theta) + \frac{m}{2}V$$

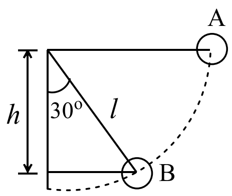
By the law of conservation of momentum

$$mv\cos\theta = \frac{-m}{2}v\cos\theta + \frac{m}{2}V \Rightarrow V = 3v\cos\theta$$

82 **(c)**

Vertical height $= h = l\cos 30°$

Loss of potential energy $= mgh$



$$= mgl\cos 30° = \frac{\sqrt{3}}{2}mgl$$

$\therefore$ Kinetic energy gained $= \frac{\sqrt{3}}{2}mgl$

83 **(a)**

Initial energy of body $= \frac{1}{2}mv^2 = \frac{1}{2} \times 1 \times (20)^2 = 200\,J$

A part of this energy consumes in doing work against gravitational force and remaining part consumes in doing work against air friction

i.e., $W_T = W_{grav.} + W_{air\ friction}$

$\Rightarrow 200 = 1 \times 10 \times 18 + W_{air} \Rightarrow W_{air} = 20\,J$

84 **(a)**

Let v be the velocity with which the bullet will emerge

Now, change in kinetic energy $=$ work done

For first case, $\frac{1}{2}m(100)^2 - \frac{1}{2}m \times 0 = F$

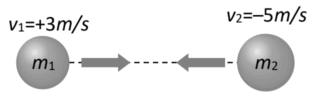
For second case, $\frac{1}{2}m(100)^2 - \frac{1}{2}mv^2 = F \times 0.5$

Dividing eq. (ii) by Eq. (i), we get

$$\frac{(100)^2 - (v)^2}{(100)^2} = \frac{0.5}{1} = \frac{1}{2} \text{ or } v = \frac{100}{\sqrt{2}}$$

$$= 50\sqrt{2}\text{ms}^{-1}$$

85 **(d)**



As $m_1 = m_2$ therefore after elastic collision velocities of masses get interchanged

$i.e.$ velocity of mass $m_1 = -5\ m/s$

and velocity of mass $m_2 = +3\ m/s$

86 **(c)**

87 **(d)**

88 **(c)**

Volume= $av = \pi r^2 v$

Mass $=$ $\pi r^2 v \times 1000$ SI units

Power of water jet

$$= \frac{\frac{1}{2}mv^2}{t} = \frac{1}{2} \times \pi r^2 v \times 1000 \times v^2 = 500\pi r^2 v^3$$

89 **(b)**

Gravitational potential energy of ball gets converted into elastic potential energy of the spring $mg(h+d) = \frac{1}{2}Kd^2$

Net work done $= mg(h+d) - \frac{1}{2}Kd^2 = 0$

90 **(a)**

Given a=$-kx$

$$a = \frac{dv}{dt} = \frac{dv}{dx}.\frac{dx}{dt} = -kx$$

Or $\frac{vdv}{dx} = -kx$

Or $v\ dv = -kx\ dx$

Let for any displacement from 0 to x,the velocity changes from $v_0 to\ v$.

$$\Rightarrow \int_{v0}^{v} vdv = -\int_0^x k\ \ x\ dx$$

Or $\frac{v^2 - v_0^2}{2} = -\frac{kx^2}{2}$

$$or\ \ m\left(\frac{v^2 - v_0^2}{2}\right) = -\frac{mkx^2}{2}$$

Or $\Delta K \propto x^2$ $\quad$ $(\Delta K\ is\ loss\ in\ KE)$

91 **(c)**

$F = \frac{-dU}{dx}$ it is clear that slope of $U - x$ curve is zero at point B and C

$\therefore F = 0$ for point B and C

92 **(d)**

Central of the mass of the rod lies at the midpoint and when the is displaced.

Through an angle 60° it lises to point B.

From the figure

$\sin 30° = \frac{BC}{AB}$

Or $\sin 30° = \frac{1}{l/2}$

Or $\frac{1}{2} = \frac{L}{l/2}$

Or $L = \frac{l}{4}$

The potential energy of the rod in this position is

$U = mgL$

$U = mg\frac{1}{4}$

93 **(d)**

When trolley are released then they possess same linear momentum but in opposite direction.

Kinetic energy acquired by any trolley will dissipate against friction

$\therefore \mu\, mg\, s = \frac{P^2}{2m} \Rightarrow s \propto 1/m^2$ [As P and u are constants]

$\Rightarrow \frac{s_1}{s_2} = \left(\frac{m_2}{m_1}\right)^2 = \left(\frac{3}{1}\right)^2 = \frac{9}{1}$

94 **(b)**

Kinetic energy of a body

$K = \frac{P^2}{2M}$

Or $K \propto P^2$

Or $\frac{p_2}{p_1} = \sqrt{\frac{K_2}{K_1}} = \sqrt{4}$

$or\ P_2 = 2P_1$

95 **(b)**

1. If the surface is smooth then the kinetic energy at B never be zero

2. If the surface is rough, the kinetic energy at B be zero. Because, work done by force of friction is negative. If work done by friction is equal to mgh then, net work done on body will be zero. Hence, net change in kinetic energy is zero. Hence, (b) is correct

3. If the surface is rough, the kinetic energy at B must be lesser than mgh. If surface is smooth, the kinetic energy at B is equal to mgh

4. The reason is same as in (a) and (b)

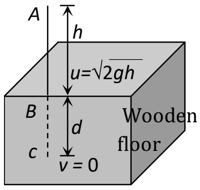
96 **(d)**

$E = \frac{P^2}{2m} \Rightarrow E \propto \frac{1}{m} \Rightarrow \frac{E_1}{E_2} = \frac{m_2}{m_1}$

97 **(a)**

98 **(c)**

Let the blade stops at depth d into the wood



$v^2 = u^2 + 2aS$

$\Rightarrow 0 = \left(\sqrt{2gh}\right)^2 + 2(g - a)d$

By solving $a = \left(1 + \frac{h}{d}\right) g$

So the resistance offered by the wood $= mg\left(1 + \frac{h}{d}\right)$

99 **(a)**

Work done=area between the graph force displacement curve and displacement

$W = \frac{1}{2} \times 6 \times 10 - 5 \times 4 + 5 \times 4 - 5 \times 2$

$W = 20\,J$

According to work energy theorem

$\Delta = K_E = W$

$K_{E_f} = W + \Delta K$

=20+25

=45J

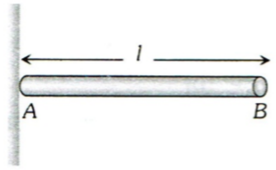
100 **(d)**

Due to the same mass of A and B as well as due to elastic collision velocities of spheres get interchanged after the colision

System of particles and Rotational Motion

RED ZONE

1. A uniform rod AB of length l and mass m is free to rotate about point A. The rod is released from rest in horizontal position. Given that the moment of inertia of the rod about A is $\frac{ml^2}{3}$ the initial angular acceleration of the rod will be



a) $\frac{2g}{3l}$ b) $mg\frac{l}{2}$ c) $\frac{3}{2}gl$ d) $\frac{3g}{2l}$

2. Four spheres of diameter 2 a and mass M are placed with their centres on the four corners of a square of side b. Then the moment of inertia of the system about an axis along one of the sides of the square is

a) $\frac{4}{5}M\,a^2 + 2M\,b^2$ b) $\frac{8}{5}M\,a^2 + 2M\,b^2$ c) $\frac{8}{5}M\,a^2$ d) $\frac{4}{5}M\,a^2 + M\,b^2$

3. The ratio of rotational and translatory kinetic energies of a sphere is

a) $\frac{2}{9}$ b) $\frac{2}{7}$ c) $\frac{2}{5}$ d) $\frac{7}{2}$

4. Angular momentum is conserved

a) Always b) Never
c) When external force is absent d) When external torque is absent

5. When a ceiling fan is switched off, its angular velocity falls to half while it makes 36 rotations. How many rotations will it make before coming to rest?

a) 24 b) 36 c) 18 d) 12

6. The angular momentum of a particle describing uniform circular motion in L. If its kinetic energy is halved and angular velocity doubled, its new angular momentum is

a) $4L$ b) $\frac{L}{4}$ c) $\frac{L}{2}$ d) $2L$

7. Three rods each of length L and mass M are placed along X, Y and Z axes in such a way that one end of each rod is at the origin. The moment of inertia of the system about Z-axis is

a) $\frac{ML^2}{3}$ b) $\frac{2ML^2}{3}$ c) $\frac{3ML^2}{2}$ d) $\frac{2ML^2}{12}$

8. Two masses of 200 g and 300 g are attached to the 20 cm and 70 cm marks of a light metre rod respectively. The moment of inertia of the system about an axis passing through 50 cm mark is

a) 0.15 kg m^2 b) 0.03 kg m^2 c) 0.3 kg m^2 d) Zero

9. A couple produces

a) No motion
b) Linear and rotational motion
c) Purely rotational motion
d) Purely linear motion

10. The centre of mass of three particles of masses 1 kg, 2kg and 3kg is at (2, 2, 2). The position of the fourth mass of 4 kg to be places in the system as that the new centre of mass is at (0, 0, 0) is

a) (-3,-3,-3)
b) (-3,3,-3)
c) (2,3,-3)
d) (2,-2,3)

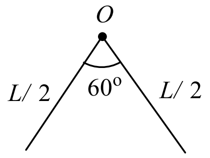
11. If there is change of angular momentum from J to $5J$ in 5 s, then the torque is

a) $\frac{3J}{5}$
b) $\frac{4J}{5}$
c) $\frac{5J}{4}$
d) None of these

12. A 2 kg body and a 3 kg body are moving along the x-axis. At a particular instant the 2 kg body has a velocity of 3 ms^{-1} and the 3 kg body has the velocity of 2 ms^{-1}. The velocity of the centre of mass at that instant is

a) 5 ms^{-1}
b) 1 ms^{-1}
c) 0
d) None of these

13. A thin rod of length L and mass M is bent at the middle point O at an angle of 60°. The moment of inertia of the rod about an axis passing through O and perpendicular to the plane of the rod will be



a) $\frac{ML^2}{6}$
b) $\frac{ML^2}{12}$
c) $\frac{ML^2}{24}$
d) $\frac{ML^2}{3}$

14. Moment of inertia of a disc about an axis which is tangent and parallel to its plane is I. Then the moment of inertia of disc about a tangent, but perpendicular to its plane will be

a) $\frac{3I}{4}$
b) $\frac{5I}{6}$
c) $\frac{3I}{2}$
d) $\frac{6I}{5}$

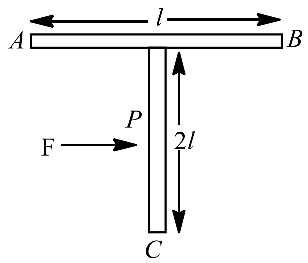
15. Moment of inertia of a ring of mass M and radius R about an axis passing through the centre and perpendicular to the plane is I. What is the moment of inertia about its diameter

a) I
b) $\frac{I}{2}$
c) $\frac{I}{\sqrt{2}}$
d) $I + MR^2$

16. 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) $1 : \sqrt{2}$

17. A T shaped object with dimension shown in the figure, is lying on a smooth floor. A force **F** is applied at the point P parallel to AB, such that the object has only the translational motion without rotation. Find the location of P with respect to C.

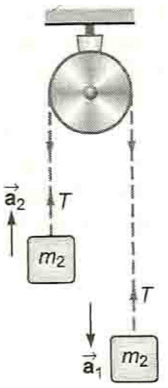


a) $\frac{2}{3}l$
b) $\frac{3}{2}l$
c) $\frac{4}{3}l$
d) l

18. A wheel of mass 8 kg and radius 40 cm is rolling on a horizontal road with angular velocity of 15 rad s^{-1}. The moment of inertia of the wheel about its axis is 0.64 kg m^{-2}. Total KE of wheel is

a) 288 J
b) 216 J
c) 72 J
d) 144 J

19. The two bodies of mass m_1 and $m_2 (m_1 > m_2)$ respectively are tied to the ends of a massless string, which passes over a light and frictionless pulley. The masses are initially at rest and the released. Then acceleration of the centre of mass of the system is

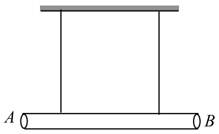


a) $\left[\frac{m_1 - m_2}{m_1 + m_2}\right]^2$ g b) $\left[\frac{m_1 - m_2}{m_1 + m_2}\right]^2$ c) g d) zero

20. The moments of inertia of two freely rotating bodies A and B are I_A and I_B respectively. $I_A > I_B$ and their angular momenta are equal. If K_A and K_B are their kinetic energies, then

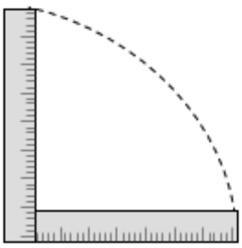
a) $K_A = K_B$ b) $K_A > K_B$ c) $K_A < K_B$ d) $K_A = 2K_B$

21. A uniform rod of mass m and length l is suspended by means of two light inextensible strings as shown in figure. Tension in one string immediately after the other string is cut is



a) $\frac{mg}{2}$ b) mg c) $2mg$ d) $\frac{mg}{4}$

22. A metre stick is held vertically with one end on the floor and is then allowed to fall. If the end touching the floor is not allowed to slip, the other end will hit the ground with a velocity of ($g = 9.8\ m/s^2$)



a) 3.2 m/s b) 5.4 m/s c) 7.6 m/s d) 9.2 m/s

23. 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) $t = 2s$ b) $t = 1s$ c) $t = 0.2\ s$ d) $t = 0.25\ s$

24. If the torque of the rotational motion be zero, then the constant quantity will be

a) Angular momentum b) Linear momentum

c) Angular acceleration d) Centripetal acceleration

25. An inclined plane makes an angle of 30° with the horizontal. A solid sphere rolling down this inclined plane from rest without slipping has a linear acceleration equal to

a) $\frac{g}{3}$ b) $\frac{2g}{3}$ c) $\frac{5g}{7}$ d) $\frac{5g}{14}$

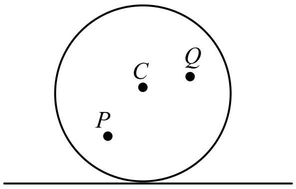
26. A torque of 30 N-m is applied on a 5 kg wheel whose moment of inertia is $2kg - m^2$ for 10 sec. The angle covered by the wheel in 10 sec will be

a) 750 $rad.$ b) 1500 $rad.$ c) 3000 $rad.$ d) 6000 $rad.$

27. A ring starts to roll down the inclined plane of height h without slipping. The velocity with it reaches the ground is

a) $\sqrt{\frac{10gh}{7}}$ b) $\sqrt{\frac{4gh}{7}}$ c) $\sqrt{\frac{4gh}{3}}$ d) $\sqrt{gh}$

28. A disc is rolling (without slipping) on a horizontal surface C is its centre and Q and P are two points equidistant from C. Let v_P, v_Q and v_C be the magnitude of velocities of pints P, Q and C respectively, then



a) $v_Q > v_C > v_P$ b) $v_Q < v_C < v_P$ c) $v_Q = v_P, v_C = \frac{1}{2} v_P$ d) $v_Q < v_C > v_P$

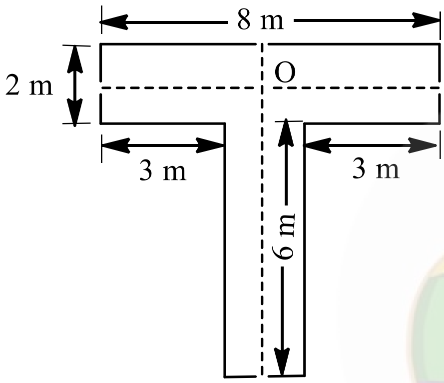
29. Four point masses, each of value m, are placed at the corners of a square ABCD of side l. The moment of inertia of this system about an axis passing through A and parallel to BD is

a) $\sqrt{3}\, ml^2$ b) $3\, ml^2$ c) ml^2 d) $2\, ml^2$

30. A metre stick of mass 400 g is pivoted at one end and displaced through an angle 60°. The increase in its potential energy is

a) 2 J b) 3 J c) 0 J d) 1 J

31. The distance of the centre of mass of the T-shaped plate from O is

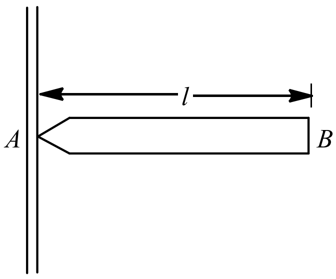


a) 7 m b) 2.7 m c) 4 m d) 1 m

32. A torque of 50 Nm acting on a wheel at rest rotates it through 200 $radians$ in 5 sec. Calculate the angular acceleration produced

a) 8 $rad\ sec^{-2}$ b) 4 $rad\ sec^{-2}$ c) 16 $rad\ sec^{-2}$ d) 12 $rad\ sec^{-2}$

33. 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 $\frac{ml^2}{3}$, the initial angular acceleration of the rod will be



a) $\frac{2g}{3l}$ b) $mg\frac{l}{2}$ c) $\frac{3}{2}gl$ d) $\frac{3g}{2l}$

34. The centre of mass of a system of two particles divides the distance them

a) In inverse ratio of square of masses of particles

b) In direct ratio of square of masses of particles

c) In inverse ratio of masses of particles

d) In direct ratio of masses of particles

35. Two wheels A and B are mounted on the same axle. Moment of inertia of A is 6 kgm^2 and it is rotating at 600 rpm when B is at rest. What is moment of inertia of B, if their combined speed is 400 rpm?

a) 8 kg m^2 b) 4 kg m^2 c) 3 kg m^2 d) 5 kg m^2

36. A particle is projected with a speed v at 45^0 with the horizontal. The magnitude of angular momentum of the projectille about the point of projection when the particle is at its maximum height h is

a) Zero b) $\frac{mvh^2}{\sqrt{2}}$ c) $\frac{mv^2h}{\sqrt{2}}$ d) $\frac{mv^2h}{\sqrt{2}}$

37. A circular turn table has a block of ice placed at its centre. The system rotates with an angular speed ω about an axis passing through the centre of the table. If the ice melts on its own without any evaporation, the speed of rotation of the system

a) Becomes zero b) Remains constant at the same value ω
c) Increases to a value greater than ω d) Decreases to a value less than ω

38. A loded spring gun of mass M fires a shot of mass m with a velocity v at an angle of elevation θ. The gun was initially at rest on a horizontal frictionless surface. After firing, the centre of mass of gun-shot system

a) Moves with a velocity $\frac{mv}{M}$
b) Moves with a velocity $\frac{mv}{M\cos\theta}$ in the horizontal direction
c) Remain at rest
d) Moves with velocity $\frac{(M-m)v}{(M+m)}$ in the horizontal direction

39. The radius of a rotating disc is suddenly reduced to half without any change in its mass. Then its angular velocity will be

a) Four times b) Double c) Half d) Unchanged

40. A non-uniform thin rod of length L is placed along X-axis as such its one of ends is at the origin. The linear mass density of rod is $l = l_0x$. The distance of centre of mass of rod from the origin is

a) $\frac{L}{2}$ b) $\frac{2L}{3}$ c) $\frac{L}{4}$ d) $\frac{L}{5}$

41. The moment of inertia of a thin uniform rod length L and mass M about an axis passing through a point at a distance of 1/3 from one of its ends and perpendicular to the rod is

a) $\frac{ML^2}{12}$ b) $\frac{ML^2}{9}$ c) $\frac{7ML^2}{48}$ d) $\frac{ML^2}{48}$

42. 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 momentum will be in the ratio

a) 1 : 2 b) $\sqrt{2}$: 1 c) 2 : 1 d) 1 : $\sqrt{2}$

43. A string is wound round the rim of a mounted fly wheel of mass 20 kg and radius 20 cm. A steady pull of 25 N is applied on the cord. Neglecting friction and mass of the string, the angular acceleration of the wheel is

a) 50 s^{-2} b) 25 s^{-2} c) 12.5 s^{-2} d) 6.25 s^{-2}

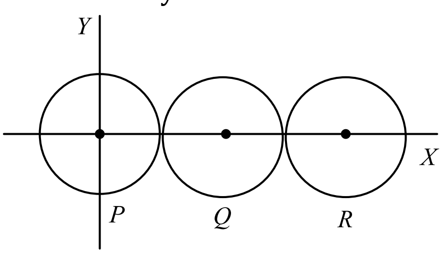
44. 2 bodies of different masses of 2 kg and 4 kg are moving with velocities 20 m/s and 10 m/s towards each other due to mutual gravitational attraction. What is the velocity of their centre of mass

a) 5 m/s b) 6 m/s c) 8 m/s d) Zero

45. One quarter of the disc of mass m is removed. If r be the radius of the disc, the new moment of inertia is

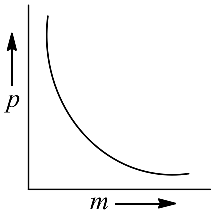
a) $\frac{3}{2}mr^2$ b) $\frac{mr^2}{2}$ c) $\frac{3}{8}mr^2$ d) None of these

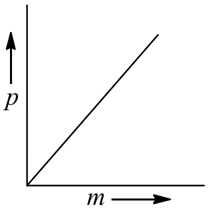
46. Three identical spheres, each of mass 1 kg are kept as shown in figure below, touching each other, with their centers on a straight line. If their centres are marked P, Q, R respectively, the distance of centre of mass of the system from P is

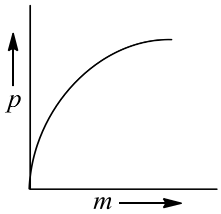


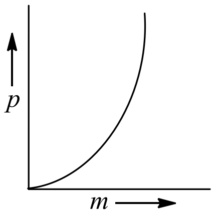
a) $\frac{PQ + PR + QR}{3}$ b) $\frac{PQ + PR}{3}$ c) $\frac{PQ + QR}{3}$ d) $\frac{PR + QR}{3}$

47. If kinetic energy of a body remains constant, then momentum-mass graph is

a) 

b) 

c) 

d) 

48. A uniform rod of length $2L$ is placed with one end in contact with the horizontal and is then inclined at an angle α to the horizontal and allowed to fall without slipping at contact point. When it becomes horizontal, its angular velocity will be

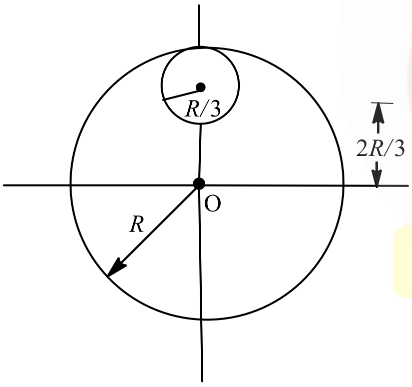
a) $\omega = \sqrt{\frac{3g\sin\alpha}{2L}}$ b) $\omega = \sqrt{\frac{2L}{3g\sin\alpha}}$ c) $\omega = \sqrt{\frac{6g\sin\alpha}{2L}}$ d) $\omega = \sqrt{\frac{2L}{g\sin\alpha}}$

49. A bag of mass M hangs by a long thread and a bullet (mass m) comes horizontally with velocity v and gets caught in the bag. For the combined system of bag and bullet, the correct option is

a) Momentum is $\frac{mMv}{(m+M)}$ b) Kinetic energy is $\frac{1}{1}Mv^2$

c) Momentum is mv d) Kinetic energy is $\frac{1}{2}\frac{m^2v^2}{(M+m)}$

50. From a circular disc of radius R and mass 9 M, a small disc of radius $R/3$ is removed from the disc. The moment of inertia of the remaining disc about an axis perpendicular to the plane of the disc and passing through O is



a) 4 MR^2 b) $\frac{40}{9}$ MR^2 c) 10 MR^2 d) $\frac{37}{9}$ MR^2

51. A solid sphere (mass 2 M) and a thin hollow spherical shell (mass M) both of the same size, roll down an inclined plane, then

a) Solid sphere will reach the bottom first b) Hollow spherical shell will reach the bottom first

c) Both will reach at the same time d) None of these

52. Two spherical bodies of masses M and $5M$ in free space with initial separation between their centres equal to $12R$. If they attract each other due to gravitational force only, then the distance covered by the smaller body just before collision is

a) 2.5 R b) 4.5 R c) 7.5 R d) 1.5 R

53. If the angular momentum of a rotating body about a fixed axis is increased by 10%. Its kinetic energy will be increased by

a) 10% b) 20% c) 21% d) 5%

54. A solid sphere is rotating about a diameter at an angular velocity ω. If it cools so that its radius reduces to $\frac{1}{n}$ of its original value, its angular velocity becomes

a) $\frac{\omega}{n}$ b) $\frac{\omega}{n^2}$ c) $n\omega$ d) $n^2\omega$

55. Three identical spheres of mass M each are placed at the corners of an equilateral triangle of side 2 m. Taking one of the corners as the origin, the position vector of the centre of mass is

a) $\sqrt{3}(\hat{\mathbf{i}}-\hat{\mathbf{j}})$ b) $\frac{\hat{\mathbf{i}}}{\sqrt{3}}+\hat{\mathbf{j}}$ c) $\hat{\mathbf{i}}+\hat{\mathbf{j}}/3$ d) $\hat{\mathbf{i}}+\hat{\mathbf{j}}/\sqrt{3}$

56. The acceleration of the centre of mass of a uniform solid disc rolling down an inclined plane of angle α is

a) g sin α b) 2/3 g sin α c) 1/2 g sin α d) 1/3 g sin α

57. Identify the correct statement for the rotational motion of a rigid body.

a) Individual particles of the body do not undergo accelerated motion.

b) The centre of mass of the body remains unchanged.

c) The centre of mass of the body moves uniformly in a circular path.

d) Individual particles and centre of mass the body undergo an accelerated motion.

58. Three masses of 2 kg, 4 kg and 4 kg are placed at the three points $(1, 0, 0)$, $(1, 1, 0)$ and $(0, 1, 0)$ respectively. The position vector of its centre of mass is

a) $\frac{3}{4}\hat{\imath}+\frac{4}{5}\hat{\jmath}$ b) $(3\hat{\imath}+\hat{\jmath})$ c) $\frac{2}{5}\hat{\imath}+\frac{4}{5}\hat{\jmath}$ d) $\frac{1}{5}\hat{\imath}+\frac{4}{5}\hat{\jmath}$

59. The moment of inertia of a flywheel having kinetic energy 360 J and angular speed of 20 rads^{-1} is

a) 18 kg m^2 b) 1.8 kg m^2 c) 2.5 kg m^2 d) 9 kg m^2

60. A small object of mass m is attached to a light string which passes through a hollow tube. The tube is hold by one hand and the string by the other. The object is set into rotation in a circle of radius R and velocity v. The string is then pulled down, shortening the radius of path of r. What is conserved

a) Angular momentum b) Linear momentum c) Kinetic energy d) None of the above

61. A uniform rod of length L and mass 1.8 kg is made to rest on two measuring scale at its two ends. A uniform block of mass 2.7 kg is placed on the rod at a distance $L/4$ from the left end. The force experienced by the measuring scale on the right end is

a) 18 N b) 27 N c) 29 N d) 45 N

62. Two bodies of mass m and $4m$ are moving with equal linear momentum. The ratio their kinetic energies is

a) 1 : 4 b) 4 : 1 c) 1 : 1 d) 1 : 12

63. A wheel having moment of inertia 2 $kg-m^2$ 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) $\frac{\pi}{18}N-m$

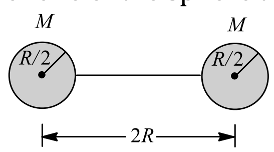
64. A non-zero external force acts on a systems of particles. The velocity and acceleration of the centre of mass are found to be v_0 and a_0 at an instant t. It is possible that

a) $v_0=0, a_0=0$ b) $v_0=0, a_0\neq 0$ c) $v_0\neq 0, a_0=0$ d) $v_0\neq 0, a_0=0$

65. A force $\vec{F}=4\hat{\imath}-5\hat{\jmath}+3\hat{k}$ is acting a point $\vec{r}_1=\hat{\imath}+2\hat{\jmath}+3\hat{k}$. The torque acting about a point $\vec{r}_2=3\hat{\imath}-2\hat{\jmath}-3\hat{k}$ is

a) Zero b) $42\hat{\imath}-30\hat{\jmath}+6\hat{k}$ c) $42\hat{\imath}+30\hat{\jmath}+6\hat{k}$ d) $42\hat{\imath}+30\hat{\jmath}-6\hat{k}$

66. Two spheres each of mass M and radius $R/2$ are connected with a massless rod of length $2R$ as shown in the figure. What will b be the moment of inertia of the system about an axis passing through the centre of one of the sphere and perpendicular to the rod



a) $\frac{21}{5}MR^2$ b) $\frac{2}{5}MR^2$ c) $\frac{5}{2}MR^2$ d) $\frac{5}{21}MR^2$

67. If the angular momentum of any rotating body increases by 200%, then the increase in its kinetic energy

a) 400% b) 800% c) 200% d) 100%

68. A uniform disc of mass M and radius R is mounted on a fixed horizontal axis. A block of mass m hangs from a massless string that is wrapped around the rim of the disc. The magnitude of the acceleration of the falling block (m) is

a) $\frac{2M}{M+2m}$ g b) $\frac{2m}{M+2m}$ g c) $\frac{M+2m}{2M}$ g d) $\frac{2M+m}{2M}$ g

69. Consider the following two statements

I. Linear momentum of a system of particles is zero.

II. Kinetic energy of a system of particles is zero. Then

a) I implies II and II implies I b) I does not imply II and II does not imply I

c) I implies II but II does not imply I d) I does not imply II but II implies I

70. A solid sphere is rotating in free space. If the radius of the sphere is increased keeping mass same which one of the following will not be affected?

a) Moment of inertia b) Angular momentum

c) Angular velocity d) Rotational kinetic energy

71. A particle performs uniform circular motion with an angular momentum L, if the frequency of particles motion is doubled and its KE is halved, the angular momentum becomes

a) $4L$ b) $0.5L$ c) $2L$ d) $0.25L$

72. An annular ring with inner and outer radii R_1 and R_2 is rolling without slipping with a uniform angular speed. The ratio of the forces experienced by the two particles situated on the inner and outer parts of the ring, $\frac{F_1}{F_2}$ is

a) $\frac{R_2}{R_1}$ b) $\left(\frac{R_1}{R_2}\right)^2$ c) 1 d) $\frac{R_1}{R_1}$

73. The direction of the angular velocity vector is along

a) The tangent to the circular path b) The inward radius

c) The outward radius d) The axis of rotation

74. Centre of mass of 3 particles 10 kg, 20 kg and 30 kg is at (0, 0, 0). Where should a particle of mass 40kg be placed so that the combination centre of mass will be at (3, 3, 3)

a) (0,0,0) b) (7.5, 7.5, 7.5) c) (1, 2, 3) d) (4, 4, 4)

75. If a force $10\hat{i}+15\hat{j}+25\hat{k}$ acts on a system and gives an acceleration $2\hat{i}+3\hat{j}-5\hat{k}$ to the centre of mass of the system, the mass of the system is

a) 5 units b) $\sqrt{38}$ units

c) $5\sqrt{38}$ units d) Given data is not correct

76. A thin circular ring of mass M and radius R rotates about an axis through its centre and perpendicular to its plane, with a constant angular velocity ω. Four small spheres each of mass m (negligible radius) are kept gently to the opposite ends of two mutually perpendicular diameters of the. The new angular velocity of the ring will be

a) 4ω b) $\frac{M}{4m}\omega$ c) $\left(\frac{M+4m}{M}\right)\omega$ d) $\left(\frac{M}{M+4m}\right)\omega$

77. Choose the correct statement about the centre of mass (CM) of a system of two particles

a) The CM lies on the line joining the two particles midway between them

b) The CM lies on the line joining them at a point whose distance from each particle is inversely proportional to the mass of that particle

c) The CM lies on the line joining them at a point whose distance from each particle is proportional to the square of the mass of that particle

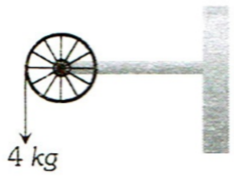
d) The CM is on the line joining them at a point whose distance from each particle is proportional to the mass of that particle

78. A circular disc rolls down an inclined plane. The ratio of rotational kinetic energy to total kinetic energy is

a) $\frac{1}{2}$ b) $\frac{1}{3}$ c) $\frac{2}{3}$ d) $\frac{3}{4}$

79. A drum of radius R and mass M, rolls down without slipping along an inclined plane of angle θ. The frictional force
a) Converts translational energy to rotational energy
b) Dissipates energy as heat
c) Decreases the rotational motion
d) Decreases the rotational and translational motions

80. A wheel of radius 0.4 m can rotate freely about its axis as shown in the figure. A string is wrapped over its rim and a mass of 4 kg is hung. An angular acceleration of 8 $rad\text{-}s^{-2}$ is produced in it due to the torque. Then, moment of inertia of the wheel is ($g = 10\ ms^{-2}$)



a) $2kg - m^2$ b) $1\ kg - m^2$ c) $4\ kg - m^2$ d) $8\ kg - m^2$

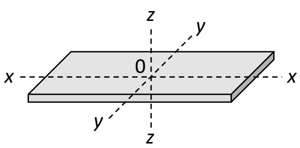
81. When a ceiling fan is switched on, it makes 10 revolutions in the first 3 seconds. Assuming a uniform angular acceleration, how many rotation it will make in the next 3 seconds
a) 10 b) 20 c) 30 d) 40

82. Moment of inertia of an object does not depend upon
a) Mass of object b) Mass distribution c) Angular velocity d) Axis of rotation

83. If the external forces acting on a system have zero resultant, the center of mass
a) May move but not accelerate b) May Accelerate
c) Must not move d) None of the above

84. A sphere rolls down on an inclined plane of inclination θ. What is the acceleration as the sphere reaches bottom
a) $\frac{5}{7}g\sin\theta$ b) $\frac{3}{5}g\sin\theta$ c) $\frac{2}{7}g\sin\theta$ d) $\frac{2}{5}g\sin\theta$

85. The rectangular block shown in the figure is rotated in turn about $x - x, y - y$ and $z - z$ axes passing through its centre of mass O. Its moment of inertia is



a) Same about all the three axes b) Maximum about $z - z$ axis
c) Equal about $x - x$ and $y - y$ axes d) Maximum about $y - y$ axis

86. The angular velocity of a wheel increases from 100 rps to 300rps in 10 s. The number of revolutions made during that time is
a) 600 b) 1500 c) 1000 d) 2000

87. If the external torque acting on a system $\vec{\tau} = 0$, then
a) $\omega = 0$ b) $\alpha = 0$ c) $J = 0$ d) $F = 0$

88. A body is rolling down an inclined plane. Its translational and rotational kinetic energies are equal. The body is a
a) Solid sphere b) Hollow sphere c) Solid cylinder d) Hollow cylinder

89. A particle of mass 1 kg is projected with an initial velocity 10 ms^{-1} at an angle of projection 45^0 with the horizontal. The average torque acting on the projectile, between the time at which it is projected and the time at which it strikes the ground, about the point of projection in newton-metre is
a) 25 b) 50 c) 75 d) 100

90. A man of mass M stands at one end of a plank of length which is at rest on a frictionless horizontal surface. The man walks to he other end of the plank. If mass of the plank is $M/3$, the distance that the man moves relative to ground is
a) L b) $L/4$ c) $3L/4$ d) $L/3$

91. A cricket bat is cut at the location of its centre of mass as shown. Then

a) The two pieces will have the same mass
b) The bottom piece will have larger mass
c) The handle piece will have larger mass
d) Mass of handle piece is double the mass of bottom piece

92. A ballet dancer, dancing on a smooth floor is spinning about a vertical axis with her arms folded with an angular velocity of 20 rad/s. When she stretches her arms fully, the spinning speed decrease in 10 rad/s. If I is the initial moment of inertia of the dancer, the new moment of inertia is

a) 2 I b) 3 I c) $I/2$ d) $I/3$

93. A particle moves in the x-y plane under the action of a force F such that the value of its linear momentum $\vec{P}$ at any time t is $p_x = 2\cos t, p_y 2\sin t$
The angel θ between $\vec{F}$ and $\vec{P}$ at a given time t will be

a) 90° b) 0° c) 180° d) 30°

94. Two objects of masses 200g and 500g possess velocities $10\hat{\imath}\ m/s$ and $3\hat{\imath} + 5\hat{\jmath}\ m/s$ respectively. The velocity of their centre of mass in m/s is

a) $5\hat{\imath} - 25\hat{\jmath}$ b) $\frac{5}{7}\hat{\imath} - 25\hat{\jmath}$ c) $5\hat{\imath} + \frac{25}{7}\hat{\jmath}$ d) $25\hat{\imath} - \frac{5}{7}\hat{\jmath}$

95. Consider a system of two particles having masses m_1 and m_2. If the particle of mass m_1 is pushed towards the centre of mass of particles through a distance d, by what distance would be particle of mass m_2 move so as to keep the centre of mass 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) $\frac{m_2}{m_1}d$

96. A constant torque of 1000 N-m turns a wheel of moment of inertia 200kg-m^2 about an axis through its centre. Its angular velocity after 3 sec is

a) 1 rad/sec b) 5 rad/sec c) 10 rad/sec d) 15 rad/sec

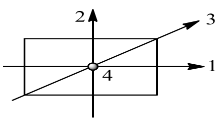
97. Moment of inertia of rod of mass M and length L about an axis passing through a point midway between centre and end is

a) $\frac{ML^2}{6}$ b) $\frac{ML^2}{12}$ c) $\frac{7ML^2}{24}$ d) $\frac{7ML^2}{48}$

98. As disc like reel with massless thread unrolls itself while falling vertically downwards the acceleration of its fall is

a) g b) $\frac{g}{2}$ c) Zero d) $\left(\frac{2}{3}\right)g$

99. About which axis in the following figure the moment of inertia of the rectangular lamina is maximum?



a) 1 b) 2 c) 3 d) 4

100. One solid sphere A and another hollow sphere B are of same mass and same outer radius. Their moments of inertia about their diameters are respectively I_A and $I_B$such that

a) $I_A = I_B$ b) $I_A > I_B$ c) $I_A < I_B$ d) $\frac{I_A}{I_B} = \frac{d_A}{d_B}$

101. The speed of a homogeneous solid sphere after rolling down an inclined plane of vertical height h, form rest without sliding, is

a) $\sqrt{\frac{10}{7}gh}$ b) $\sqrt{gh}$ c) $\sqrt{\frac{6}{5}gh}$ d) $\sqrt{\frac{4}{3}gh}$

102. The motion of planets in the solar system is an example of conservation of

a) Mass b) Momentum c) Angular momentum d) Kinetic energy

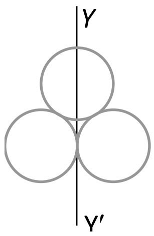
103. A constant torque acting on a uniform circular wheel changes its angular momentum form A_0 to 4 A_0 in 4s. The magnitude of this torque is

a) $\frac{3A_0}{4}$ b) A_0 c) $4A_0$ d) $12A_0$

104. A nucleus reptures into two nuclear parts which have their velocity ratio equal to 2:1. What will be the ratio of their nuclear size?

a) $2^{1/3}:1$ b) $1:2^{1/3}$ c) $3^{1/2}:1$ d) $1:3^{1/2}$

105. Three rings each of mass M and radius R are arranged as shown in the figure. The moment of inertia of the system about YY' will be



a) $3\ MR^2$ b) $\frac{3}{2}\ MR^2$ c) $5\ MR^2$ d) $\frac{7}{2}\ MR^2$

106. Two point objects of mass 1.5 g and 2.5 g respectively are at a distance of 16 cm apart, the centre of gravity is at a distance x from the object of mass 1.5g, where x is

a) 10 cm b) 6 cm c) 13 cm d) 3 cm

107. Two observers are situated in different inertial reference frames. Then

a) The momentum of a body by both observers may be same

b) The momentum of a body measured by both observers must be same

c) The kinetic energy measured by both observers must be same

d) None of the above

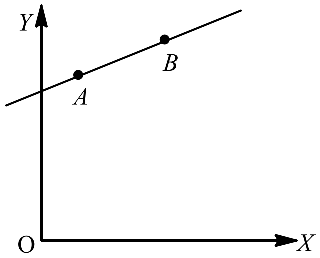
108. A hemispherical bowl or radius R is kept on a horizontal table. A small sphere of radius $r(r \ll R)$ is placed at the highest point at the inside of the bowl and let go. The sphere rolls without slipping. Its velocity at the lowest point is

a) $\sqrt{5gR/7}$ b) $\sqrt{3gR/2}$ c) $\sqrt{4gR/3}$ d) $\sqrt{10gR/7}$

109. The angle turned by a body undergoing circular motion depends on time as $\theta = \theta_0 + \theta_1 t + \theta_2 t^2$. Then the angular acceleration of the body is

a) θ_1 b) θ_2 c) $2\theta_1$ d) $2\theta_2$

110. 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) $L_A = L_B$

c) The relationship between L_A and L_B depends upon the slope of the line AB

d) $L_A < L_B$

111. Two discs of moment of inertia I_1 and I_2 and angular speeds ω_1 and ω_2 are rotating along collinear axes passing through their centre of mass and perpendicular to their plane. If the two are made to rotate combindly along the same axis the rotational KE of system will be

a) $\frac{I_1\omega_1 + I_2\omega_2}{2(I_1 + I_2)}$ b) $\frac{(I_1 + I_2)(\omega_1 + \omega_2)^2}{2}$ c) $\frac{(I_1\omega_1 + I_2\omega_2)^2}{2(I_1 + I_2)}$ d) None of these

112. Circular hole of radius 1 cm is cut off from a disc of radius 6 cm. The centre of hole is 3 m from the centre of the disc. The position of centre of mass of the remaining disc from the centre of disc is

a) $-\frac{3}{35}$ cm b) $\frac{}{35}$ cm c) $\frac{3}{10}$ cm d) None of these

113. Two bodies of mass 1 kg and 3 kg have position vectors $\hat{\imath} + 2\hat{\jmath} + \hat{k}$ and $-3\hat{\imath} - 2\hat{\jmath} + \hat{k}$, respectively. The centre of mass of this system has a position vector

a) $-2\hat{\imath} + 2\hat{k}$ b) $-2\hat{\imath} - \hat{\jmath} + \hat{k}$ c) $2\hat{\imath} - \hat{\jmath} - \hat{k}$ d) $-\hat{\imath} + \hat{\jmath} + \hat{k}$

114. A thin hollow cylinder open at both ends:

(i) Sliding without rolling

(ii) Rolls without slipping, with the same speed

The ratio of kinetic energy in the two cases is

a) 1:1 b) 4:1 c) 1:2 d) 2:1

115. By keeping moment of inertia of a body constant, if we double the time period, then angular momentum of body

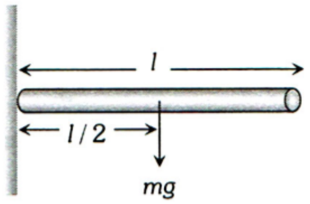
a) Remains constant b) Becomes half c) Doubles d) quadruples

: HINTS AND SOLUTIONS :

1 **(d)**

Weight of the rod will produce the torque

$$\tau = I\alpha \Rightarrow mg \times \frac{l}{2} = \frac{ml^2}{3} \times \alpha$$

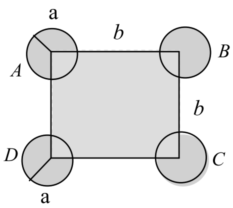


Angular acceleration

$$\alpha = \frac{3g}{2l}$$

2 **(b)**

We calculate moment of inertia of the system about AD



Moment of inertia of each of the sphere A and D about

$$AD = \frac{2}{5} Ma^2$$

Moment of inertia of each of the sphere B and C about AD

$$= \left(\frac{2}{5} Ma^2 + Mb^2\right)$$

Using theorem of parallel axes

$\therefore$ Total moment of inertia

$$I = \left(\frac{2}{5}Ma^2\right) \times 2 + \left(\frac{2}{5}Ma^2 + Mb^2\right) \times 2$$

$$= \frac{8}{5}Ma^2 + 2Mb^2$$

3 **(c)**

$$\frac{\text{Rotational kinetic energy}}{\text{Translatory kinetic energy}} = \frac{\frac{1}{2}mv^2 \frac{K^2}{R^2}}{\frac{1}{2}mv^2} = \frac{K^2}{R^2} = \frac{2}{5}$$

4 **(d)**

According to law of conservation of angular momentum, if there is no torque on the system, then the angular momentum remains constant.

5 **(d)**

From third equation of angular motion,

$\omega^2 = \omega_0^2 = 2\alpha$ (Here, $\omega = \frac{\omega_0}{2}, \theta = 36 \times 2\pi$)

$\therefore \left(\frac{\omega_0}{2}\right)^2 = \omega_0^2 - 2\alpha \times 36 \times 2\pi$

or $\quad 4 \times 36\pi\alpha = \omega_0^2 - \frac{\omega_0^2}{4}$

or $\quad 4 \times 36\pi\alpha = \frac{3\omega_0^2}{4}$

or $\quad \alpha = \frac{\omega_0^2}{16 \times 12\pi}$

...(i)

According to question again applying the third equation of angular motion

$\omega^2 = \omega_0^2 -$

$2\alpha\theta$ (Here, $\omega = 0$)

$\therefore \quad 0 = \left(\frac{\omega_0}{2}\right)^2 - 2 \times \frac{\omega_0^2 . \theta}{16 \times 12\pi}$

or $\quad \theta = 24\pi \quad$ or $\quad \theta = 12 \times 2\pi$

But $\quad 2\pi = 1$ cycle

So, $\quad \theta = 12$ cycle

6 **(b)**

We know

$L = I\omega$

...(i)

$L^2 = 2KI$

From Eq. (i)

$L^2 = 2K\frac{L}{\omega}$

$L = \frac{2K}{\omega}$

$L' = \frac{2\left(\frac{K}{2}\right)}{2\omega} = \frac{L}{4}$

7 **(b)**

Moment of inertia of a rod about one end $= \frac{ML^2}{3}$

As, $\; I = I_1 + I_2 + I_3$

$\therefore \; I = 0 + \frac{ML^2}{3} + \frac{ML^2}{3} = \frac{2ML^2}{3}$

8 **(b)**

$I = m_1r_1^2 + m_2r_2^2$

$$= \frac{200}{1000}\left(\frac{30}{100}\right)^2 + \frac{300}{1000}\left(\frac{20}{100}\right)^2 = 0.03 \text{ kg m}^2$$

9 **(c)**

A couple consists of two equal and opposite forces acting at a separation, so that net force becomes zero. When a couple acts on a body it rotates the body but does not produce any translatory motion. Hence, only rotational motion is produced.

10 **(a)**

$m_1 = 1$ kg, $m_2 = 2$ kg, $m_3 = 3$ kg

Position of centre of mass (2, 2, 2,)

$m_4 = 4$ kg

New position of centre of mass (0, 0, 0).

For initial position

$$X_{CM} = \frac{m_1x_1+m_2x_2+m_3x_3}{m_1+m_2+m_3}$$

$$2 = \frac{m_1x_1+m_2x_2+m_3x_3}{1+2+3}$$

$$m_1x_1 + m_2x_2 + m_3x_3 = 12$$

Similarly, $m_1y_1 + m_2y_2 + m_3y_3 = 12$

and $m_1z_1 + m_2z_2 + m_3z_3 = 12$

For new position,

$$X'_{CM} = \frac{m_1x_1+m_2x_2+m_3x_3+m_4x_4}{m_1+m_2+m_3+m_4}$$

$$0 = \frac{12+4\times x_4}{1+2+3+4}$$

$$4x_4 = -12$$

$$x_4 = -3$$

Similarly, $y_4 = -3$

$z_4 = -3$

$\therefore$ Position of fourth mass (-3, -3, -3)

11 **(b)**

We know that rate of change of angular momentum (J) of a body is equal to the external torque (τ) acting upon the body.

ie. $\frac{dJ}{dt} = \tau$

Given, $J_1 = J,\ J_2 = 5J$

$\therefore$ $\Delta J = J_2 - J_1 = 5J - J = 4J$

Hence, $\tau = \frac{4}{5}J$

12 **(d)**

$$\vec{v}_{cm} = \frac{m_1\vec{v}_1 + m_2\vec{v}_2}{m_1 + m_2} = \frac{2\times 3 + 3\times 2}{2+3} = \frac{12}{5}$$

$$= 2.4 m/s$$

13 **(b)**

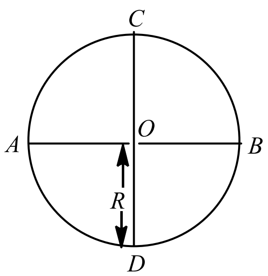
Moment of inertia of a uniform rod about one end$= \frac{ml^2}{3}$

$\therefore$ Moment of inertia of the system

$$= 2\times\left(\frac{M}{2}\right)\frac{(L/2)^2}{3} = \frac{ML^2}{12}$$

14 **(d)**

The moment of inertia of the disc about an axis parallel to its plane is



$$I_t = I_d + MR^2$$

$\Rightarrow$ $I = \frac{1}{4}MR^2 + MR^2$

$= \frac{5}{4}MR^2$

or $MR^2 = \frac{4I}{5}$

Now, moment of inertia about a tangent perpendicular to its plane is

$$I' = \frac{3}{2}MR^2 = \frac{3}{2}\times\frac{4}{5}I = \frac{6}{5}I$$

15 **(b)**

Moment of inertia of a ring of mass M and radius R about an axis passing through the centre and perpendicular to the plane

$I = MR^2$ ...(i)

Moment of inertia of a ring about its diameter

$I_{diameter} = \frac{MR^2}{2} = \frac{I}{2}$ [Using (i)]

16 **(d)**

Radius of gyration of circular disc $k_{disc} = \frac{R}{\sqrt{2}}$

Radius of gyration of circular ring $k_{ring} = R$

Ratio $= \frac{k_{disc}}{k_{ring}} = \frac{1}{\sqrt{2}}$

17 **(c)**

For translator motion the force should be applied on the centre of mass of the body so we have to calculate the location of centre of mass of T shaped object.

Let mass of rod AB is m so the mass of rod CD will be $2m$.

Let y_1 is the centre of mass of rod AB and y_2 is the centre of mass of rod CD. We can consider that whole mass of the rod is placed at their respective centre of mass *ie*, mass m is placed at y_1 and mass $2m$ is placed at y_2.

Taking point c at the origin position vector of points y_1 and y_2 can be written as

$$\mathbf{r}_1 = 2l\mathbf{j}, \mathbf{r}_2 = l\mathbf{j}$$

and $m_1 = m$ and $m_2 = 2m$

Position vector of centre of mass of the system

$$r_{CM} = \frac{m_1\mathbf{r}_1+m_2\mathbf{r}_2}{m+m_2} = \frac{m2l\hat{j}+2ml\hat{j}}{m+2m} = \frac{4ml\hat{j}}{3m} = \frac{4l\hat{j}}{3}$$

18 **(b)**

Here, $m = 8$ kg, $r = 40$ cm $= \frac{2}{5}$ m,

$\omega = 12$ rad s^{-1}, $I = 0.64$ kg m^2

Total KE $= \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2$

$= \frac{1}{2}I\omega^2 + \frac{1}{2}mr^2\omega^2$

$= \frac{1}{2}\times 0.64\times 15^2 + \frac{1}{2}\times 8\times\left(\frac{2}{5}\right)^2\times 15^2 = 216$ J

19 **(a)**

In the pulley arrangement $|\vec{a}_1| = |\vec{a}_2| = a = \left(\frac{m_1-m_2}{m_1+m_2}\right)g$

But $\vec{a}_1$ is in downward direction and in the upward direction *ie*, $\vec{a}_2 = -\vec{a}_1$

$\therefore$ Acceleration of centre of mass

$$\vec{a}_{CM} = \frac{m_1\vec{a}_1 + m_2\vec{a}_2}{m_1 + m_2}$$

$$= \frac{m_1\left[\frac{m_1-m_2}{m_1+m_2}\right]g - m_2\left[\frac{m_1-m_2}{m_1+m_2}\right]g}{(m_1 + m_2)}$$

$$= \left[\frac{m_1 - m_2}{m_1 + m_2}\right]^2 g$$

20 **(c)**

Kinetic energy $E = \frac{L^2}{2I}$

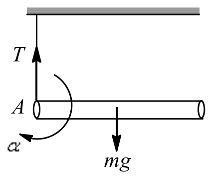
If angular momenta are equal then $E \propto \frac{1}{I}$

Kinetic energy $E = K$ [Given in the problem]

If $I_A > I_B$ then $K_A < K_B$

21 **(d)**

When one string is cut off, the rod will rotate about the other point A. Let a be the linear acceleration of centre of mass of the rod and α be the linear acceleration of centre of mass of the rod and α be the angular acceleration of the rod about A. As is clear from figure,



$mg - T = ma$ ...(i)

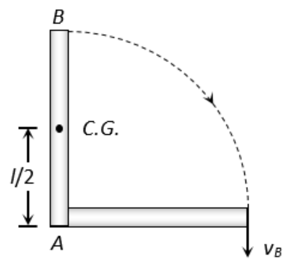
$\alpha = \frac{\tau}{I} = \frac{mg(l/2)}{ml^2/3} = \frac{3g}{4}$ ...(ii)

$a = r\alpha = \frac{l}{2}\alpha = \frac{l}{2}\frac{3g}{2l} = \frac{3g}{4}$

From Eq. (i), $T = mg - ma = mg - \frac{3mg}{4} = \frac{mg}{4}$

22 **(b)**

In this process potential energy of the metre stick will be converted into rotational kinetic energy



P.E. of meter stick $= mg\left(\frac{l}{2}\right)$

Because its centre of gravity lies at the middle point of the rod

Rotational kinetic energy $E = \frac{1}{2}I\omega^2$

$I =$ M.I. of metre stick about point $A = \frac{ml^2}{3}$

$\omega =$ Angular speed of the rod while striking the ground

$v_B =$ Velocity of end B of metre stick while striking the ground

By the law of conservation of energy,

$$mg\left(\frac{l}{2}\right) = \frac{1}{2}I\omega^2 = \frac{1}{2}\frac{ml^2}{3}\left(\frac{v_B}{l}\right)^2$$

By solving we get, $v_B = \sqrt{3gl} = \sqrt{3 \times 10 \times 1} = 5.4 m/s$

23 **(b)**

Torque zero means, α zero

$\therefore \frac{d^2\theta}{dt^2} = 0 \Rightarrow 12t - 12 = 0$

$\therefore t = 1$ second

24 **(a)**

As torque $\tau = \frac{dL}{dt}$

If $\tau = 0$, then $L =$constant.

25 **(d)**

$$a = \frac{g\sin\theta}{1 + \frac{K^2}{R^2}} = \frac{g\sin\theta}{1 + \frac{2}{5}} = \frac{g/2}{7/5} = \frac{5g}{14}$$

As $\theta = 30°$ and $\frac{K^2}{R^2} = \frac{2}{5}$

26 **(a)**

$$\alpha = \frac{\tau}{I} = \frac{30}{2} = 15\, rad/s^2$$

$$\because \theta = \omega_0 t + \frac{1}{2}\alpha t^2 = 0 + \frac{1}{2} \times (15) \times (10)^2$$

$$= 750\, rad$$

27 **(d)**

For a ring $K^2 = r^2$ then

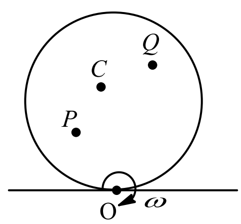
$$v^2 = \sqrt{\frac{2gh}{1+\frac{K^2}{r^2}}}$$

$\therefore$ $v^2 = \frac{2gh}{2} = gh$

$v = \sqrt{gh}$

28 **(a)**

In case of pure rolling bottommost point is the instantaneous centre of zero velocity.



Velocity of any point on the disc, $v = r\omega$, where r is distance of point from O.

$r_Q > r_C > r_P$

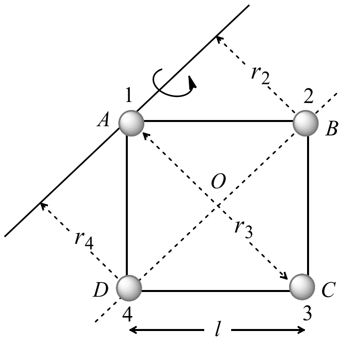
$\therefore$ $v_Q > v_C > v_P$

29 **(b)**

$r_2 = r_4 = OA = \frac{l}{\sqrt{2}}$ and $r_3 = l\sqrt{2}$

Moment of inertia of the system about given axis

$I = I_1 + I_2 + I_3 + I_4$



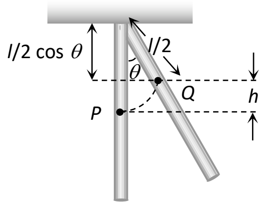
$\Rightarrow I = 0 + m(r_2)^2 + m(r_3)^2 + m(r_4)^4$

$\Rightarrow I = m\left(\frac{l}{\sqrt{2}}\right)^2 + m(l\sqrt{2})^2 + m\left(\frac{l}{\sqrt{2}}\right)^2 \quad \therefore I$

$= 3ml^2$

30 **(d)**

Centre of mass of a stick lies at the mid point and when the stick is displaced through an angle 60° it rises upto height $'h'$ from the initial position



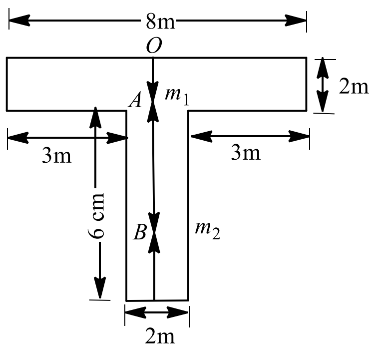
From the figure $h = \frac{l}{2} - \frac{l}{2}\cos\theta = \frac{l}{2}(1-\cos\theta)$

Hence the increment in potential energy of the stick $= mgh = mg\frac{l}{2}(1-\cos\theta) = 0.4 \times 10 \times \frac{1}{2}(1-\cos 60°) = 1J$

31 **(b)**

Co-ordinate of CM is given by

$$X_{CM} = \frac{m_1x_1 + m_2x_2}{m_1+m_2}$$



Taking parts A and B as two bodies of same system

$$m_1 = l \times b \times \sigma = 8 \times 2 \times \sigma = 16\sigma$$
$$m_2 = l \times b \times \sigma = 6 \times 2 \times \sigma = 12\sigma$$

Choosing O as origin,

$$x_1 = 1\text{ m}, x_2 = 2 + 3 = 5\text{ m}$$

$\therefore \quad X_{CM} = \frac{16\sigma \times 1 + 12\sigma \times 5}{16\sigma + 12\sigma} = \frac{19}{7}$

$= 2.7$ m from O

32 **(c)**

$\theta = \omega_0 t + \frac{1}{2}\alpha t^2 \Rightarrow 200 = \frac{1}{2}\alpha(5)^2 \Rightarrow \alpha$

$= 16 rad/s^2$

33 **(d)**

The moment of inertia of the uniform rod about an axis through one end and perpendicular to its length is

$$I = \frac{ml^2}{3}$$

Where m is mass of rod and l is length.

Torque ($\tau = I\alpha$) acting on centre of gravity of rod is given by

$$\tau = mg\,\frac{1}{2}$$

or $\quad I\alpha = mg\,\frac{1}{2}$

or $\quad \frac{ml^2}{3}\alpha = mg\frac{1}{2}$

or $\quad \alpha = \frac{3g}{2l}$

34 **(c)**

$m_1r_1 = m_2r_2$

$\frac{r_1}{r_2} = \frac{m_2}{m_1} \quad \therefore r \propto \frac{1}{m}$

35 **(c)**

Applying the principle of conservation of angular momentum,

$(I_1 + I_2)\omega = I_1\omega_1 + I_2\omega_2$

$(6 + I_2)\frac{400}{60} \times 2\pi = 6 \times \frac{600}{60} \times 2\pi + I_2 \times 0$

Which gives, $I_2 = 3$ kg m^2

36 **(d)**

When a particle is projected with a speed v at 45° with the horizontal then velocity of the projectile at maximum height.

$$v' = v\cos 45° = \frac{v}{\sqrt{2}}$$

Angular momentum of the projectile about the point of projection

$= mv'h$

$= m\frac{v}{\sqrt{2}}h = \frac{mvh}{\sqrt{2}}$

37 **(d)**

Melting of ice produces water which will spread over larger distance away from the axis of rotation. This increases the moment of inertia so angular velocity decreases

38 **(c)**

Since gun-shot system is an isolated closed system, its centre of mass must remain at rest.

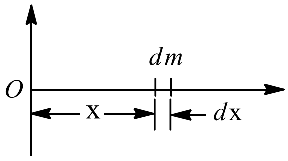
39 **(a)**

$L = \frac{1}{2}MR^2\omega =$ constant $\therefore \omega \propto \frac{1}{R^2}$ [If $m =$ constant]

If radius is reduced to half then angular velocity will be four times

40 **(b)**

The mass of considered element is



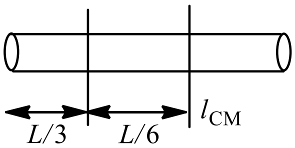
$dm = \lambda dx = \lambda_0 \, xdx$

$$\therefore \; x_{\rm CM} = \frac{\int_0^L x \, dm}{\int dm} = \frac{\int_0^L x(\lambda_0 x dx)}{\int_0^L \lambda_0 x dx}$$

$$= \frac{\lambda \left[\frac{x^3}{3}\right]_0^L}{\lambda_0 \left[\frac{x^2}{2}\right]_0^L} = \frac{\lambda_0 \frac{L^3}{3}}{\lambda_0 \frac{L^2}{2}} = \frac{2}{3}L$$

41 **(b)**

$I_{\rm CM} = \frac{ML^2}{12}$ (about middle point)



$\therefore \quad I = I_{\rm CM} + Mx^2$

$= \frac{ML^2}{12} + M\left(\frac{L}{6}\right)^2$

$I = \frac{ML^2}{9}$

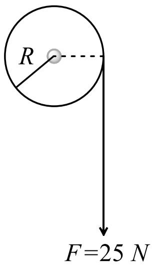
42 **(d)**

$L = \sqrt{2IE}$. If E are equal then $\frac{L_1}{L_2} = \sqrt{\frac{I_1}{I_2}} = \sqrt{\frac{I}{2I}} = \frac{1}{\sqrt{2}}$

43 **(c)**

Here, $M = 20kg, R = 20cm = \frac{1}{5}m$

Moment of inertia of flywheel about its axis is



$$I = \frac{1}{2}MR^2 = \frac{1}{2} \times 20kg \times \left(\frac{1}{5}m\right)^2$$

$= 0.4kgm^2$

As $\tau = I\alpha$

Where α is the angular acceleration

$$\therefore \alpha = \frac{\tau}{I} = \frac{FR}{I} = \frac{25 \times \frac{1}{5}}{0.4} = \frac{5Nm}{0.4kgm^2} = 12.5s^{-2}$$

44 **(d)**

$m_1 = 2kg, m_2 = 4kg, \vec{v}_1 = 20m/s, \vec{v}_2 = -10m/s$

$$\vec{v}_{cm} = \frac{m_1\vec{v}_1 + m_2\vec{v}_2}{m_1 + m_2} = \frac{2 \times 20 - 4 \times 10}{2 + 4} = 0 \; m/s$$

45 **(c)**

Moment of inertia of whole disc about an axis through centre of disc and perpendicular to its plane is $I = \frac{1}{2}mr^2$

As one quarter of disc is removed, new mass,

$m' = \frac{3}{4}m$

$\therefore I' = \frac{1}{2}\left(\frac{3}{4}m\right)r^2 = \frac{3}{8}mr^2$

46 **(b)**

$r_1 = 0, r_2 = PQ, r_3 = PR$

Distance of centre of mass from P is

$$r = \frac{r_1+r_2+r_3}{3} = \frac{0+PQ+PR}{3} = \frac{PQ+PR}{3}$$

47 **(c)**

$K = \frac{p^2}{2m}$

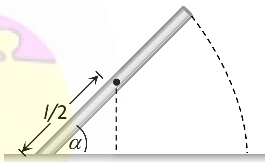
$p^2 = 2Km$

This is an equation of parabola. Hence, (c) is correct.

48 **(a)**

By the conservation of energy

$P.E.$ of rod = Rotational $K.E.$



$$mg\frac{l}{2}\sin\alpha = \frac{1}{2}I\omega^2 \Rightarrow mg\frac{l}{2}\sin\alpha = \frac{1}{2}\frac{ml^2}{3}\omega^2$$

$$\Rightarrow \omega = \sqrt{\frac{3g\sin\alpha}{l}}$$

But in the problem length of the rod $2L$ is given

$$\Rightarrow \omega = \sqrt{\frac{3g\sin\alpha}{2L}}$$

49 **(c)**

As $\vec{F}_{\rm ext} = 0$, hence momentum remains conserved and final momentum = initial momentum = mv

50 **(a)**

$I_{\rm remaining} = I_{\rm whole} - I_{\rm removed}$

or $\quad I = \frac{1}{2}(9M)(R^2) - \left[\frac{1}{2}m\left(\frac{R}{3}\right)^2 + \frac{1}{2}m\left(\frac{2R}{3}\right)^2\right]$

...(i)

Here, $\quad m = \frac{9M}{\pi R^2} \times \pi\left(\frac{R}{3}\right)^2 = M$

Substituting in Eq. (i), we have

$I = 4MR^2$

51 **(a)**

Time of descent $t = \frac{1}{\sin\theta}\sqrt{\frac{2h}{g}\left(1 + \frac{K^2}{R^2}\right)}$

For solid sphere $\frac{K^2}{R^2} = \frac{2}{5}$

For hollow sphere $\frac{K^2}{R^2} = \frac{2}{3}$

As $\left(\frac{K^2}{R^2}\right)_{\text{Hollow}} > \left(\frac{K^2}{R^2}\right)_{\text{Solid}}$

$i.e.$ solid sphere will take less time so it will reach the bottom first

52 **(c)**

Distance between the centre of spheres $= 12R$

$\therefore$ Distance between their surfaces $=12R - (2R + R) = 9R$

Since there is no external force, hence centre of mass must remain unchanged and hence

$\Rightarrow \; m_1 r_1 = m_2 r_2 \Rightarrow Mx = 5M(9R - x) \Rightarrow x = 7.5R$

53 **(c)**

Kinetic energy $K = \frac{J^2}{2I}$

where J is angular momentum and I the moment of inertia.

$\therefore \; K_1 = \frac{J^2}{2I}, \quad K_2 = \frac{\left(J + \frac{10}{100}J\right)^2}{2I}$

$\therefore \; \frac{K_1}{K_2} = \frac{(100)^2}{(110)^2} = \frac{100}{121}$

% change $= \frac{K_2 - K_1}{K_1} = \frac{K_2}{K_1} - 1$

$= \frac{121}{100} - 1 = 21\%$

54 **(d)**

On applying law of conservation of angular momentum

$I_1\omega_1 = I_2\omega_2$

For solid sphere,

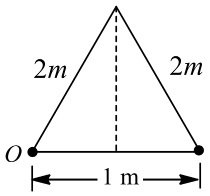
$I = \frac{2}{5}mr^2 \Rightarrow \frac{2}{5}mr_1^2\omega_1 = \frac{2}{5}mr_2^2\omega_2$

$r^2\omega = \left(\frac{r}{n}\right)^2 \omega_2 \Rightarrow \omega_2 = n^2\omega$

55 **(c)**

$x_{CM} = \frac{\sum m_i x_i}{\sum m_i}$, Refer to figure

$$= \frac{M \times 0 + M \times 1 + M \times 2}{M + M + M} = 1$$



$$y_{CM} = \frac{\sum m_i y_i}{\sum m_i}$$

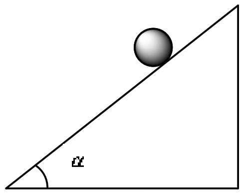
$$= \frac{M \times 0 + M(2\sin 60°) + M \times 0}{M + M + M}$$

$$= \frac{\sqrt{3}M}{3M} = \frac{1}{\sqrt{3}}$$

$\therefore$ Position vector of centre of mass is $\left(\hat{\mathbf{i}} + \frac{1}{\sqrt{3}}\hat{\mathbf{j}}\right)$

56 **(b)**

The acceleration of the body which is rolling down an inclined plane of angle α is



$a = \frac{g\sin\alpha}{1 + \frac{K_2}{R^2}}$

where K =radius of gyration,

R =radius of body.

Now, here the body is a uniform solid disc.

So, $\quad \frac{K^2}{R^2} = \frac{1}{2}$

$\therefore \quad a = \frac{g\sin\alpha}{1 + \frac{1}{2}}$

or $\quad a = \frac{g\sin\alpha}{3/2}$

or $\quad a = \frac{2g\sin\alpha}{3}$

57 **(c)**

In rotational motion of a rigid body, the centre of mass of the body moves uniformly in a circular path.

58 **(a)**

For centre of mass,

$$x_{cm} = \frac{2 \times 1 + 4 \times 1 + 4 \times 0}{2 + 4 + 4} = \frac{6}{10} = \frac{3}{5}$$

$$y_{cm} = \frac{2 \times 0 + 4 \times 1 + 4 \times 1}{2 + 4 + 4} = \frac{8}{10} = \frac{4}{5}$$

$\therefore$ Coordinate for $cm = \left(\frac{3}{5}\hat{\imath}, \frac{4}{5}\hat{\jmath}\right)$

Where $\hat{\imath}$ and $\hat{\jmath}$ are unit vector along x and y axis

59 **(b)**

Rotational kinetic energy of flywheel

$K = 360$ J

Angular speed of flywheel $(\omega) = 20$ rads^{-1}

Rotational kinetic energy, $K = \frac{1}{2}I\omega^2$

$\therefore \quad$ Moment of inertia, $I = \frac{2K}{\omega^2}$

$$= \frac{2 \times 360}{(20)^2} = 1.8 \text{ kg} - \text{m}^2$$

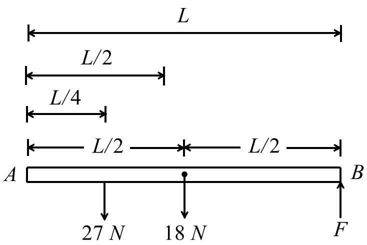
60 **(a)**

In the absence of external torque angular momentum remains constant

61 **(a)**

Mass of a rod, $m = 1.8kg$

$\therefore$ Weight of a rod, $W = mg = 1.8kg \times 10ms^{-2} = 18\,N$



As the rod is uniform, therefore weight of the rod is acting at its midpoint

Taking moments about A,

$$27 \times \frac{L}{4} + 18 \times \frac{L}{2} = F \times L$$

$$\Rightarrow FL = \frac{L}{4}[27 + 36] = \frac{63L}{4} \Rightarrow F = \frac{63}{4} = 16N$$

62 **(b)**

$$\frac{K_1}{K_2} = \frac{\frac{p_1^2}{2m_1}}{\frac{p_2^2}{2m_2}} = \frac{m_2}{m_1} = \frac{4m}{m} = 4:1 \quad (\because p_1 = p_2)$$

63 **(c)**

$$\alpha = \frac{2\pi(n_2 - n_1)}{t} = \frac{2\pi\left(0 - \frac{60}{60}\right)}{60} = \frac{-2\pi}{60}$$

$$= \frac{-\pi}{30} rad/sec^2$$

$$\therefore \tau = I\alpha = \frac{2 \times \pi}{30} = \frac{\pi}{15} N - m$$

64 **(b)**

If external force is non-zero then acceleration of centre of mass must be non-zero $\left(a_0 = \frac{F_{\text{ext}}}{M} \neq 0\right)$.

However, at a particular instant of time velocity of centre of mass may be zero or non-zero. Hence option (b) is correct.

65 **(d)**

Position vector of the point at which force is acting

$\overrightarrow{r_1} = \hat{\imath} + 2\hat{\jmath} + 3\hat{k}$

But we have to calculate the torque about another point. So its position vector about that another point

$$\overrightarrow{r_1'} = \overrightarrow{r_1} - \overrightarrow{r_2} = (\hat{\imath} + 2\hat{\jmath} + 3\hat{k}) - (3\hat{\imath} - 2\hat{\jmath} - 3\hat{k})$$

$$= -2\hat{\imath} + 4\hat{\jmath} + 6\hat{k}$$

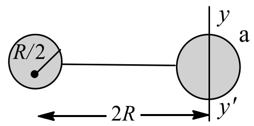
Now, $\vec{\tau} = \overrightarrow{r_1'} \times \vec{F} = (-2\hat{\imath} + 4\hat{\jmath} + 6\hat{k}) \times (4\hat{\imath} - 5\hat{\jmath} + 3\hat{k})$

$$\vec{\tau} = \begin{vmatrix} \hat{\imath} & \hat{\jmath} & \hat{k} \\ -2 & 4 & 6 \\ 4 & -5 & 3 \end{vmatrix}$$

$$= \hat{\imath}(12 + 30) - \hat{\jmath}(-6 - 24) + \hat{k}(10 - 16)$$

$$= (42\hat{\imath} + 30\hat{\jmath} - 6\hat{k})N - m$$

66 **(a)**



Moment of inertia of the system about yy'

$I_{yy'}$ =Moment of inertia of sphere P about yy' + Moment of inertia of sphere Q about yy'

Moment of inertia of sphere P about yy''

$$= \frac{2}{5} M \left(\frac{R}{2}\right)^2 + M(x)^2$$

$$= \frac{2}{5} M \left(\frac{R}{2}\right)^2 + M(2R)^2$$

$$= \frac{MR^2}{10} + 4MR^2$$

Moment of inertia of sphere Q about yy'' is

$\frac{2}{5} M \left(\frac{R}{2}\right)^2$

Now, $I_{yy'} = \frac{MR^2}{10} + 4MR^2 + \frac{2}{5} M \left(\frac{R}{2}\right)^2 = \frac{21}{5} MR^2$

67 **(b)**

$$E = \frac{L^2}{2I} \quad \therefore E \propto L^2 \Rightarrow \frac{E_2}{E_1} = \left(\frac{L_2}{L_1}\right)^2$$

$$\frac{E_2}{E_1} = \left[\frac{L_1 + 200\% \text{ of } L_1}{L_1}\right] = \left[\frac{L_1 + 2L_1}{L_1}\right]^2 = (3)^2$$

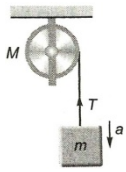
$$\Rightarrow E_2 = 9E_1$$

Increment in kinetic energy $\Delta E = E_2 - E_1 = 9E_1 - E_1$

$\Delta E = 8E_1 \; \therefore \frac{\Delta E}{E_1} = 8$ or percentage increase = 800%

68 **(b)**

When pulley has a finite mass M and radius R, then tension in two segments of string are different.



Here, $ma = mg - T$

$$a = \frac{m}{m + \frac{M}{2}} g = \frac{2m}{2m + M} g$$

69 **(a)**

Linear momentum p and kinetic energy K are interrelated as

$K = \frac{p^2}{2m}$ or $p = \sqrt{2mK}$, hence zero momentum implies zero kinetic energy and *vice versa*.

70 **(b)**

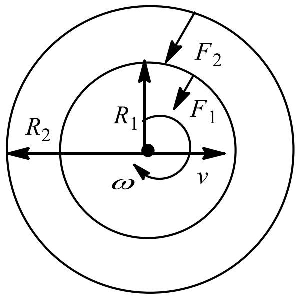
In free space neither acceleration due to gravity nor external torque act on the rotating solid space. Therefore, taking the same mass of sphere if radius is increased then moment of inertia, rotational kinetic energy and angular velocity will change but according to law of conservation of momentum, angular momentum will not change.

71 **(d)**

From $E = \frac{1}{2} r\omega^2$, we find that when frequency (n) is doubled, $\omega = 2\pi n$ is doubled, ω^2 becomes 4 times. As E reduces to half, I must have been reduced to $\frac{1}{8}$th. From $L = I\omega, L$ becomes $\frac{1}{8} \times 2 = \frac{1}{4}$ times *ie*, 0.25 L

72 **(d)**

Since ω is constant, v would also be constant. So, no net force or torque is acting on ring. The force experienced by any particle is only along radical direction, or we can say the centripetal force.



The force experienced by inner part, $F_1 = m\omega^2 R_1$ and the force experienced by outer part, $F_2 = m\omega^2 R_2$

$$\frac{F_1}{F_2} = \frac{R_1}{R_2}$$

73 **(d)**

Angular velocity is a axial vector

74 **(b)**

$$X = \frac{m_1x_1 + m_2x_2 + m_3x_3 + m_4x_4}{m_1 + m_2 + m_3 + m_4}$$

$$X = \frac{0 + 40\,x_4}{100} \Rightarrow 3 = \frac{40\,x_4}{100}$$

$$x_4 = \frac{300}{40} = 7.5$$

Similarly $y_4 = 7.5$ and $z_4 = 7.5$

75 **(d)**

External force acting on the system is given as

$$\mathbf{F}_{\text{ext}} = M\mathbf{a}_{\text{CM}}$$

ie, $\mathbf{a}_{\text{CM}}$ lies in the direction of $\mathbf{F}_{\text{ext}}$.

Here, $\mathbf{F}_{\text{ext}} = 5(2\hat{\mathbf{i}} + 3\hat{\mathbf{j}} - 5\hat{\mathbf{k}})$

$$\mathbf{a}_{\text{CM}} = 2\hat{\mathbf{i}}+3\hat{\mathbf{j}}\text{-}5\hat{\mathbf{k}}$$

Since, $\mathbf{F}_{\text{ext}}$ and $\mathbf{a}_{\text{CM}}$ are not lying in the same direction, given data is incorrect.

76 **(d)**

According to conservation of angular momentum,

$$I\omega = \text{constant}$$

ie, we can write

$$I_1\omega_1 = I_2\omega_2$$

or $MR^2\omega = (M + 4m)R^2\omega_2$

or $\omega_2 = \left(\frac{M}{M+4m}\right)\omega$

77 **(b)**

We know $m_1r_1 = m_2r_2 \Rightarrow m \times r = \text{constant} \therefore r \propto \frac{1}{m}$

78 **(b)**

Rotational kinetic energy $K_R = \frac{1}{2}I\omega^2$

$$K_R = \frac{1}{2} \times \frac{MR^2}{2} \times \omega^2 = \frac{1}{4}Mv^2 \quad [\because v = R\omega]$$

Translational kinetic energy $K_T = \frac{1}{2}Mv^2$

Total kinetic energy $= K_T + K_R$

$$= \frac{1}{2}Mv^2 + \frac{1}{4}Mv^2 = \frac{3}{4}Mv^2$$

$$\frac{\text{Rotational kinetic energy}}{\text{Total kinetic energy}} = \frac{\frac{1}{4}Mv^2}{\frac{3}{4}Mv^2} = \frac{1}{3}$$

79 **(a)**

When a body rolls down without slipping along an inclined plane of inclination θ, it rotates about a horizontal axis through its centre of mass and also its centre of mass moves. Therefore, rolling motion may be regarded as a rotational motion about an axis through its centre of mass plus a translational motion of the centre of mass. As it rolls down, it suffers loss in gravitational potential energy provided translational energy due to frictional force is converted into rotational energy.

80 **(a)**

Given, $r = 0.4m, \alpha = 8\,rad\,s^{-2}$

$m = 4kg, I = ?$

Torque, $\tau = I\alpha = mgr \Rightarrow 4 \times 10 \times 0.4 = I \times 8$

$$\Rightarrow I = \frac{16}{8} = 2kg - m^2$$

81 **(c)**

Angle turned in three second, $\theta_{3s} = 2\pi \times 10 = 20\pi\,rad$

From $\theta = \omega_0 t + \frac{1}{2}\alpha t^2 \Rightarrow 20\pi = 0 + \frac{1}{2}\alpha \times (3)^2$

$$\Rightarrow \alpha = \frac{40\pi}{9} rad/s^2$$

Now angle turned in 6 sec from the starting

$$\theta_{6s} = \omega_0 t + \frac{1}{2}\alpha t^2 = 0 + \frac{1}{2} \times \left(\frac{40\pi}{9}\right) \times (6)^2$$

$$= 80\pi\,rad$$

$\therefore$ angle turned between $t = 3s$ to $t = 6s$

$\theta_{\text{last }3s} = \theta_{6s} - \theta_{3s} = 80\pi - 20\pi = 60\pi$

Number of revolution $= \frac{60\pi}{2\pi} = 30\,rev$

82 **(c)**

Moment of inertia $I = MR^2$

M = mass of object,

$R =$ distance of centre of mass from axis of rotation.
Hence, moment of inertia does not depend upon angular velocity.

83 **(a)**

According to the equation of motion of the centre of mass

$$M\,\mathbf{a}_{\mathrm{CM}} = \mathbf{F}_{\mathrm{ext}}$$

If $\mathbf{F}_{\mathrm{ext}} = 0, \mathbf{a}_{\mathrm{CM}} = 0$

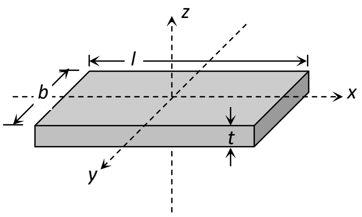
$\therefore\ \mathbf{v}_{\mathrm{CM}} =$ constant

ie, if no external force acts on a system the velocity of its centre of mass remains constant. Thus, the centre of mass may move but not accelerate.

84 **(a)**

$$a = \frac{g\sin\theta}{1+\frac{K^2}{R^2}} = \frac{g\sin\theta}{1+\frac{2}{5}} = \frac{5}{7}g\sin\theta$$

85 **(b)**



M.I. of block about x axis, $I_x = \frac{m}{12}(b^2+t^2)$

M.I. of block about y axis, $I_y = \frac{m}{12}(l^2+t^2)$

M.I. of block about z axis, $I_z = \frac{m}{12}(l^2+b^2)$

As $l > b > t\ \therefore I_z > I_y > I_x$

86 **(d)**

Angular displacement during time

$$\begin{aligned}\theta &= (\omega_2-\omega_1)t\\ &= (2\pi n_2 - 2\pi n_1)t\\ &= (600\pi - 200\pi)\times 10\\ &= 4000\,\pi \text{ rad}\end{aligned}$$

Therefore, number of revolutions made during this time

$$= \frac{4000\pi}{2\pi} = 2000$$

87 **(b)**

$\tau = I\alpha$, if $\tau = 0$ then $\alpha = 0$ because moment of inertia of any body cannot be zero

88 **(d)**

When a body rolls down an inclined plane, it is accompanied by rotational and translational kinetic energies.

Rotational kinetic energy $= \frac{1}{2}I\omega^2 = K_R$

Where I is moment of inertia and ω the angular velocity.

Translational kinetic energy

$$= \frac{1}{2}mv^2 = K_r = \frac{1}{2}m(r\omega)^2$$

where m is mass, v the velocity and ω the angular velocity.

Given,

Translational KE=rotational KE

$$\frac{1}{2}mv^2 = \frac{1}{2}I\omega^2$$

Since, $\quad v = r\omega$

$\therefore \quad \frac{1}{2}m(r^2\omega^2) = \frac{1}{2}I\omega^2$

$\Longrightarrow \quad I = mr^2$

We know that mr^2 is the moment of inertia of hollow cylinder about its axis is where m is mass of hollow cylinderical body and r the radius of cylinder.

89 **(b)**

$\tau = \frac{dL}{dt} = m(u^2\cos^2\theta) = (1)(10)^2\cos^2 45° = 50$ Nm

90 **(c)**

If speed of man relative to plank be v, then it can be shown easily that speed of man relative to ground

$$v_{\mathrm{mg}} = v\frac{M}{\left(M+\frac{M}{3}\right)} = \frac{3}{4}v$$

$\therefore$ Distance covered by man relative to ground

$$= L\frac{v_{\mathrm{mg}}}{v} = \frac{L}{v}\frac{3}{4}v = \frac{3L}{4}$$

91 **(b)**

Centre of mass is closer to massive part of the body therefore the bottom piece of bat has larger mass

92 **(a)**

Angular momentum of system remains constant

$$I \propto \frac{1}{\omega} \Rightarrow \frac{I_2}{I_1} = \frac{\omega_1}{\omega_2} = \frac{20}{10} \Rightarrow I_2 = 2I_1 = 2I$$

93 **(a)**

$$P = \sqrt{p_x^2 + p_y^2}$$

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

If m be the mass of the body, then kinetic energy

$$= \frac{p^2}{2m} = \frac{(2)^2}{2m} = \frac{2}{m}$$

Since kinetic energy does not change with time, both work done and power are zero

Now Power $= Fv\cos\theta = 0$

As $F \neq 0, v \neq 0$

$\therefore\ \cos\theta = 0$

Or $\theta = 90°$

As direction of $\vec{p}$ is same that $\vec{v}(\because \vec{p} = m\vec{v})$ hence angle between $\vec{F}$ and $\vec{p}$ is equal to $90°$

94 **(c)**

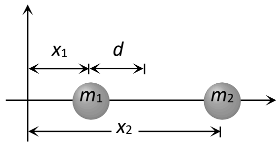
$$\vec{v}_{cm} = \frac{m_1\vec{v}_1 + m_2\vec{v}_2}{m_1 + m_2}$$

$$= \frac{200 \times 10\hat{\imath} + 500 \times (3\hat{\imath} + 5\hat{\jmath})}{200 + 500}$$

$$\vec{v}_{cm} = 5\hat{\imath} + \frac{25}{7}\hat{\jmath}$$

95 **(b)**

Initial position of centre of mass $r_{cm} = \frac{m_1x_1+m_2x_2}{m_1+m_2}$ ...(i)



If the particles of mass m_1 is pushed towards the centre of mass of the system through distance d and to keep the centre of mass at the original position let second particle be displaced through distance d' away from the centre of mass

Now $r_{cm} = \frac{m_1(x_1+d)+m_2(x_2+d')}{m_1+m_2}$ ...(ii)

Equating (i) and (ii)

$$\frac{m_1x_1 + m_2x_2}{m_1 + m_2} = \frac{m_1(x_1 + d) + m_2(x_2 + d')}{m_1 + m_2}$$

By solving $d' = -\frac{m_1}{m_2}d$

Negative sign shows that particle m_2 should be displaced towards the centre of mass of the system

96 **(d)**

$\omega = \omega_0 + \alpha t \Rightarrow \omega = 0 + \left(\frac{\tau}{I}\right)t$ [As $\tau = I\alpha$]

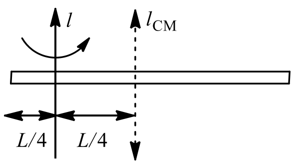
$$\omega = 0 + \frac{1000}{200} \times 3 = 15rad/s$$

97 **(d)**

$$I = I_{CM} + Mx^2$$

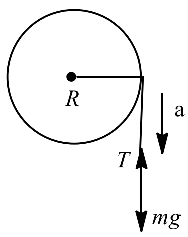
$$= \frac{ML^2}{12} + M\left[\frac{L}{4}\right]^2$$

$$= \frac{ML^2}{12} + \frac{ML^2}{16} = \frac{7ML^2}{48}$$



98 **(d)**

Let a be acceleration of fall of the thread, then net force acting downwards, balances the force due to tension (T) in the thread.



$$mg - T = ma$$

$\Rightarrow \quad mg - ma = T$ ...(i)

Also torque (also known as moment or couple acts on the system).

τ = force ×

perpendicular distance axis of rotation

$$\tau = T \times R$$

From Eq. (i),

$\tau = m(g - a) \times R$ ...(ii)

Let I is moment of inertia of reel and α the angular acceleration, then torque is

$\tau = I\alpha$ ...(iii)

where, $I = \frac{1}{2}MR^2, \alpha = \frac{a}{R}$

$\therefore \quad \tau = \frac{1}{2}MR^2 \times \frac{a}{R} = \frac{MRa}{2}$ ...(iv)

Equating Eqs. (ii) and (iv), we get

$$\tau = m(g - a)R = \frac{mRa}{2}$$

$\Rightarrow \quad g - a = \frac{a}{2}$

$\Rightarrow \quad a = \frac{2}{3}g$

99 **(c)**

The moment of inertia is maximum about axis 3, because rms distance of mass is maximum for this axis

100 **(c)**

Let same mass and same outer radii of solid sphere and hollow sphere are M and R respectively. The moment of inertia of solid sphere A about its diameter

$$I_A = \frac{2}{5}MR^2$$

...(i)

Similarly, the moment of inertia of hollow sphere (spherical shell) B about its diameter

$$I_B = \frac{2}{3}MR^2$$

...(ii)

It is clear from Eqs. (i) and (ii), we get

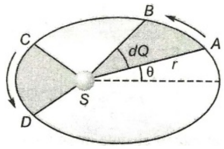
$$I_A < I_B$$

101 **(a)**

$$v = \sqrt{\frac{2gh}{1 + \frac{K^2}{R^2}}} = \sqrt{\frac{2gh}{1 + \frac{2}{5}}} = \sqrt{\frac{10}{7}gh}$$

102 **(c)**

From Kepler's second law of motion, a line joining any planet to the sun sweeps out equal areas in equal intervals of time. Let any instant t, the planet is in position A. Then area swept out by SA is



dA = area of the curved triangle SAB

$$= \frac{1}{2}(AB \times SA) = \frac{1}{2}(rd\theta \times r) = \frac{1}{2}r^2 d\theta$$

The instantaneous areal speed is

$$\frac{dA}{dt} = \frac{1}{2}r^2\frac{d\theta}{dt} = \frac{1}{2}r^2\omega$$

Let J be angular momentum, I the moment of inertia and m the mass, then

$$J = I\omega = mr^2\omega$$

$\therefore \quad \frac{dA}{dt} = \frac{J}{2m}$ =constant

Hence, angular momentum of the planet is conserved.

103 **(a)**

$$\mathbf{c} = \frac{\mathbf{dL}}{dt} = \frac{L_2 - L_1}{\Delta t} = \frac{4A_0 - A_0}{4} = \frac{3A_0}{4}$$

104 **(b)**

From conservation law of momentum

$$\frac{v_1}{v_2} = \frac{2}{1} = \frac{m_2}{m_1} = \frac{\frac{4}{3}\pi r_2^3\rho}{\frac{4}{3}\pi r_1^3\rho} = \left(\frac{r_2}{r_1}\right)^3$$

$$\Rightarrow \frac{r_2}{r_1} = (2)^{1/3}:1$$

Or $\quad r_1 : r_2 = 1 : (2)^{1/3}$

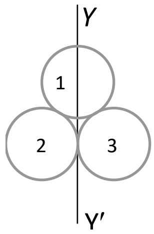
105 **(d)**

Moment of inertia of system about YY'

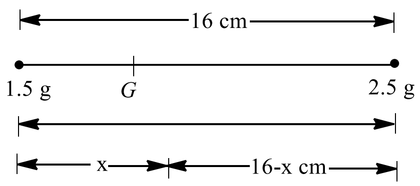
$$I = I_1 + I_2 + I_3$$

$$= \frac{1}{2}MR^2 + \frac{3}{2}MR^2 + \frac{3}{2}MR^2$$

$$= \frac{7}{2}MR^2$$



106 **(a)**



Taking the moment of forces about centre of gravity G is

$$(1.5)\text{g}x = 2.5\text{g}(16 - x)$$

$$\Longrightarrow \quad 3x = 80 - 5x$$

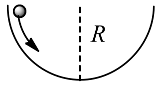
or $\quad 8x = 80 \quad$ or $\quad x = 10$ cm

107 **(a)**

The velocity of a body in different reference frames may be same or different. So, momentum and kinetic energy of a body may be same or different in different reference frames

108 **(d)**

As is clear from figure,



On reaching the bottom of the bowl, loss in PE=mgR, and

Gain in KE= $\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

$$= \frac{1}{2}mv^2 + \frac{1}{2} \times \left(\frac{2}{5}mr^2\right)\omega^2$$

$$= \frac{1}{2}mv^2 + \frac{1}{5}mv^2 = \frac{7}{10}mv^2$$

As again in KE =loss in PE

$$\therefore \quad \frac{7}{10}mv^2 = mgR$$

$$v = \sqrt{\frac{10gR}{7}}$$

109 **(d)**

Angle turned by the body

$$\theta = \theta_0 + \theta_1 t + \theta_2 t^2$$

Angular velocity $\omega = \frac{d\theta}{dt}$

$$= \frac{d}{dt}(\theta_0 + \theta_1 t + \theta_2 t)$$

$$= \theta_1 + 2\theta_2 t$$

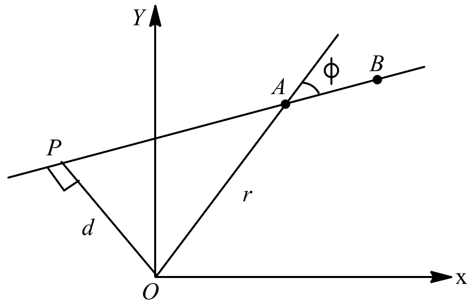
Angular acceleration $\alpha = \frac{d\omega}{dt}$

$$= \frac{d}{dt}(\theta_1 + 2\theta_2 t)$$

$$= 2\theta_2$$

110 **(b)**

From the definition of angular momentum,



$$\mathbf{L} = \mathbf{r} \times \mathbf{p} = rmv\sin\phi(-\hat{\mathbf{k}})$$

Therefore, the magnitude of L is

$$L = mvr\sin\phi = mvd$$

where $d = r\sin\phi$ is the distance of closest approach of the particle to the origin. As d is same for both the particles, hence $L_A = L_B$.

111 **(c)**

Conservation of angular momentum

$$I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\omega$$

Angular velocity of system $\omega = \frac{I_1\omega_1 + I_2\omega_2}{I_1 + I_2}$

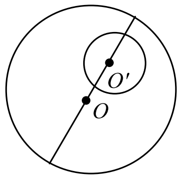
$\therefore$ Rotational kinetic energy $= \frac{1}{2}(I_1 + I_2)\omega^2$

$$= \frac{1}{2}(I_1 + I_2)\left(\frac{I_1\omega_1 + I_2\omega_2}{I_1 + I_2}\right) = \frac{(I_1\omega_1 + I_2\omega_2)^2}{2(I_1 + I_2)}$$

112 **(a)**

For the calculation of the position of centre of mass, cut off mass is taken as negative. The mass of disc is

$m_1 = \pi r_1^2 \sigma$



$= \pi(6)^2\sigma = 36\pi\sigma$

Where σ is surface mass density

The mass of cutting portion is

$m_2 = \pi(1)^2\sigma = \pi\sigma$

$$x_{\text{CM}} = \frac{m_1x_1 - m_2x_2}{m_1 - m_2}$$

Taking origin at the centre of disc,

$x_1 = 0, x_2 = 3$ cm

$$x_{\text{CM}} = \frac{36\pi\sigma \times 0 - \pi\sigma \times 3}{36\pi\sigma - \pi\sigma} = \frac{-3\pi\sigma}{35\pi\sigma} = -\frac{3}{35}\text{cm}$$

113 **(b)**

$$\vec{r}_{cm} = \frac{m_1\vec{r_1} + m_2\vec{r_2}}{m_1 + m_2}$$

$$= \frac{1(\hat{\imath} + 2\hat{\jmath} + \hat{k}) + 3(-3\hat{\imath} - 2\hat{\jmath} + \hat{k})}{1 + 3}$$

$\Rightarrow \vec{r}_{cm} = -2\hat{\imath} - \hat{\jmath} + \hat{k}$

114 **(c)**

When hollow cylinder slides with out rolling, it possess only translational kinetic energy, $K_\tau = \frac{1}{2}mv^2$

When it rolls without slipping, it possess both types of kinetic energy,

$$K_N = \frac{1}{2}mv^2\left(1 + \frac{K^2}{R^2}\right)$$

$\therefore \frac{K_T}{K_N} = \frac{1}{\left(1+\frac{K^2}{R^2}\right)} = \frac{1}{2}$ [For hollow cylinder $\frac{K^2}{R^2} = 1$]

115 **(b)**

Angular of the body is given by

$L = I\omega$

or $L = I \times \frac{2\pi}{T}$ or $L \propto \frac{1}{T}$

$\Rightarrow \frac{L_1}{L_2} = \frac{T_2}{T_1}$

$\frac{L}{L_2} = \frac{2T}{T}$

$(As, T_2 = 2T)$

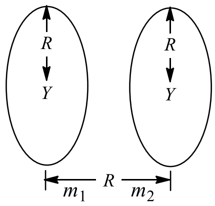
So, $L_2 = \frac{L}{2}$

Thus, on doubling the time period, angular momentum of body becomes half.

Gravitation

RED ZONE

1. Radius of orbit of satellite of earth is R. Its kinetic energy is proportional to
   a) $\frac{1}{R}$ b) $\frac{1}{\sqrt{R}}$ c) R d) $\frac{1}{R^{3/2}}$
2. A satellite is to revolve round the earth in a circle of radius 8000 km. The speed at which this satellite be projected into an orbit, will be
   a) 3 km/s b) 16 km/s c) 7.15 km/s d) 8 km/s
3. Time speed of revolution of a nearest satellite around a planet of radius R is T. Period of revolution around another planet, whose radius is 3R but having same density is
   a) T b) $3T$ c) $9T$ d) $3\sqrt{3}T$
4. Two identical thin rings each of radius R are coaxially placed at a distance R. If the rings have a uniform mass distribution and each has mass m_1 and m_2 respectively, then the work done in moving a mass m from centre of one ring to that of the other is



   a) $\frac{Gmm_1(\sqrt{2}+1)}{m_2R}$
   b) $\frac{Gm(m_1-m_2)(\sqrt{2}+1)}{\sqrt{2}R}$
   c) $\frac{Gm\sqrt{2}(m_1+m_2)}{R}$
   d) Zero
5. Kepler's second law regarding constancy of aerial velocity of a planet is consequence of the law of conservation of
   a) Energy b) Angular momentum c) Linear momentum d) None of these
6. The acceleration of a body due to the attraction of the earth (radius R) at a distance $2R$ from the surface of the earth is (g = acceleration due to gravity at the surface of the earth)
   a) $\frac{g}{9}$ b) $\frac{g}{3}$ c) $\frac{g}{4}$ d) g

7. A satellite of mass m is placed at a distance r from the centre of earth (mass M). The mechanical energy of the satellite is

a) $-\frac{GMm}{r}$ b) $\frac{GMm}{r}$ c) $\frac{GMm}{2r}$ d) $-\frac{GMm}{2r}$

8. The escape velocity of a body on the surface of the earth is 11.2 km/s. If the earth's mass increases to twice its present value and the radius of the earth becomes half, the escape velocity would become

a) 5.6 km/s b) 11.2 km/s (remain unchanged)
c) 22.4 km/s d) 44.8 km/s

9. A geostationary satellite is orbiting the earth at a height of $5R$ above the surface of the earth, R being the radius of the earth. The time period of another satellite in hours at a height of $2R$ from the surface of the earth is

a) 5 b) 10 c) $6\sqrt{2}$ d) $\frac{6}{\sqrt{2}}$

10. The escape velocity of a sphere of mass m from earth having mass M and radius R is given by

a) $\sqrt{\frac{2GM}{R}}$ b) $2\sqrt{\frac{GM}{R}}$ c) $\sqrt{\frac{2GMm}{R}}$ d) $\sqrt{\frac{GM}{R}}$

11. Gravitational potential on the surface of earth is (M =mass of the earth, R = radius of earth)

a) $-GM/2R$ b) $-gR$ c) gR d) GM/R

12. If orbital velocity of planet is given by $v = G^a M^b R^c$, then

a) $a = 1/3, b = 1/3, c = -1/3$ b) $a = 1/2, b = 1/2, c = -1/2$
c) $a = 1/2, b = -1/2, c = 1/2$ d) $a = 1/2, b = -1/2, c = -1/2$

13. If both the masses and radius o the earth, each decreases by 50%, the acceleration due to gravity would

a) Remain same b) Decrease by 50% c) Decrease by 100% d) Increase by 100%

14. A spherical planet for out in space has a mass M_0 and diameter D_0. A particle of mass m falling freely new the surface of this planet will experience an acceleration due to gravity which is equal to

a) GM_0/D_0^2 b) $4mGM_0/D_0^2$ c) $4GM_0/D_0^2$ d) GmM_0/D_0^2

15. Kepler discovered

a) Laws of motion b) Laws of rotational motion
c) Laws of planetary motion d) Laws of curvilinear motion

16. The ratio $\frac{g}{g_h}$, where g and g_h are the accelerations due to gravity at the surface of the earth and at a height h above the earth's surface respectively, is

a) $\left(1+\frac{h}{R}\right)^2$ b) $\left(1+\frac{R}{h}\right)^2$ c) $\left(\frac{R}{h}\right)^2$ d) $\left(\frac{h}{R}\right)^2$

17. In planetary motion the areal velocity of position vector of a planet depends on angular velocity (ω) and the distance of the planet from sun (r). If so the correct relation for areal velocity is

a) $\frac{dA}{dt} \propto \omega r$ b) $\frac{dA}{dt} \propto \omega^2 r$ c) $\frac{dA}{dt} \propto \omega r^2$ d) $\frac{dA}{dt} \propto \sqrt{\omega r}$

18. Earth binds the atmosphere because of

a) Gravity b) oxygen between earth and atmosphere
c) Both (a) and (b) d) None of the above

19. A point mass is placed inside a thin spherical shell of radius R and mass M at a distance $R/2$ from the centre of the shell. The gravitational force exerted by the shell on the point mass is

a) $\frac{GM}{2R^2}$ b) $-\frac{GM}{2R^2}$ c) Zero d) $\frac{GM}{4R^2}$

20. What is the height the weight of body will be the same as at the same depth from the surface of the earth? Radius of earth is R

a) $\frac{R}{2}$ b) $\sqrt{5}R - R$ c) $\frac{\sqrt{5}R - R}{2}$ d) $\frac{\sqrt{3}R - R}{2}$

21. An asteroid of mass m is approaching earth, initially at a distance of 10 R_e with speed v_i. It hits the earth with a speed v_f (R_e and M_e are radius and mass of earth), then

a) $v_f^2 = v_i^2 + \frac{2Gm}{M_e R}\left(1 - \frac{1}{10}\right)$
b) $v_f^2 = v_i^2 + \frac{2GM_e}{R_e}\left(1 + \frac{1}{10}\right)$
c) $v_f^2 = v_i^2 + \frac{2GM_e}{R_e}\left(1 - \frac{1}{10}\right)$
d) $v_f^2 = v_i^2 + \frac{2Gm}{R_e}\left(1 - \frac{1}{10}\right)$

22. Assuming earth to be a sphere of radius R, if $g_{30°}$ is value of acceleration due to gravity at latitude of 30° and g at the equator, the value of $g - g_{30°}$ is

a) $\frac{1}{4}\omega^2 R$
b) $\frac{3}{4}\omega^2 R$
c) $\omega^2 R$
d) $\frac{1}{2}\omega^2 R$

23. The weight of an object in the coal mine, sea level, at the top of the mountain are W_1, W_2 and W_3 respectively, then

a) $W_1 < W_2 > W_3$
b) $W_1 = W_2 = W_3$
c) $W_1 < W_2 < W_3$
d) $W_1 > W_2 > W_3$

24. As we go from the equator to the poles, the value of g

a) Remains the same
b) Decreases
c) Increases
d) Decreases upto a latitude of 45°

25. The escape velocity of a body from earth's surface is v_e. The escape velocity of the same body from a height equal to $7R$ from earth's surface will be

a) $\frac{v_e}{\sqrt{2}}$
b) $\frac{v_e}{2}$
c) $\frac{v_e}{2\sqrt{2}}$
d) $\frac{v_e}{4}$

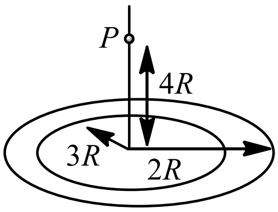
26. The escape velocity from the earth is 11 kms^{-1}. The escape velocity from a planet having twice the radius and the same mean density as the earth would be

a) 5.5 kms^{-1}
b) 11 kms^{-1}
c) 15.5 kms^{-1}
d) 22 kms^{-1}

27. If density of earth increased 4 times and its radius become half of what it is, our weight will

a) Be four times its present value
b) Be doubled
c) Remain same
d) Be halved

28. A thin uniform annular disc (see figure) of mass M has outer radius $4R$ and inner radius $3R$. The work



required to take a unit mass from point P on its axis to infinity is

a) $\frac{2GM}{7R}(4\sqrt{2} - 5)$
b) $-\frac{2GM}{7R}(4\sqrt{2} - 5)$
c) $\frac{GM}{4R}$
d) $\frac{2GM}{5R}(\sqrt{2} - 1)$

29. If then radius of earth R, then the height h at which the value of g becomes one-fourth, will be

a) $\frac{R}{8}$
b) $\frac{3R}{8}$
c) $\frac{3R}{4}$
d) $\frac{R}{2}$

30. The escape velocity for a body projected vertically upwards from the surface of earth is 11 kms^{-1}. If the body is projected at an angle of 45° with the vertical, the escape velocity will be

a) 11 $\sqrt{2}\text{kms}^{-1}$
b) 22 kms^{-1}
c) 11 kms^{-1}
d) $11/\sqrt{2}$ ms^{-1}

31. A rocket is launched with velocity 10 km/s. If radius of earth is R, then maximum height attained by it will be

a) $2R$
b) $3R$
c) $4R$
d) $5R$

32. The acceleration due to gravity is g at a point distant r from the centre of earth of radius R. If $r < R$, then

a) $g \propto r$
b) $g \propto r^2$
c) $g \propto r^{-1}$
d) $g \propto r^{-2}$

33. In the following four periods
(i) Time of revolution of a satellite just above the earth's surface (T_{st})
(ii) Period of oscillation of mass inside the tunnel bored along the diameter of the earth (T_{ma})
(iii) Period of simple pendulum having a length equal to the earth's radius in a uniform field of $9.8 N/kg (T_{sp})$
(iv) Period of an infinite length simple pendulum in the earth's real gravitational filed (T_{is})
a) $T_{st} > T_{ma}$
b) $T_{ma} > T_{st}$
c) $T_{sp} > T_{is}$
d) $T_{st} = T_{ma} = T_{sp} = T_{is}$

34. If the mass of earth is 80 times of that of a planet and diameter is double that of planet and $'g'$ on earth is $9.8 m/s^2$, then the value of $'g'$ on that planet is
a) $4.9\ m/s^2$
b) $0.98\ m/s^2$
c) $0.49\ m/s^2$
d) $49\ m/s^2$

35. An iron ball and a wooden ball of the same radius are released from a height $'h'$ in vacuum. The time taken by both of them to reach the ground is
a) Unequal
b) Exactly equal
c) Roughly equal
d) Zero

36. A geostationary satellite is orbiting the earth at a height of $6R$ above the surface of the earth; R being the radius of the earth. What will be the time period of another satellite at a height 2.5 R from the surface of the earth?
a) $6\sqrt{2}$ h
b) $6\sqrt{2.5}$ h
c) $6\sqrt{3}$ h
d) 12 h

37. If the radius of the earth shrinks by 1%, its mass remaining same, the acceleration due to gravity on the surface of earth will
a) Decrease by 2%
b) Decrease by 0.5%
c) Increase by 2%
d) Increase by 0.5%

38. Two identical solid copper spheres of radius R are placed in contact with each other. The gravitational attraction between them is proportional to
a) R^2
b) R^{-2}
c) R^4
d) R^{-4}

39. Gravitational field is
a) Conservative
b) Non-conservative
c) Electromagnetic
d) Magnetic

40. A satellite is revolving round the earth in an orbit of radius r with time period T. If the satellite is revolving round the earth in an orbit of radius $r + \Delta r (\Delta r \ll r)$ with time period $T + \Delta T (\Delta T \ll T)$ then
a) $\frac{\Delta T}{T} = \frac{3}{2} \frac{\Delta r}{r}$
b) $\frac{\Delta T}{T} = \frac{2}{3} \frac{\Delta r}{r}$
c) $\frac{\Delta T}{T} = \frac{\Delta r}{r}$
d) $\frac{\Delta T}{T} = -\frac{\Delta r}{r}$

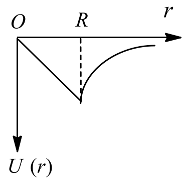
41. Assume that the acceleration due to gravity on the surface of the moon is 0.2 times the acceleration due to gravity on the surface of the earth. If R_e is the maximum range of a projectile on the earth's surface, what is the maximum range on the surface of the moon for the same velocity of projection
a) $0.2\ R_e$
b) $2\ R_e$
c) $0.5\ R_e$
d) $5\ R_e$

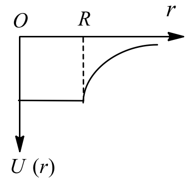
42. The escape velocity of a body from the earth is v_e. If the radius of earth contracts to 1/4th of its value, keeping the mass of the earth constant, the escape velocity will be
a) Doubled
b) Halved
c) Tripled
d) Unaltered

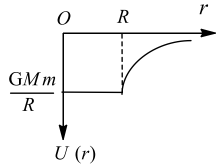
43. A body is released from a point distance r from the centre of earth. If R is the earth and $r > R$, then the velocity of the body at the time of striking the earth will be
a) $\sqrt{gR}$
b) $\sqrt{2gR}$
c) $\sqrt{\frac{2gR}{r-R}}$
d) $\sqrt{\frac{2gR(r-R)}{r}}$

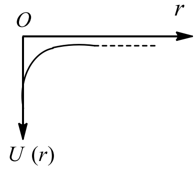
44. A satellite revolves around the earth in an elliptical orbit. Its speed
a) Is the same at all points in the orbit
b) Is greatest when it is closest to the earth
c) Is greatest when it is farthest from the earth
d) Goes on increasing or decreasing continuously depending upon the mass of the satellite

45. A shell of mass M and radius R has a point mass m placed at a distance r from its centre.

a) 

b) 

c) 

d) 

46. In a satellite, if the time of revolution is T, then KE is proportional to

a) $\frac{1}{T}$ b) $\frac{1}{T^2}$ c) $\frac{1}{T^3}$ d) $T^{-2/3}$

47. Three identical bodies of mass M are located at the vertices of an equilateral triangle of side L. They revolve under the effect of mutual gravitational force in a circular orbit, circumscribing the triangle while preserving the equilateral triangle. Their orbital velocity is

a) $\sqrt{\frac{GM}{L}}$ b) $\sqrt{\frac{3GM}{2L}}$ c) $\sqrt{\frac{3GM}{L}}$ d) $\sqrt{\frac{2GM}{3L}}$

48. A particle of mass m is placed at the centre of a uniform spherical shell of mass 3 m and radius R. The gravitational potential on the surface of the shell is

a) $-\frac{Gm}{R}$ b) $-\frac{3Gm}{R}$ c) $-\frac{4Gm}{R}$ d) $-\frac{2Gm}{R}$

49. The work that must be done in lifting a body of weight P from the surface of the earth to a height h is

a) $\frac{PRh}{R-h}$ b) $\frac{R+h}{PRh}$ c) $\frac{PRh}{R+h}$ d) $\frac{R-h}{PRh}$

50. If satellite is shifted towards the earth. Then time period of satellite will be

a) Increase b) Decrease c) Unchanged d) Nothing can be said

51. A missile is launched with a velocity less than the escape velocity. The sum of its kinetic and potential energy is

a) Positive
b) Negative
c) Zero
d) May be positive or negative depending upon its initial velocity

52. Weight of a body is maximum at

a) Moon b) Poles of earth c) Equator of earth d) Centre of earth

53. The kinetic energy needed to project a body of mass m from the earth surface (radius R) to infinity is

a) $mgR/2$ b) $2\,mgR$ c) mgR d) $mgR/4$

54. The ratio of radii of earth to another planet is $\frac{2}{3}$ and the ratio of their mean densities is $\frac{4}{5}$. If an astronaut can jump to a maximum height of 1.5 m on the earth, with the same effort, the maximum height he can jump on the planet is

a) 1 m b) 0.8 m c) 0.5 m d) 1.25 m

55. The binding energy of a satellite of mass m in a orbit of radius r is ($R =$ radius of earth, $g =$ acceleration due to gravity)

a) $\frac{mgR^2}{r}$ b) $\frac{mgR^2}{2r}$ c) $-\frac{mgR^2}{r}$ d) $-\frac{mgR^2}{2r}$

56. Two satellites of mass m and $9m$ are orbiting a planet in orbit of radius R. Their periods of revolution will be in the ratio of

a) 1:3 b) 1:1 c) 3:1 d) 9:1

57. Two spheres of mass m and M are situated in air and the gravitational force between them is F. The space around the masses is now filled with a liquid of specific gravity 3. The gravitational force will now be

a) F b) $\frac{F}{3}$ c) $\frac{F}{9}$ d) $3F$

58. For a body to escape from earth, angle at which it should be fired is?
a) 45° b) > 45° c) < 45° d) any angle

59. If an object of mass m is taken from the surface of earth (radius R) to a height $2R$, then the work done is
a) $2mgR$ b) mgR c) $\frac{2}{3}mgR$ d) $\frac{3}{2}mgR$

60. Two bodies of masses m_1 and m_2 are initially at rest at infinite distance apart. They are then allowed to move towards each other under mutual gravitational attraction. Their relative velocity of approach at a separation distance r between them is
a) $\left[2G\frac{(m_1-m_2)}{r}\right]^{1/2}$ b) $\left[\frac{2G}{r}(m_1+m_2)\right]^{1/2}$ c) $\left[\frac{r}{2G(m_1m_2)}\right]^{1/2}$ d) $\left[\frac{2G}{r}m_1m_2\right]^{1/2}$

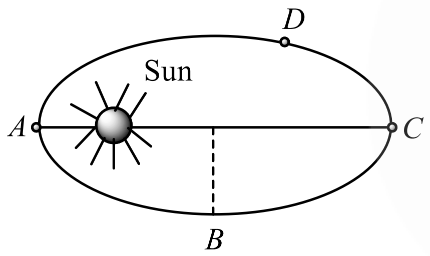
61. In the solar system, which is conserved
a) Total Energy b) K.E. c) Angular Velocity d) Linear Momentum

62. The total energy of a circularly orbiting satellite is
a) Twice the kinetic energy of the satellite
b) Half the kinetic energy of the satellite
c) Twice the potential energy of the satellite
d) Half the potential energy of the satellite

63. The time period of a simple pendulum on a freely moving artificial satellite is
a) Zero b) 2 sec c) 3 sec d) Infinite

64. A satellite is revolving around the planet. The gravitational force between them varies with $R^{-5/2}$, where R is the radius of the satellite. The square of the time period T will be directly proportional to
a) R^3 b) $R^{7/2}$ c) $R^{3/2}$ d) $R^{5/7}$

65. A planet revolves around the sun in an elliptical orbit. The linear speed of the planet will be maximum at



a) D b) B c) A d) C

66. If a man weighs 90 kg on the surface of earth, the height above the surface of the earth of radius R, where the weight is 30 kg is
a) 0.73 R b) $R/\sqrt{3}$ c) $R/3$ d) $\sqrt{3}R$

67. In a gravitational field, at a point where the gravitational potential is zero
a) The gravitational field is necessarily zero
b) The gravitational field is not necessarily zero
c) Nothing can be said definitely about the gravitational field
d) None of these

68. A body is projected vertically upwards from the surface of a planet of radius R with a velocity equal to half the escape velocity for that planet. The maximum height attained by the body is
a) $R/3$ b) $R/2$ c) $R/4$ d) $R/5$

69. Four particles each of mass M, are located at the vertices of a square with side L. The gravitational potential due to this at the centre of the square is
a) $-\sqrt{32}\frac{GM}{L}$ b) $-\sqrt{64}\frac{GM}{L^2}$ c) Zero d) $\sqrt{32}\frac{GM}{L}$

70. A point mass m is placed inside a spherical shell of radius R and mass M. at a distance $R/2$ from the centre of the shell. The gravitational force exerted by the shell on the point mass is
a) $\frac{GMm}{R^2}$ b) $-\frac{GMm}{R^2}$ c) Zero d) $4\frac{GMm}{R^2}$

71. A projectile is projected with velocity kv_e in vertically upward direction from the ground into the space. (v_e is escape velocity and $k < 1$). If resistance is considered to be negligible then the maximum height from the centre of earth to which it can go, will be : (R = radius of earth)

a) $\frac{R}{k^2+1}$ b) $\frac{R}{k^2-1}$ c) $\frac{R}{1-k^2}$ d) $\frac{R}{k+1}$

72. A planet moves around the sun. At a given point P, it is closest from the sun at a distance d_1 and has a speed v_1. At another point Q, when it is farthest from the sun at a distance d_2, its speed will be

a) $\frac{d_1^2 v_1}{d_2^2}$ b) $\frac{d_2 v_1}{d_1}$ c) $\frac{d_1 v_1}{d_2}$ d) $\frac{d_2^2 v_1}{d_1^2}$

73. A body of mass m rises to a height $h = R/5$ from the surface of earth, where R is the radius of earth. If g is the acceleration due to gravity at the surface of earth, the increase in potential energy is

a) $(4/5)mgh$ b) $(5/6)mgh$ c) $(6/7)mgh$ d) mgh

74. Orbital velocity of an artificial does not depend upon

a) Mass of the earth b) Mass of the satellite
c) Radius of the earth d) Acceleration due to gravity

75. A body has weight 90 kg on the earth's surface, the mass of the moon is 1/9 that of the earth's mass and its radius is 1/2 that of the earth's radius. On the moon the weight of the body is

a) 45 kg b) 202.5 kg c) 90 kg d) 40 kg

76. A satellite is revolving around the earth with a kinetic energy E. The minimum addition of kinetic energy needed to make it escape from its orbit is

a) $2E$ b) $\sqrt{E}$ c) $E/2$ d) E

77. How high a man be able to jump on surface of a planet of radius 320 km, but having density same as that of the earth if he jumps 5 m on the surface of the earth (Radius of earth = 6400 km)

a) 60 m b) 80 m c) 100 m d) 120 m

78. Two identical satellite A and B are circulating round the earth at the height of R and $2R$ respectively. (where R is radius of the earth). The ratio of kinetic energy of A to that of B is

a) $\frac{1}{2}$ b) $\frac{2}{3}$ c) 2 d) $\frac{3}{2}$

79. The centripetal force acting on a satellite orbiting round the earth and the gravitational force of earth acting on the satellite both equal F. The net force on the satellite is

a) Zero b) F c) $F\sqrt{2}$ d) $2F$

80. Two bodies of masses m and $4m$ are placed at a distance r. The gravitational potential at a point on the line joining them where the gravitational field is zero is

a) $-\frac{4Gm}{r}$ b) $-\frac{6Gm}{r}$ c) $-\frac{9Gm}{r}$ d) zero

: HINTS AND SOLUTIONS :

1 **(a)**

$$K.E. = \frac{GMm}{2R}$$

2 **(c)**

$$v_0 = \sqrt{\frac{GM}{r}} = \sqrt{\frac{gR^2}{r}} = \sqrt{\frac{10 \times (64 \times 10^5)^2}{8000 \times 10^3}}$$

$= 71.5 \times 10^2 m/s = 7.15\ km/s$

3 **(a)**

Time period of satellite which is very near to planet

$$T = 2\pi\sqrt{\frac{R^3}{GM}} = 2\pi\sqrt{\frac{R^3}{G\frac{4}{3}\pi R^3 \rho}} \therefore T \propto \sqrt{\frac{1}{\rho}}$$

$i.e.$ time period of nearest satellite does not depends upon the radius of planet, it only depends upon the density of the planet.

In the problem, density is same so time period will be same

4 **(b)**

V_A =(Potential at A due to A) + (Potential at A due to B)

$$\Rightarrow\ V_A = -\frac{Gm_1}{R} - \frac{Gm_2}{\sqrt{2}R}$$

Similarly,

V_B =(Potential at B due to A) + (Potential at B due to B)

$$\Rightarrow\ V_B = -\frac{Gm_2}{R} - \frac{Gm_1}{\sqrt{2}R}$$

Since, $W_{A\to B} = m(V_B - V_A) \Rightarrow W_{A\to B}$

$$= \frac{Gm(m_1 - m_2)(\sqrt{2}-1)}{\sqrt{2}R}$$

5 **(b)**

$\frac{dA}{dt} = \frac{L}{2m} =$ constant

6 **(a)**

$$g' = g\left(\frac{R}{R+h}\right)^2 = g\left(\frac{R}{R+2R}\right)^2 = \frac{g}{9}$$

7 **(d)**

8 **(c)**

$$v_e = \sqrt{\frac{2GM}{R}} \therefore v_e \propto \sqrt{\frac{M}{R}}$$

If M becomes double and R becomes half then escape velocity becomes two times

9 **(c)**

$$\frac{T_1^2}{T_2^2} = \frac{R_1^3}{R_2^3} = \frac{(6R)^3}{(3R)^3} = 8$$

$$\frac{24 \times 24}{T_2^2} = 8$$

$$T_2^2 = \frac{24 \times 24}{8}$$

$T_2^2 = 72$

$T_2^2 = 36 \times 2$

$T_2 = 6\sqrt{2}$

10 **(a)**

Escape velocity does not depend on the mass of the projectiles

11 **(b)**

Gravitational potential at a point on the surface of earth

$$V = \frac{-GM}{R} = \frac{-gR^2}{R} = -gR$$

12 **(b)**

$$v = \sqrt{\frac{GM}{R}} = G^{1/2}M^{1/2}R^{-1/2}$$

13 **(d)**

Here, $g = GM/R$ and $g' = \frac{G(M/2)}{(R/2)^2} = \frac{2GM}{R^2} = 2g$

$\therefore$ % increase in g $= \left(\frac{g'-g}{g}\right) \times 100$

$$= \left(\frac{2g - g}{g}\right) \times 100 = 100\%$$

14 **(c)**

$$g = \frac{GM}{R^2} = \frac{GM_0}{(D_0/2)^2} = \frac{4GM_0}{D_0^2}$$

15 **(c)**

16 **(a)**

The value of acceleration due to gravity g at height h above the surface of earth is

$$g_h = \frac{g}{\left(1 + \frac{h}{R}\right)^2}$$

Where R is radius of earth.

$$\therefore \qquad \frac{g}{g_h} = \left(1 + \frac{h}{R}\right)^2$$

17 **(c)**

$$\frac{dA}{dt} = \frac{L}{2m} \Rightarrow \frac{dA}{dt} \propto vr \propto \omega r^2$$

18 **(a)**

Earth is surrounded by an atmosphere of gases (air). The reason is that in earth's atmosphere the average thermal velocity of even the highest molecules at the maximum possible temperature is small compared to escape velocity which in turn depends upon gravity ($v_e = \sqrt{gR_e}$). Therefore, the molecules of gases cannot escape from the earth. Hence, an atmosphere exists around the earth.

19 **(c)**

Gravitational field inside hollow sphere will be zero

20 **(c)**

$$\frac{gR^2}{(R+h)^2} = g\left(1 - \frac{h}{R}\right)$$

or $\left(1 - \frac{h}{R}\right)\left(1 + \frac{h^2}{R^2} + \frac{2h}{R}\right) = 1$

or $\frac{h^3}{R^3} + \frac{h^2}{R^2} - \frac{h}{R} = 0$

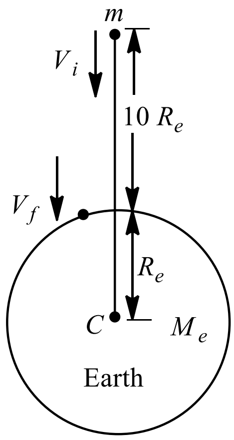
or $\frac{h}{R}\left(\frac{h^2}{R^2} + \frac{h}{R} - 1\right) = 0$

or $\frac{h}{R} = \frac{-1 \pm \sqrt{1+4}}{2} = \frac{\sqrt{5}-1}{2}$

or $h = \frac{\sqrt{5}R - R}{2}$

21 **(c)**

Applying law of conservation of energy for asteroid at a distance 10 R_e and at earth's surface.



$$K_i + U_i = K_f + U_f \qquad \text{....(i)}$$

Now, $K_f = \frac{1}{2}mv_i^2$ and $U_i = -\frac{GM_e m}{10R_e}$

$K_f = \frac{1}{2}mv_f^2$ and $U_f = -\frac{GM_e m}{R_e}$

Substituting these values in Eq. (i), we get

$$\frac{1}{2}mv_i^2 - \frac{GM_e m}{10R_e} = \frac{1}{2}mv_f^2 - \frac{GM_e m}{R_e}$$

$$\Rightarrow \frac{1}{2}mv_f^2 = \frac{1}{2}mv_f^2 + \frac{GM_e m}{R_e} - \frac{GM_e m}{10R_e}$$

$$\Rightarrow v_f^2 = v_i^2 + \frac{2GM_e}{R_e} - \frac{2GM_e}{10R_e}$$

$$\therefore \quad v_f^2 = v_i^2 + \frac{GM_e m}{R_e}\left(1 - \frac{1}{10}\right)$$

22 **(b)**

The value of acceleration due to gravity at latitude λ is given by

$$g_\lambda = g - R\omega^2\cos^2\lambda$$

$$\therefore \quad g - g_\lambda = R\omega^2\cos^2\lambda$$

At $\lambda = 30°$,

$$g - g_{30°} = R\omega^2\cos^2 30°$$

$$= R\omega^2\left(\frac{\sqrt{3}}{2}\right)^2$$

$$= \frac{3}{4}R\omega^2$$

23 **(a)**

Because value of g decreases when we move either in coal mine or at the top of mountain

24 **(c)**

25 **(c)**

$v_e \propto \frac{1}{\sqrt{r}}$ where r is a position of body from the surface

$$\frac{v_1}{v_2} = \sqrt{\frac{r_1}{r_2}} = \sqrt{\frac{R+7R}{R}} \Rightarrow v_2 = \frac{v_1}{2\sqrt{2}}$$

26 **(d)**

Escape velocity $v_e = \sqrt{\frac{2GM}{R}}$

$$v_e = \sqrt{\frac{2G\frac{4}{3}\pi R^3 \times d}{R}}$$

$$\sqrt{2G\frac{4}{3}\pi R^3 \times d} = R\sqrt{\frac{8}{3}\pi Gd}$$

where d = mean density of earth

$\because \quad v_e \propto R\sqrt{d}$

$$\therefore \quad \frac{v_e}{v_p} = \frac{R_e}{R_p}\sqrt{\frac{d_e}{d_p}}$$

$$= \frac{R_e}{2R_e}\sqrt{\frac{d_e}{d_e}}$$

$= v_p = 2v_e$

$= 2 \times 11 = 22\text{kms}^{-1}$

27 **(b)**

$g \propto \rho R$

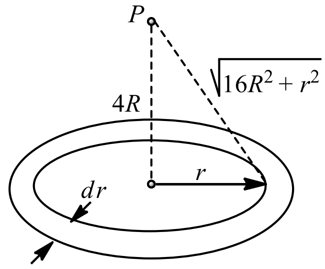
28 **(a)**

$$W = \Delta U = U_f - U_i = U_\infty - U_P$$

$$= -U_P = -mV_P$$

$$= -V_P (\text{as } m = 1)$$

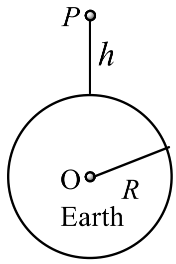
Potential at point P will be obtained by in integration as given below. Let dM be the mass of small rings as shown



$$dM = \frac{M}{\pi(4R)^2 - \pi(3R)^2}(2\pi r)dr$$
$$= \frac{2Mr\,dr}{7R^2}$$
$$dV_P = -\frac{G.dM}{\sqrt{16R^2+r^2}}$$
$$= -\frac{2GM}{7R^2}\int_{3R}^{4R}\frac{r}{\sqrt{16R^2+r^2}}\cdot dr$$
$$= -\frac{2GM}{7R}(4\sqrt{2}-5)$$
$$\therefore \quad W = +\frac{2GM}{7R}(4\sqrt{2}-5)$$

29 **(b)**

The value of acceleration due to gravity at height h above the surface of the earth is given by



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

Given, $\quad g' = \frac{g}{4}$

$$\frac{g}{4} = g\left(1-\frac{2h}{R}\right)$$
$$\Rightarrow \quad \frac{1}{4} = 1 - \frac{2h}{R}$$
$$\Rightarrow \quad \frac{2h}{R} = \frac{3}{4}$$
$$\Rightarrow \quad h = \frac{3R}{8}$$

30 **(c)**

The escape velocity is independent of angle of projection, hence, it will remain same *ie.* 11 kms^{-1}.

31 **(c)**

If the body is projected with velocity $v(v < v_e)$ then height up to where it rises,

$$h = \frac{R}{\frac{v_e^2}{v^2} - 1}$$
$$\Rightarrow h = \frac{R}{\left(\frac{11.2}{10}\right)^2 - 1} = 4R \text{ (approx.)}$$

32 **(a)**

Inside the earth $g' = \frac{4}{3}\pi\rho G r \;\therefore g' \propto r$

33 **(c)**

(i) $T_{st} = 2\pi\sqrt{\frac{(R+h)^3}{GM}} = 2\pi\sqrt{\frac{R}{g}}$ [As $h << R$ and $GM = gR^2$]

(ii) $T_{ma} = 2\pi\sqrt{\frac{R}{g}}$

(iii) $T_{sp} = 2\pi\sqrt{\frac{1}{g\left(\frac{1}{l}+\frac{1}{R}\right)}} = 2\pi\sqrt{\frac{R}{2g}}$ [As $l = R$]

(iv) $T_{is} = 2\pi\sqrt{\frac{R}{g}}$ [As $l = \infty$]

34 **(c)**

$$g_p = g_e\left(\frac{M_p}{M_e}\right)\left(\frac{R_e}{R_p}\right)^2 = 9.8\left(\frac{1}{80}\right)(2)^2$$
$$= 9.8/20 = 0.49 m/s^2$$

35 **(b)**

Time of decent $t = \sqrt{\frac{2h}{g}}$. In vacuum no other force works except gravity so time period will be exactly equal

36 **(a)**

According to Kepler's law of periods

$$T^2 \propto a^3 [a = \text{semi-major axis}]$$

Here, in case I a is $7R$ as satellite is $6R$ above the earth and for a geostationary satellite $T = 24$ h

$$\therefore \quad (24)^2 \propto (7R)^3 \quad \ldots.(i)$$

Similarly for case II

$$T^2 \propto (3.5R)^3 \quad \ldots.(ii)$$

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

$$\frac{(24)^2}{T^2} = \frac{(7R)^3}{(3.5R)^3}$$
$$\Rightarrow \quad T^2 = \frac{(24)^2}{8}$$
$$\text{or} \quad T = 6\sqrt{2}\text{ h}$$

37 **(c)**

$$\text{g} = \frac{GM}{r^2}$$

$\therefore \log \text{g} = \log G + \log M - 2\log r$

Differentiating both sides w.r.t. t

$$\frac{1}{\text{g}}\frac{d\text{g}}{dt} = 0 - 2\times\frac{1}{r}\frac{dr}{dt}\left(\frac{dr}{dt}\times 100 = -1\right)$$

$$\Rightarrow \frac{1}{g}\left(\frac{dg}{dt}\times 100\right) = -2\times\frac{1}{r}\left(\frac{dr}{dt}\times 100\right)$$
$$\Rightarrow \frac{dg}{dt}\times 100 = -2\times(-1) = 2$$
$\therefore$ g increasing by 2%

38 **(c)**

$$F = \frac{G\times m\times m}{(2R)^2} = \frac{G\times\left(\frac{4}{3}\pi R^3\rho\right)^2}{4R^2} = \frac{4}{3}\pi^2\rho^2R^4$$
$\therefore F \propto R^4$

39 **(a)**

40 **(a)**

Since, $T^2 = kr^3$
$$\Rightarrow \frac{2\Delta T}{T} = \frac{3\Delta r}{r} \Rightarrow \frac{\Delta T}{T} = \frac{3}{2}\frac{\Delta r}{r}$$

41 **(d)**

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

If u and θ are constant then $R \propto \frac{1}{g}$
$$\frac{R_m}{R_e} = \frac{g_e}{g_m} \Rightarrow \frac{R_m}{R_e} = \frac{1}{0.2} \Rightarrow R_m = \frac{R_e}{0.2} \Rightarrow R_m = 5R_e$$

42 **(a)**

Escape velocity $v_e = \sqrt{\frac{2GM}{R}}$

If $R' = \frac{R}{4}$
$$v'_e = 2\sqrt{\frac{2GM}{R}}$$
Since, G and M are constant hence,
$$v'_e = 2v_e$$

43 **(d)**

Using law of conservation of energy
$$-\frac{GMm}{r} = \frac{1}{2}mv^2 - \frac{GMm}{R}$$
$$\frac{v^2}{2} = \frac{GM}{R} - \frac{GM}{r}$$
$$= GM\left(\frac{r-R}{rR}\right) = gR\left(\frac{r-R}{r}\right)$$
$$v = \sqrt{2gR(r-R)/r}$$

44 **(b)**

45 **(b)**

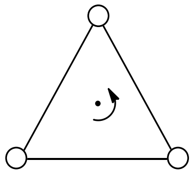
$$U_{(r)} = \begin{cases} -\frac{GMm}{r}, r \geq R \\ -\frac{GMm}{R}, r < R \end{cases}$$

46 **(d)**

Velocity of satellite $v = \sqrt{\frac{GM}{r}}$
$$\text{KE} \propto v^2 \propto \frac{1}{r}$$
and $\quad T^2 \propto r^3$
$$\text{KE} \propto T^{-2/3}$$

47 **(a)**

$$\frac{GMM}{L^2} = \frac{MV^2}{L}$$
$$\Rightarrow V = \sqrt{\frac{GM}{L}}$$



48 **(c)**

Gravitational potential on the surface of the shell is

V = Gravitational potential due to particle (V_1)
+ Gravitational potential due to shell particle (V_2)
$$= -\frac{Gm}{R} + \left(-\frac{G3m}{R}\right) = -\frac{4Gm}{R}$$

49 **(c)**

Force on the body $= \frac{GMm}{x^2}$

To move it by a small distance dx,

Work done $= F\,dx = \frac{GMm}{x^2}dx$

Total work done $= GMm\int_R^{R+h}\frac{dx}{x^2} = \left[\frac{-GMm}{x}\right]_R^{R+h}$
$$= GMm\left[\frac{1}{R} - \frac{1}{R+h}\right]$$
$$= \left[\frac{(R+h)-R}{R(R+h)}\right] = \frac{GMmh}{R(R+h)}$$
$$\frac{GM}{R^3}\times\frac{mhR}{R+h} = \frac{gmhR}{R+h} = \frac{PRh}{R+h}$$

50 **(b)**

$T^2 \propto r^3$

51 **(b)**

If missile is launched with escape velocity, then it will escape from the gravitational field and at infinity its total energy becomes zero

But if the velocity of projection is less than escape velocity then sum of energies will be negative.

This shows that attractive force is working on the missile

52 **(b)**

53 **(c)**

$$\frac{1}{2}mv_e^2 = \frac{1}{2}m\,2gR = mgR$$

54 **(c)**

Given $\frac{R_e}{R_p} = \frac{2}{3}$

$\frac{d_e}{d_p} = \frac{4}{5}$

As $MG = gR_e^2$

and $M = d_e \times \frac{4}{3}\pi R_e^3$

$$d_e \times \frac{4}{3}\pi R_e^3 \times G = g_e R_e^2$$

or $d_e \times \frac{4}{3}\pi R_e \times G = g_e$ .... (i)

Similarly for planet

$$d_p \times \frac{4}{3}\pi R_p G = g_p \quad .... (ii)$$

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

$$\frac{g_e}{g_p} = \frac{R_e}{R_p} \times \frac{d_e}{d_p}$$

$$\frac{g_e}{g_p} = \frac{2}{3} \times \frac{4}{5} = \frac{8}{15} = 0.5$$

55 **(b)**

The energy required to remove the satellite from its orbit around the earth to infinity is called binding energy of the satellite. It is equal to negative of total mechanical energy of satellite in its orbit.

Thus, binding energy $= -E = \frac{GMm}{2r}$

but, $g = \frac{GM}{R^2}$

$\Longrightarrow$ $GM = gR^2$

$\therefore$ $\text{BE} = \frac{gmR^2}{2r}$

56 **(b)**

Time period is independent of mass. Therefore their periods of revolution will be same.

57 **(a)**

Gravitational force dsesnot depend on the medium.

58 **(d)**

The body can be fired at any angle because the energy is sufficient to take the body out of the gravitational field of earth

59 **(c)**

Work done

$$W = \Delta U = \frac{mgh}{1 + \frac{-h}{R}}$$

Substituting $R = \frac{h}{L}$ we get

$$\Delta U = \frac{mg \times 2R}{1+2}$$

$$\Delta U = \frac{2mgR}{3}$$

60 **(b)**

Let velocities of these masses at r distance from each other be v_1 and v_2 respectively

By conservation of momentum

$m_1v_1 - m_2v_2 = 0$

$\Rightarrow m_1v_1 = m_2v_2$ ...(i)

By conservation of energy

Change in $P.E. =$ change in $K.E.$

$$\frac{Gm_1m_2}{r} = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$

$$\Rightarrow \frac{m_1^2v_1^2}{m_1} + \frac{m_2^2v_2^2}{m_2} = \frac{2Gm_1m_2}{r} \quad ...(ii)$$

On solving equation (i) and (ii)

$$v_1 = \sqrt{\frac{2Gm_2^2}{r(m_1+m_2)}} \text{ and } v_2 = \sqrt{\frac{2Gm_1^2}{r(m_1+m_2)}}$$

$$\therefore v_{\text{app}} = |v_1| + |v_2| = \sqrt{\frac{2G}{r}(m_1+m_2)}$$

61 **(a)**

62 **(d)**

Kinetic energy of the satellite is $K = \frac{GMm}{2r}$ ...(i)

Potential energy of the satellite is $U = -\frac{GMm}{r}$ ...(ii)

Total energy of the satellite is $E = -\frac{GMm}{2r}$ ...(iii)

Divide (iii) by (i), we get $\frac{E}{K} = -1$ or $E = -K$

Divide (iii) by (ii), we get $\frac{E}{U} = \frac{1}{2}$ or $E = \frac{U}{2}$

63 **(d)**

Time period of simple pendulum $T = 2\pi\sqrt{\frac{1}{g'}}$

In artificial satellite $g' = 0$ $\therefore T =$ infinite

64 **(b)**

Gravitational force provides the required centripetal force *ie*,

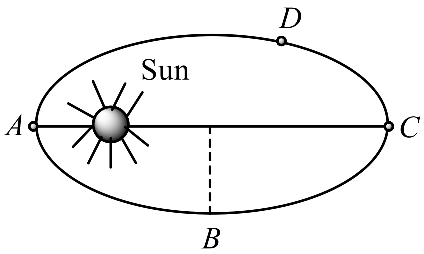
$$m\omega^2 R = \frac{GMm}{R^{\frac{5}{2}}}$$

$$\Longrightarrow \frac{m4\pi^2}{T^2} = \frac{GMm}{R^{\frac{7}{2}}}$$

$$\Longrightarrow T^2 \propto R^{7/2}$$

65 **(c)**

From Kepler's second law of planetary motion, the linear speed of a planet is maximum, when its distance from the sun is least, *ie*, at point A.



66 **(a)**

Given, $\frac{mg'}{mg} = \frac{30}{90}$ or $\frac{g'}{g} = \frac{1}{3}$

Now, $g' = g\frac{R^2}{(R+h)^2}$ or $\frac{g'}{g} = \frac{R^2}{(R+h)^2} = \frac{1}{3}$

or $\frac{R}{R+h} = \frac{1}{\sqrt{3}}$ or $(R+h) = \sqrt{3}R$

or $h = (\sqrt{3}-1)R = 0.73R$

67 **(a)**

$$I = \frac{-dV}{dx}$$

If $V = 0$ then gravitational field is necessarily zero

68 **(a)**

If body is projected with velocity $v(v < v_e)$ then

Height up to which it will rise, $h = \frac{R}{\frac{v_e^2}{v^2}-1}$

$v = \frac{v_e}{2}$ (Given) $\therefore h = \frac{R}{\left(\frac{(v_e)}{v_e/2}\right)^2-1} = \frac{R}{4-1} = \frac{R}{3}$

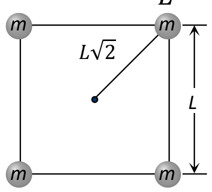
69 **(a)**

Potential at the centre due to single mass $= \frac{-GM}{L/\sqrt{2}}$

Potential at the centre due to all four masses

$$= -4\frac{GM}{L/\sqrt{2}} = -4\sqrt{2}\frac{GM}{L}$$

$$= -\sqrt{32} \times \frac{GM}{L}$$



70 **(c)**

Gravitational field due to a spherical shell

At a point inside the shell, $i.e., r < R$

$E_{\text{inside}} = 0$

$\therefore$ The gravitational force acting on a point mass m at a distance $R/2$ is

$F = mE_{\text{inside}} = 0$

71 **(c)**

Kinetic energy = Potential energy

$$\frac{1}{2}m(kv_e)^2 = \frac{mgh}{1+\frac{h}{R}} \Rightarrow \frac{1}{2}mk^2 2gR = \frac{mgh}{1+\frac{h}{R}} \Rightarrow h$$

$$= \frac{Rk^2}{1-k^2}$$

Height of Projectile from the earth's surface $= h$

Height from the centre $r = R + h = R + \frac{Rk^2}{1-k^2}$

By solving $r = \frac{R}{1-k^2}$

72 **(c)**

Angular momentum remains constant

$$mv_1d_1 = mv_2d_2 \Rightarrow v_2 = \frac{v_1d_1}{d_2}$$

73 **(b)**

Gravitational force on a body at a distance x from the centre of earth $F = \frac{GMm}{x^2}$

Work done,

$$W = \int_R^{R+h} F\,dx = \int_R^{R+h} \frac{GM\,m}{x^2}dx$$

$$= GMm\left[-\frac{1}{x}\right]_R^{R+h} = mgR^2\left[\frac{1}{R} - \frac{1}{R+h}\right]$$

This work done appears as increase in potential energy

$$\Delta E_p = mgR^2\left[\frac{1}{R} - \frac{1}{R+h}\right]$$

$$= mg(5h)^2\left[\frac{1}{5h} - \frac{1}{6h}\right] = \frac{5}{6}mgh$$

74 **(b)**

$$v = \sqrt{\frac{GM}{r}}$$

75 **(d)**

Acceleration due to gravity on earth is given by

$g = \frac{GM}{R^2}$

$$\left(\text{Here, } M_m = \frac{M_e}{9}, R_m = \frac{R_e}{2}\right)$$

Hence, $\frac{g_e}{g_m} = \frac{M_e}{M_m} \times \frac{R_m^2}{R_e^2} = \frac{9M_e}{M_e} \times \left(\frac{R_e}{2R_e}\right)^2$

or $\frac{g_e}{g_m} = \frac{9}{4}$

So, $\frac{g_m}{g_e} = \frac{4}{9}$

$\because$ Weight of body on moon

$= \text{weight of body on earth} \times g_m/g_e$

$= 90 \times \frac{4}{9} = 90 \times \frac{4}{9} = 40\text{kg}$

76 **(d)**

Kinetic energy of satellite in its orbit

$$E = \frac{1}{2}mv_o^2$$

or $E = \frac{1}{2}m\left(\frac{GM}{r}\right) = \frac{GMm}{2r}$

kinetic energy at escape velocity

$$E' = \frac{1}{2}mv_e^2$$

$$= \frac{1}{2} m \left(\frac{2GM}{r}\right) = \frac{GMm}{r}$$
$$= 2E$$

Therefore, additional kinetic energy required

$$= 2E - E = E$$

77 **(c)**

For earth, $g = \frac{GM}{R^2} = \frac{4}{3}\pi R \rho G$

For the planet, $g_1 = \frac{GM_1}{R_1^2} = \frac{4}{3}\pi R_1 \rho G$

$$\frac{g}{g_1} = \frac{R}{R_1} = \frac{6400}{320} = 20$$

Let h and h_1 be the distance upto which the man can jump on surface of the earth and planet, then

$mgh = mg_1 h_1$

$$\therefore\ h_1 = \frac{g}{g_1} h = 20 \times 5 = 100 \text{ m}$$

78 **(d)**

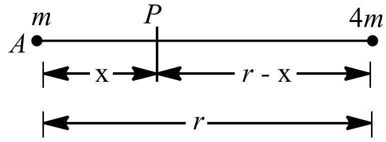
$$\frac{K_A}{K_B} = \frac{r_B}{r_A} = \left(\frac{R + h_B}{R + h_A}\right) = \left(\frac{R + 2R}{R + R}\right) = \frac{3}{2}$$

79 **(b)**

Actually gravitational force provides the centripetal force

80 **(c)**

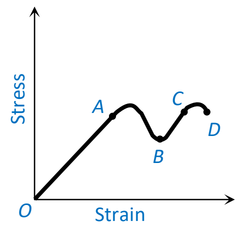
Let gravitation field is zero at P as shown in figure.



$$\therefore \quad \frac{Gm}{x^2} = \frac{G(4m)}{(r-x)^2}$$
$$\Rightarrow \quad 4x^2 = (r-x)^2$$
$$\Rightarrow \quad 2x = r - x$$
$$\Rightarrow \quad x = \frac{r}{3}$$
$$\therefore \quad V_p = \frac{Gm}{x} - \frac{G(4m)}{r-x}$$
$$= -\frac{3Gm}{r} - \frac{6Gm}{r} = -\frac{9Gm}{r}$$

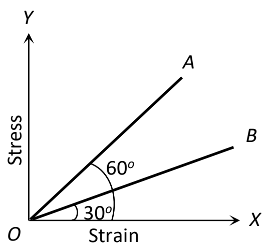
Mechanical Properties of Solids

1. The bulk modulus of an ideal gas at constant temperature
   a) Is equal to its volume V
   b) Is equal to $p/2$
   c) Is equal to its pressure p
   d) Can not be determined
2. Young's modulus of perfectly rigid body material is
   a) Infinite
   b) Zero
   c) $10 \times 10^{10}\ \mathrm{Nm}^{-2}$
   d) $1 \times 10^{10}\ \mathrm{Nm}^{-2}$
3. A graph is shown between stress and strain for a metal. The part in which Hooke's law holds good is



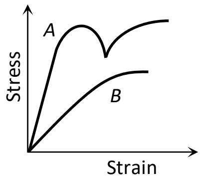
   a) OA
   b) AB
   c) BC
   d) CD
4. Two identical wires are suspended from the same rigid support but one is of copper and the other is of iron. Young's modulus of iron is thrice that of copper. The weights to be added on copper and iron wires so that the ends are on the same level must be in the ratio of
   a) 1 : 3
   b) 2 : 1
   c) 3 : 1
   d) 4 : 1

5. Young's modulus of the wire depends on
   a) Length of the wire
   b) Diameter of the wire
   c) Material of the wire
   d) Mass hanging from the wire
6. Hooke's law defines
   a) Stress
   b) Strain
   c) Modulus of elasticity
   d) Elastic limit
7. The stress versus strain graphs for wires of two materials A and B are as shown in the figure. If Y_A and Y_B are the Young's modulii of the materials, then



   a) $Y_B = 2Y_A$
   b) $Y_A = Y_B$
   c) $Y_B = 3Y_A$
   d) $Y_A = 3Y_B$

8. The diagram shows stress v/s strain curve for the materials A and B. From the curves we infer that



a) A is brittle but B is ductile
b) A ductile and B is brittle
c) Both A and B are ductile
d) Both A and B are brittle

9. Which of the following rods of same material undergoes maximum elongation when subjected to a given force?
a) L= 1m, d= 2 mm
b) L= 1m, d= 1 mm
c) L= 2m, d= 1 mm
d) L= 2m, d= 2 mm

10. Which one of the following statements is wrong
a) Young's modulus for a perfectly rigid body is zero
b) Bulk modulus is relevant for solids, liquids and gases
c) Rubber is less elastic than steel
d) The Young's modulus and shear modulus are relevant for solids

11. The modulus of elasticity is dimensionally equivalent to
a) Surface tension
b) Stress
c) Strain
d) None of these

12. A wire of length L and radius r fixed at one end and a force F applied to the other end produces an extension l. The extension produced in another wire of the same material of length $2L$ and radius $2r$ by a force $2F$, is
a) l
b) $2\,l$
c) $4\,l$
d) $\frac{l}{2}$

13. Which of the following substances has the highest elasticity?
a) Sponge
b) Steel
c) Rubber
d) Copper

14. Two wires of the same material have lengths in the ratio 1 : 2 and their radii are in the ratio $1 : \sqrt{2}$. If they are stretched by applying equal forces, the increase in their lengths will be in the ratio
a) $\sqrt{2} : 2$
b) $2 : \sqrt{2}$
c) 1 : 1
d) 1 : 2

15. A copper wire of length $4.0m$ and area of cross-section $1.2cm^2$ is stretched with a force of $4.8 \times 10^3 N$. If Young's modulus for copper is $1.2 \times 10^{11} N/m^2$, the increase in the length of the wire will be
a) 1.33 mm
b) 1.33 cm
c) 2.66 mm
d) 2.66 cm

16. The ratio of the adiabatic to isothermal elasticities of a triatomic gas is
a) $\frac{3}{4}$
b) $\frac{4}{3}$
c) 1
d) $\frac{5}{3}$

17. Modulus of rigidity of a liquid
a) Non zero constant
b) Infinite
c) Zero
d) Can not be predicted

18. There are two wires of the same length. The diameter of second wire is twice that of the first. On applying the same load to both the wires, the extension produced in them will be in ratio of
a) 1:4
b) 1:2
c) 2:1
d) 4:1

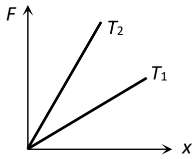
19. A cube is subjected to a uniform volume compression. If the side of the cube decreases by 1% the bulk strain is
a) 0.01
b) 0.02
c) 0.03
d) 0.06

20. The Young's modulus of a wire of length L and radius r is $Y\ N/m^2$. If the length and radius are reduced to $L/2$ and $r/2$, then its Young's modulus will be
a) $Y/2$
b) Y
c) $2Y$
d) $4Y$

21. According to Hooke's law of elasticity, if stress is increased, them the ratio of stress to strain
a) Becomes zero
b) Remains constant
c) Decreases
d) Increases

22. If the thickness of the wire is doubled, then the breaking force in the above question will be
a) $6F$
b) $4F$
c) $8F$
d) F

23. The diagram shows the change x in the length of a thin uniform wire caused by the application of stress F at two different temperatures T_1 and T_2. The variation shown suggest that



a) $T_1 > T_2$ b) $T_1 < T_2$ c) $T_1 = T_2$ d) None of these

24. A ball falling in a lake of depth 200 m shows a decrease of 0.1% in its volume at the bottom. The bulk modulus of elasticity of the material of the ball is (Take g=10 ms^{-2})

a) 10^9 Nm^{-2} b) 2×10^9 Nm^{-2} c) 3×10^9 Nm^{-2} d) 4×10^9 Nm^{-2}

25. If E_θ and E_ϕ denote the isothermal and adiabatic elasticities respectively of a gas, then $\frac{E_\theta}{E_\phi}$

a) < 1 b) > 1 c) $= 1$ d) $= 3.2$

26. The isothermal bulk modulus of a gas at atmospheric pressure is

a) 1 mm of Hg b) 13.6 mm of Hg c) $1.013 \times 10^5 N/m^2$ d) $2.026 \times 10^5 N/m^2$

27. A copper rod of length L and radius r is suspended from the ceiling by one of its ends. What will be elongation of the rod due to its own weight when ρ and Y are the density and Young's modulus of the copper respectively?

a) $\frac{\rho^2 g L^2}{2Y}$ b) $\frac{\rho g L^2}{2Y}$ c) $\frac{\rho^2 g^2 L^2}{2Y}$ d) $\frac{\rho g L}{2Y}$

28. When a weight w is hung from one and of the wire other end being fixed, the elongation produced in it be l. If this wire goes over a pulley and two weights w each are hung at the two ends, the elongation of the wire will be

a) $4l$ b) $2l$ c) l d) $l/2$

29. A and B are two wires. The radius of A is twice that of B. They are stretched by the same load. Then the stress on B is

a) Equal to that on A b) Four times that on A c) Two times that on A d) Half that on A

30. Under elastic limit the stress is

a) Inversely, proportional to strain b) Directly proportional to strain
c) Square root of strain d) Independent of strain

31. In steel, the Young's modulus and the strain at the breaking point are 2×10^6Nm^{-2} and 0.15 respectively. The stress at the break point for steel is

a) 1.33×10^{11}Nm^{-2} b) 1.33×10^{12} Nm^{-2} c) 2×10^{10} Nm^{-2} d) 3×10^{10} Nm^{-2}

32. A cube of side 40 mm has its upper face displaced by 0.1 mm by a tangential force of 8 kN. The shearing modulus of cube is

a) 2×10^9Nm^{-2} b) 4×10^9Nm^{-2} c) 8×10^9Nm^{-2} d) 16×10^9Nm^{-2}

33. Which is the most elastic

a) Iron b) Coppera#####Z c) Quartz d) Wood

34. Identify the incorrect statement.

a) Young's modulus and shear modulus are relevant only for solids
b) Bulk modulus is relevant for solids, liquids and gases
c) Alloys have larger values of Young's modulus than metals
d) Metals have larger values of Young's modulus than elastomers

1 **(c)**

Isothermal bulk modulus = Pressure of gas

2 **(a)**

Young's modulus of a material is given by

$$Y = \frac{F \times L}{A \times l}$$

For a perfectly rigid body,

$l = 0$

$\therefore\ Y = \infty$ (infinite)

3 **(a)**

In the figure OA, stress ∝ strain $i.e.$ Hooke's law hold good

4 **(a)**

$Y \propto F$

$$\therefore\ \frac{F_{Cu}}{F_{Fe}} = \frac{Y_{Cu}}{Y_{Ee}} = \frac{1}{3}$$

5 **(c)**

Young's modulus of wire depends only on the nature of the material of the wire

6 **(c)**

7 **(d)**

$$\frac{Y_A}{Y_B} = \frac{\tan\theta_A}{\tan\theta_B} = \frac{\tan 60}{\tan 30} = \frac{\sqrt{3}}{1/\sqrt{3}} = 3 \Rightarrow Y_A = 3Y_B$$

8 **(b)**

In ductile materials, yield point exist while in Brittle material, failure would occur without yielding

9 **(c)**

As $l = \frac{F}{\pi\left(\frac{d^2}{4}\right)} \times \frac{L}{Y}$ so, $l \propto \frac{L}{d^2}$

$\frac{L}{d^2}$ is maximum for option (c).

10 **(a)**

11 **(b)**

12 **(a)**

When strain is small, the ratio of the longitudinal stress to the corresponding longitudinal strain is called the Young's modulus (Y) of the material of the body.

$$Y = \frac{\text{stress}}{\text{strain}} = \frac{F/A}{l/L}$$

Where F is force, A the area, l the change in length and L the original length.

$$\therefore\ Y = \frac{FL}{\pi r^2 l}$$

r being radius of the wire.

Given $r_2 = 2r_1,\ L_2 = 2L_1, F_2 = 2F_1$

Since, Young's modulus is a property of material, we have

$Y_1 = Y_2$

$$\therefore\ \frac{F_1 L_1}{\pi r_1^2 l_1} = \frac{2F_1 \times 2L_1}{\pi (2r_1)^2 l_2}$$

$l_2 = l_1 = l$

Hence, extension produced is same as that in the other wire.

13 **(b)**

Out of the given substances, steel has greater value of Young's modulus. Therefore, steel has highest elasticity.

14 **(c)**

$$Y = \frac{Fl}{\pi r^2 \Delta l} \text{ or } \Delta l = \frac{F}{\pi r^2 Y}$$

$$\Delta l \propto \frac{1}{r^2}, \Delta l' \propto \frac{2l}{\left(\sqrt{2r}\right)^2} \text{ or } \Delta l' \propto \frac{1}{r^2}$$

$$\therefore\ \frac{\Delta l}{\Delta l'} = 1$$

15 **(a)**

$$l = \frac{FL}{AY} = \frac{4.8 \times 10^3 \times 4}{1.2 \times 10^{-4} \times 1.2 \times 10^{11}} = 1.33\ mm$$

16 **(b)**

For triatomic gas $\gamma = \frac{4}{3}$

17 **(c)**

18 **(d)**

Young's modulus, $Y = \frac{\text{Stress}}{\text{Strain}} = \frac{\frac{\text{Force}}{\text{Area}}}{\frac{l}{L}}$

Where, l is change in length and L the original length.

Force $= mg$, Area $= A = \pi r^2$

$\therefore Y = \frac{FL}{\pi r^2 l}$

$\therefore \frac{Y_1}{Y_2} = \frac{F_1 L_1}{\pi r_1^2 l_1} \times \frac{\pi r_2^2 l_2}{F_2 L_2}$

$\Rightarrow \quad \frac{l_1}{l_2} = \frac{r_2^2}{r_1^2}$

(as all other quantities remain same for both the wires)

Given, $r_2 = 2r_1$

$\therefore \frac{l_1}{l_2} = \frac{(2r_1)^2}{r_1^2} = \frac{4}{1}$

19 **(c)**

Let L be the length of each side of cube. Initial volume $= L^3$. When each side decreases by 1%.

New length $L' = L - \frac{1}{100} = \frac{99L}{100}$

New volume $= L'^3 = \left(\frac{99L}{100}\right)^3$, change in volume,

$\Delta V = L^3 - \left(\frac{99L}{100}\right)^3$

$= L^3\left[1 - \left(1 - \frac{3}{100} + \cdots\right)\right] = L^3\left[\frac{3}{100}\right] = \frac{3L^3}{100}$

$\therefore Bulk\ strain = \frac{\Delta V}{V} = \frac{3L^3/100}{L^3} = 0.03$

20 **(b)**

Young's modulus of wire does not vary with dimension of wire. It is the property of given material

21 **(b)**

According the Hooke's law modulus of elasticity E.

$= \frac{\text{Stress}}{\text{Strain}} = \text{Constant}$

Hence, if stress is increased, then the ratio of stress to strain remains constant.

22 **(b)**

Breaking force $\propto \pi r^2$

If thickness (radius) of wire is doubled then breaking force will become four times

23 **(a)**

Elasticity of wire decreases at high temperature $i.e.$ at higher temperature slope of graph will be less

So we can say that $T_1 > T_2$

24 **(b)**

$\Delta p = h\rho g = 200 \times 10^3 \times 10 \text{Nm}^{-2}$

$= 2 \times 10^6 \text{ Nm}^{-2}$

$K = \frac{\Delta p}{\frac{\Delta V}{V}} = \frac{2 \times 10^6}{\frac{0.1}{100}} = \frac{2 \times 10^8}{0.1} \text{ Nm}^{-2} = 2 \times 10^9 \text{ Nm}^{-2}$

25 **(a)**

Isothermal elasticity $= p$, Adiabatic elasticity $= \gamma P$

$\therefore \frac{E_\theta}{E_\phi} = \frac{1}{\Upsilon}, \Upsilon > 1$

$\therefore \frac{E_\theta}{E_\phi} < 1$

26 **(c)**

Isothermal elasticity $K_i = P = 1 atm = 1.013 \times 10^5 \ N/m^2$

27 **(d)**

The weight of the rod can be assumed to act at its mid-point.

Now, the mass of the rod is

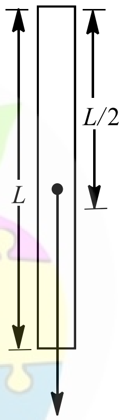
$M = V\rho$

$\Rightarrow M = AL\rho$

Here, $A =$ area of cross $-$ sections,

L= length of the rod.

Now, we know that the Young's modulus



$Mg = V\rho g$

$Y = \frac{\frac{MgL}{2}}{A \cdot l}$ (Here, $L = \frac{L}{2}, l =$ extension)

$\Rightarrow \quad l = \frac{\frac{MgL}{2}}{AY}$

or $\quad l = \frac{MgL}{2AY}$

On putting the value of M from Eq.(i), we get

$l = \frac{AL\rho \cdot gL}{2AY}$

or $l = \frac{\rho g L^2}{2Y}$

28 **(c)**

$Y = \frac{w}{A} \times \frac{L}{l}$ or $l = \frac{wL}{YA}$

When wire goes over a pulley and weight w is attached each free ad end of wire, then the tension in the wire is doubled, but the original length of wire is reduced to half, so extension in the wire is

$l' = \frac{2w \times (L/2)}{YA} = \frac{wL}{YA} = l$

29 **(b)**

Stress $= \frac{\text{force}}{\text{Area}} \therefore$ Stress $\propto \frac{1}{\pi r^2}$

$$\frac{S_B}{S_A} = \left(\frac{r_A}{r_B}\right)^2 = (2)^2 \Rightarrow S_B = 4S_A$$

30 **(b)**

31 **(d)**

Stress = Strain

$= 2 \times 10^{11} \times 0.15 \text{ Nm}^{-2} = 3 \times 10^{10} \text{ Nm}^{-2}$

32 **(a)**

Shearing modulus of cube

$$\eta = \frac{FL}{Al}$$

$$= \frac{8 \times 10^3 \times 40 \times 10^{-3}}{(40 \times 10^{-3})^2 \times (0.1 \times 10^{-3})} = 2 \times 10^9 \text{Nm}^{-2}$$

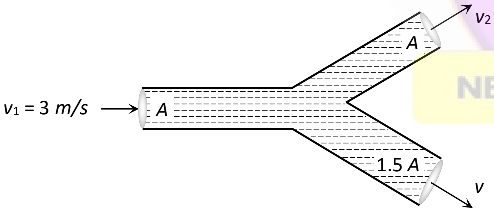
33 **(c)**

34 **(d)**

Metals have larger values of Young's modulus than elastomers because the alloys having high densities, *ie,* alloys have larger values of Young's modulus than metals.

Fluid Mechanics

1. A container with square base of side a hight H with a liquid. A hole is made at a depth h from the free surface of water. With what acceleration the container must be accelerated, so that the water does not come out?
   a) G b) $\frac{g}{2}$ c) $\frac{2gH}{2}$ d) $\frac{2gh}{a}$
2. The pressure on a swimmer 20 m below the surface of water at sea level is
   a) 1.0 atm b) 2.0 atm c) 2.5 atm d) 3.0 atm
3. If a drop of water is broken in to smaller drops the surface energy
   a) Increases b) Decreases
   c) Remains unchanged d) Can increases as well as decreases
4. An incompressible liquid flows through a horizontal tube as shown in the following fig. Then the velocity v of the fluid is



   a) 3.0 m/s b) 1.5 m/s c) 1.0 m/s d) 2.25 m/s
5. Determine the energy stored in the surface of a soap bubble of radius 2.1 cm if its surface tension is 4.5×10^{-2} Nm^{-1}.
   a) 8 mJ b) 2.46 mJ c) 4.93×10^{-4} J d) None of these
6. If the velocity head of a stream of water is equal to 10 cm, then its speed of flow is ($g = 10$ ms^{-2})
   a) 10 ms^{-1} b) 140 ms^{-1} c) 1.4 ms^{-1} d) 0.1 ms^{-1}
7. If pressure at half the depth of a lake is equal to 2/3 pressure at the bottom of the lake then what is depth of the lake
   a) 10 m b) 20 m c) 60 m d) 30 m
8. For a liquid which is rising in a capillary, the angle of contact is
   a) Obtuse b) 180° c) Acute d) 90°
9. The relative velocity of two parallel layers of water is 8 cms^{-1}. If the perpendicular distance between the layers is 0.1 cm, then velocity gradient will be
   a) 40 s^{-1} b) 50 s^{-1} c) 60 s^{-1} d) 80 s^{-1}

10. A horizontal pipe of non-uniform cross-section allows water to flow through it with a velocity 1 ms^{-1} when pressure is 50 kPa at a point. If the velocity of flow has to be 2 ms^{-1} at some other point, the pressure at that point should be

a) 50 kPa b) 100 kPa c) 48.5 kPa d) 24.25 kPa

11. The height of a mercury barometer is 75 cm at sea level and 50 cm at the top of a hill. Ratio of density of mercury to that of air is 10^4. The height of the hill is

a) 250 m b) 2.5 km c) 1.25 km d) 750 m

12. With the increase in temperature, the angle of contact

a) Decreases b) Increases
c) Remains constant d) Sometimes increases and sometimes decreases

13. A small spherical ball of steel falls through a viscous medium with terminal velocity$v$. If a ball of twice the radius of the first one but of the same mass is dropped through the same method, it will fall with a terminal velocity (neglect buoyancy)

a) $\frac{v}{2}$ b) $\frac{v}{\sqrt{2}}$ c) v d) $2v$

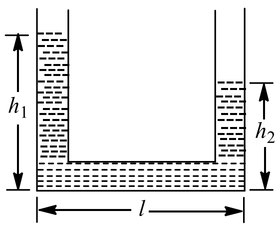
14. The work done in increasing the size of a rectangular soap film with dimensions 8cm × 3.75 cm to 10cm × 6cm is 2×10^{-4} J. The surface tension of the film in Nm^{-1} is

a) 1.65×10^{-2} b) 3.3×10^{-2} c) 6.6×10^{-2} d) 8.25×10^{-2}

15. The height of the dam, in an hydroelectric power station is 10 m. In order to generate 1 MW of electric power, the mass of water (in kg) that must fall per second on the blades of the turbine is

a) 10^6 b) 10^5 c) 10^3 d) 10^4

16. A liquid of density ρ is filled in a U-tube is accelerated with an acceleration a so that the height of liquid in its two vertical arms are h_1 and h_2 as shown in the figure. If l is the length of horizontal arm of the tube, the acceleration a is



a) $\frac{g(h_1-h_2)}{2l}$ towards right b) $\frac{g(h_1-h_2)}{2l}$ towards left
c) $\frac{g(h_1-h_2)}{l}$ towards right d) $\frac{g(h_1-h_2)}{l}$ towards left

17. A frame made of metallic wire enclosing a surface area A is covered with a soap film. If the area of the frame of metallic wire is reduced by 50% , the energy of the soap film will be changed by

a) 100% b) 75% c) 50% d) 25%

18. When a pinch of salt or any other salt which is soluble in water is added to water, its surface tension

a) Increases b) Decreases
c) May increase or decrease depending upon salt d) None of the above

19. The pressure inside two soap bubble is 1.01 and 1.02 atm respectively. The ratio of their respective volume is

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

20. One drop of soap bubble of diameter D breaks into 27 drops having surface tension . The change in surface energy is

a) $2\pi TD^2$ b) $4\pi TD^2$ c) πTD^2 d) $8\pi TD^2$

21. Two rain drops of same radii $'r'$, falling with terminal velocity $'v'$ merge and form a bigger drop of radius R. The terminal velocity of the bigger drop is

a) $v\frac{R}{r}$ b) $v\frac{R^2}{r^2}$ c) v d) $2v$

22. A bigger drop of radius R is converted into n smaller drops of radius r, the required energy is

a) $(4\,\pi r^2 n - 4\,\pi\, R^2)T$ b) $\left(\frac{4}{3}\,\pi r^2 n - \frac{4}{3}\,\pi\, R^3\right)T$ c) $(4\,\pi R^2 - 4\,\pi\, r^2)nT$ d) $(n4\,\pi r^2 - n4\,\pi\, R^2)T$

23. Why the dam of water reservoir is thick at the bottom

a) Quantity of water increases with depth
b) Density of water increases with depth
c) Pressure of water increases with depth
d) Temperature of water increases with depth

24. The level of water in a tank is 5 m high. A hole of area 10 cm^2 is made in the bottom of the tank. The rate of leakage of water from the hole is

a) $10^{-2}\text{m}^3\text{s}^{-1}$ b) $10^{2}\text{m}^3\text{s}^{-1}$ c) $10\ \text{m}^3\text{s}^{-1}$ d) $10^{-2}\text{m}^{-3}\text{s}^{-1}$

25. Two pieces of metal when immersed in a liquid have equal upthrust on them; then

a) Both pieces must have equal weights
b) Both pieces must have equal densities
c) Both pieces must have equal volumes
d) Both are floating to the same depth

26. Streamline flow is more likely for liquid with

a) high density and low viscosity
b) low density and high viscosity
c) high density and high viscosity
d) low density and low viscosity

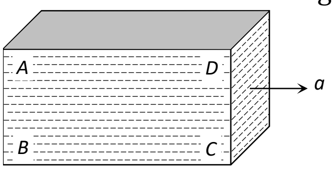
27. Work done forming a liquid drop of radius R is W_1 and that of radius $3R$ is W_2. The ratio of work done is

a) 1:3 b) 1:2 c) 1:4 d) 1:9

28. Two capillary tubes of radii 0.2 cm and 0.4 cm are dipped in the same liquid. The ratio of heights through which liquid will rise in the tubes is

a) 1 : 2 b) 2 : 1 c) 1 : 4 d) 4 : 1

29. A closed rectangular tank is completely filled with water and is accelerated horizontally with an acceleration a towards right. Pressure is (i) maximum at, and (ii) minimum at



a) (i) B (ii) D b) (i) C (ii) D c) (i) B (ii) C d) (i) B (ii) A

30. At which of the following temperatures, the value of surface tension of water is minimum?

a) 4°C b) 25°C c) 50°C d) 75°C

31. A body floats in water with one-third of its volume above the surface of water. If it is placed in oil, it floats with half of its volume above the surface of the oil. The specific gravity of the oil is

a) $\frac{5}{3}$ b) $\frac{4}{3}$ c) $\frac{3}{2}$ d) 1

32. A horizontal pipe line carries water in streamline flow. At a point where the cross-sectional area is 10 cm^2 the water velocity is 1 ms^{-1} and pressure is 2000 Pa. The pressure of water at another point where the cross-sectional area is 5 cm^2, is

a) 200 Pa b) 400 Pa c) 500 Pa d) 800 Pa

33. A manometer connected to a close tap reads $3.5 \times 10^5\ \text{Nm}^{-2}$. When the valve is opened, the reading of manometer falls to $3.0 \times 10^5\ \text{Nm}^{-2}$, then velocity of flow of water is

a) $100\ \text{ms}^{-1}$ b) $10\ \text{ms}^{-1}$ c) $1\ \text{ms}^{-1}$ d) $10\sqrt{10}\ \ \text{ms}^{-1}$

34. The neck and bottom of a bottle are 3 cm and 15 cm in radius respectively. If the cork is pressed with a force 12 N in the neck of the bottle, then force exerted on the bottom of the bottle is

a) 30 N b) 150 N c) 300 N d) 600 N

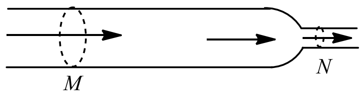
35. If the atmospheric pressure is P_a, then the pressure P at depth h below the surface of a liquid of density ρ open to the atmosphere is

a) $P_a - \frac{\rho g h}{2}$ b) $P_a - \rho g h$ c) P_a d) $P_a + \rho g h$

36. A ball whose density is $0.4 \times 10^3 \text{kg m}^{-3}$ falls into water from a height of 9 cm. To what depth does the ball sink?

a) 9 cm b) 6 cm c) 4.5 cm d) 2.25 cm

37. Horizontal tube of non-uniform cross-section has radii of 0.1 m and 0.05 m respectively at M and N. For a streamline flow of liquid the rate of liquid flow is



a) Changing continuously with time b) Greater at M than N
c) Greater at N than at M d) Same at M and N

38. In a turbulent flow, the velocity of the liquid in contact with the walls of the tube is

a) Zero b) maximum
c) in between zero and maximum d) equal to critical velocity

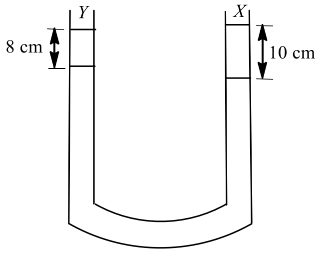
39. A block of ice floats on a liquid of density 1.2 in a beaker then level of liquid when ice completely melt

a) Remains same b) Rises c) Lowers d) (a), (b) or (c)

40. A square wire frame of size L is dipped in a liquid. On taking out a membrane is formed. If the surface tension of liquid is T, then the force acting on a frame will be

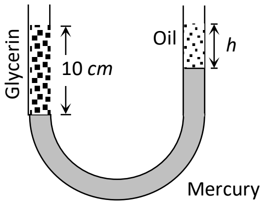
a) $2\,T/L$ b) $4T/L$ c) $8\,T/L$ d) $16\,T/L$

41. A liquid X of density 3.36 g cm^{-3} is poured in a U-tube, which contains Hg. Another liquid Y is poured in left arm with height 8 cm, upper levels of X and Y are same. What is density of Y?



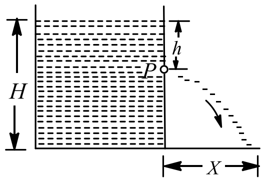
a) 0.8 gcc^{-1} b) 1.2 gcc^{-1} c) 1.4 gcc^{-1} d) 1.6gcc^{-1}

42. A vertical U-tube of uniform inner cross section contains mercury in both sides of its arms. A glycerin (density $= 1.3\ g/cm^3$) column of length $10\ cm$ is introduced into one of its arms. Oil of density $0.8\ gm/cm^3$ is poured into the other arm until the upper surfaces of the oil and glycerin are in the same horizontal level. Find the length of the oil column. Density of mercury $= 13.6\ g/cm^3$



a) 10.4 cm b) 8.2 cm c) 7.2 cm d) 9.6 cm

43. A tank is filled with water upto a height H. Water is allowed to come out of a hole P in one of the walls at a depth h below the surface of water (see figure). Express the horizontal distance X in terms of H and h



a) $X = \sqrt{h(H-h)}$ b) $X = \sqrt{\frac{h}{2}(H-h)}$ c) $X = 2\sqrt{h(H-h)}$ d) $X = 4\sqrt{(H-h)}$

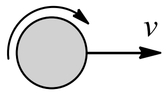
44. Bernoulli's theorem is a consequence of the law of conservation of

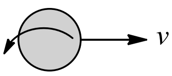
a) Momentum b) Mass c) Energy d) angular momentum

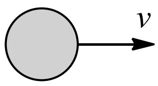
45. Two very wide parallel glass plates are held vertically at a small separation r, and dipped in water of surface tension S. Some water climbs up in the gap between the plates. If p_0 is the atmospheric pressure, then the pressure of water just below the water surface in the region between the two plates is

a) $p_0 - \frac{2S}{r}$ b) $p_0 + \frac{2S}{r}$ c) $p_0 - \frac{4S}{r}$ d) $p_0 + \frac{4S}{r}$

46. To get the maximum flight, a ball must be thrown as

a) 

b) 

c) 

d) None of these

47. A liquid of density 800 kg m^3 is filled in a tank open at the top. The pressure of the liquid at the bottom of the tank is 6.4 atm. The velocity of efflux through a hole at the bottom is($1\text{ atm} = 10^5\ Nm^{-2}$)

a) $10\ ms^{-1}$ b) $20\ ms^{-1}$ c) $30\ ms^{-1}$ d) $40\ ms^{-1}$

48. When a number of small droplets combine to form a large drop, then

a) energy is absorbed b) energy is liberated

c) energy is neither liberated nor absorbed d) process is independent of energy

49. The velocity of the surface layer of water in a river of depth 10 m is 5 m s^{-1}. The shearing stress between the surface layer and the bottom layer is (Coefficient of viscosity of water, $\eta = 10^{-3}$ SI units)

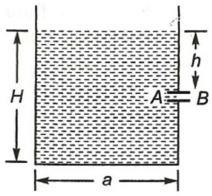
a) $0.6 \times 10^{-3} N\ m^{-2}$ b) $0.8 \times 10^{-3} N\ m^{-2}$ c) $0.5 \times 10^{-3} N\ m^{-2}$ d) $10^{-3} N\ m^{-2}$

: HINTS AND SOLUTIONS :

1 **(d)**

Bernoulli's theorem is a form of conversion of energy, hence we have

$$H_0 + h\rho g = H_0 + \frac{1}{2}\rho v^2$$



When vessel is accelerated down with an acceleration g (free fall), then pseudo acceleration g will act vertically upwards and effective value of g is zero. Hence, water will not flow.

2 **(d)**

Pressure at depth $h = p_a + \rho g h$

where p_a is atmospheric pressure

$= 1.01 \times 10^5$ Nm^2

$\therefore \quad p_{\text{total}} = 1.01 \times 10^5 + 10^3 \times 10 \times 20$

$= 3.01 \times 10^5$ Pa $= 3$ atm

3 **(a)**

When a drop of radius R splits into n smaller drops, (each of radius r), then surface area of liquid increases and hence surface energy increases.

4 **(c)**

If the liquid is incompressible then mass of liquid entering through left end, should be equal to mass of liquid coming out from the right end

$\therefore M = m_1 + m_2 \Rightarrow Av_1 = Av_2 + 1.5A.v$

$\Rightarrow A \times 3 = A \times 1.5 + 1.5A.v \Rightarrow v = 1\ m/s$

5 **(c)**

Surface energy $U = S \times 2 \times 4\pi R^2$

(As there are 2 surfaces in soap bubble)

$U = 4.5 \times 10^{-2} \times 8\pi \times (2.1 \times 10^{-2})^2$

$= 4.93 \times 10^{-4}$ J

6 **(c)**

Velocity head, $h = \frac{1}{2}\frac{v^2}{g}$ or $v = \sqrt{2gh}$

$= \sqrt{2 \times 10 \times 0.1} = 1.4$ ms^{-1}

7 **(b)**

Pressure at bottom of the lake $= P_0 + h\rho g$

Pressure at half the depth of a lake $= P_0 + \frac{h}{2}\rho g$

According to given condition

$$P_0 + \frac{1}{2}h\rho g = \frac{2}{3}(P_0 + h\rho g) \Rightarrow \frac{1}{3}P_0 = \frac{1}{6}h\rho g$$

$$\Rightarrow h = \frac{2P_0}{\rho g} = \frac{2 \times 10^5}{10^3 \times 10} = 20m$$

8 **(c)**

The angle θ, which the tangent to the liquid surface at the point of contact makes with the solid surface inside the liquid, is called the angle of contact or the capillary angle. The angle of contact is acute (less than 90°) in the case of liquids which wet the walls of the container, then liquid rises in the capillary and angle of contact is obtuse (greater than 90°) for the liquid which do not wet the walls of the container, *ie*, they fall in capillary tube.

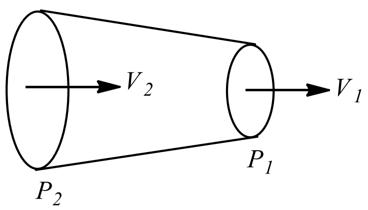
9 **(d)**

The velocity gradient

$$= \frac{\Delta V}{\Delta r} = \frac{8}{0.1} = 80 s^{-1}$$

10 **(c)**

According to Bernoulli's equation for horizontal pipe,



$$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$$

$$\Longrightarrow p_1 + \frac{1}{2}\rho(v_1^2 - v_2^2) = p_2$$

$$\Longrightarrow \quad p_2 = 50 \times 10^3 + \frac{1}{2} \times 10^3 \times (1^2 - 2^2)$$

$$\Longrightarrow \quad p_2 = 50 \times 10^3 - 1.5 \times 10^3$$

$= 48.5$ kPa

11 **(b)**

Difference of pressure between sea level and the top of hill

$\Delta P = (h_1 - h_2) \times \rho_{Hg} \times g = (75 - 50) \times 10^{-2} \times \rho_{Hg} \times g$ ...(i)

and pressure difference due to h metre of air

$\Delta P = h \times \rho_{air} \times g$ ...(ii)

By equating (i) and (ii) we get

$h \times \rho_{air} \times g = (75 - 50) \times 10^{-2} \times \rho_{Hg} \times g$

$\therefore h = 25 \times 10^{-2} \left(\frac{\rho_{Hg}}{\rho_{air}}\right) = 25 \times 10^{-2} \times 10^4$

$= 2500m$

$\therefore$ Height of the hill $= 2.5\ km$

12 **(a)**

With the increase in temperature, the surface tension of liquid decreases and angle of angle also decreases

13 **(a)**

Given, $v = \frac{2r^2\rho g}{9\eta}$ ...(i)

Mass $= \frac{4}{3}\pi r^3 \rho = \frac{4}{3}\pi (2r)^3 \rho_1$

Or $\rho_1 = \rho/8$

Terminal velocity of second ball is

$$v_1 = \frac{2(2r)^2(\rho/8)g}{8\,\eta} = \frac{v}{2}$$

14 **(b)**

Change in surface energy $= 2 \times 10^{-4}$ J

$\Delta A = 10 \times 6 - 8 \times 3.75$

$= 30\ \text{cm}^2$

$= 30 \times 10^{-4}\text{m}^2$

Work done $W = T \times 2 \times$ (change in area)

Now, change in surface energy = Work done

$2 \times 10^{-4} = T \times 2 \times 30 \times 10^{-4}$

$T = 3.3 \times 10^{-2}\ \text{Nm}^{-1}$

15 **(d)**

Using

Potential energy $= mgh \Rightarrow 1 \times 10^6 = m \times 10 \times 10$

$m = 10^4 kg/sec$

16 **(c)**

Pressure on left end of horizontal tube,

$p_1 = p_0 + h_1\rho g$

Pressure on right end of horizontal tube,

$p_2 = p_0 + h_2\rho\ g$

As $p_1 > p_2$, so acceleration should be towards right hand side. If A is the area of cross-section of the tube in the horizontal portion of U-tube, then

$p_1\ A - p_2\ A = (l\ A\ \rho)a$

Or $(h_1 - h_2)\rho\ g\ A = l\ A\ \rho\ a = \frac{g(h_1 - h_2)}{l}$

17 **(c)**

Surface energy = surface tension $\times$ surface area

$E = T \times 2A$

New surface energy,

$E_1 = T \times 2\left(\frac{A}{2}\right) = T \times A$

% decrease in surface energy $= \frac{E - E_1}{E} \times 100$

$= \frac{2TA - TA}{2TA} \times 100 = 50\%$

18 **(a)**

When a highly soluble salt (like sodium chloride) is dissolved in water, the surface tension of water increases

19 **(a)**

Excess pressure is given by $p = \frac{4T}{r}$

$\Rightarrow\ r = \frac{4T}{p}$

$\therefore\ \frac{r_1}{r_2} = \frac{p_2}{p_1} = \frac{1.02}{1.01} = \frac{102}{101}$

Ratio of volume's $= \frac{\frac{4}{3}\pi r_1^3}{\frac{4}{3}\pi r_2^3} = \frac{(102)^3}{(101)^3} \approx 2$

20 **(a)**

Surface tension (T) of a liquid is equal to the work (W) required to increases the surface area (ΔA) of the liquid film by unity at constant temperature.

$W = T\Delta A$ = surface energy

Also, volume of big drop $= 27 \times$ volume of small drop

$ie, V' = 27V$

Where V' is volume of big drop of diameter D and V the volume of small drop of diameter d.

$\therefore\ \frac{4}{2}\pi\left(\frac{D}{2}\right)^3 = 27 \times \frac{4}{3}\pi\left(\frac{d}{2}\right)^3$

$\Rightarrow\ \frac{D}{2} = 3 \times \frac{d}{2}$

$\Rightarrow\ d = \frac{D}{3}$

Radius of small drop, $r = \frac{d}{2} = \frac{D}{6}$.

$\therefore$ Change in surface energy $= T(A_2 - A_1)$

$= T[27.4\pi r^2 - 4\pi R^2]$

$= T4\pi\left[27\left(\frac{D}{6}\right)^2 - \left(\frac{D}{6}\right)^2\right]$

$= 4\pi T\left[\frac{3D^2}{4} - \frac{D^2}{4}\right] = 2\pi D^2 T$

21 **(b)**

Terminal velocity

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

$v \alpha r^2$

$\frac{v}{V} = \frac{r^2}{R^2} \Rightarrow V = \frac{vR^2}{r^2}$

22 **(a)**

Work done = surface tension × increase in surface area

$= T(n\, 4\, \pi r^2 - 4\, \pi\, R^2)$

23 **(c)**

A torque is acting on the wall of the dam trying to make it topple. The bottom is made very broad so that the dam will be stable

24 **(a)**

Velocity of efflux, $v = \sqrt{2\, gh}$;

Volume of liquid flowing out per sec

$= v \times A = \sqrt{2\, gh} \times A$

$= \sqrt{2 \times 10 \times 5} \times (10 \times 10^{-4}) = 10^{-2} \mathrm{m^3 s^{-1}}$

25 **(c)**

Since, up thrust $(F) = V\sigma g$ *i.e.* $F \propto V$

26 **(d)**

Streamline flow is more likely for non-viscous and incompressible liquid. So low density and low viscosity is the correct answer.

27 **(d)**

$W = T \times 4\pi R^2$

$\Longrightarrow \frac{W_1}{W_1} = \frac{T \times 4\pi R^2}{T \times 4\pi (3R)^2}$

$= \frac{T \times 4\pi R^2}{T \times 36\pi R^2} = \frac{1}{9}$

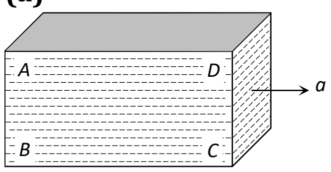
$\therefore\ W_1 : W_2 = 1:9$

28 **(b)**

Height, $h \propto 1/R$

So $h_1/h_2 = R_2/R_1 = 0.4/0.2 = 2$

29 **(a)**



Due to acceleration towards right, there will be a pseudo force in a left direction. So the pressure will be more on rear side (Points A and B) in comparison with front side (Point D and C)

Also due to height of liquid column pressure will be more at the bottom (points B and C) in comparison with top (point A and D)

So overall maximum pressure will be at point B and minimum pressure will be at point D

30 **(d)**

Surface tension of water decreases with rise in temperature

31 **(b)**

Weight of body

= weight of water displaced

= weight of oil displaced

$\Rightarrow \frac{2}{3} V \rho_w g = \frac{1}{2} V \rho_0 g$

$\Rightarrow \rho_0 = \frac{4}{3} \rho_w$

$\therefore$ Specific gravity of oil $= \frac{\rho_0}{\rho_w} = \frac{4}{3}$

32 **(c)**

Since cross-sectional area is halved, therefore, velocity is doubled.

Now, $p_1 = 2000\mathrm{Pa}, v_1 = 1\mathrm{ms^{-1}}$

$p_2 = ?, v_2 = 2\ \mathrm{ms^{-1}}$

Again $p_2 + \frac{1}{2} \times 1000 \times 2 \times 2$

$= 2000 + \frac{1}{2} \times 1000 \times 1 \times 1$

or $p_2 = 2000 + 500(1 - 4) = 500\mathrm{Pa}$

33 **(b)**

Bernoulli's theorem for unit mass of liquid

$\frac{P}{\rho} + \frac{1}{2} v^2$ constant

As the liquid starts flowing , it pressure energy decreases

$\frac{1}{2} v^2 = \frac{P_1 - P_2}{\rho}$

$\Longrightarrow \frac{1}{2} v^2 = \frac{3.5 \times 10^5 - 3 \times 10^5}{10^3}$

$\Longrightarrow v^2 = \frac{2 \times 0.5 \times 10^5}{10^3}$

$\Longrightarrow v^2 = 100$

$\Longrightarrow v = 10\ \mathrm{ms^{-1}}$

34 **(c)**

Pressure at neck of bottle

$p_1 = \frac{F_1}{A_1} = \frac{F_1}{\pi\, r_1^2}$

Similarly, pressure at bottom of bottle

$p_2 = \frac{F_2}{A_2} = \frac{F_2}{\pi\, r_2^2}$

According to Pascal's law, liquids transmits pressure equal in all directions.

$\therefore\ \frac{F_2}{A_2} = \frac{F_2}{\pi\, r_2^2}$ *or* $F_2 = F_1 \times \left(\frac{r_2}{r_1}\right)^2$

$= 12 \times \left(\frac{15}{3}\right)^2 = 12 \times 25 = 300\mathrm{N}$

35 **(d)**

$P = P_a + \rho g h$

36 **(b)**

The velocity of ball before entering the water surface

$v = \sqrt{2gh} = \sqrt{2g \times 9}$

When a ball enters into water, due to upthrust of water the velocity of ball decreases (or retarded) The retardation,

$a = \dfrac{\text{apparent weight}}{\text{mass of ball}}$

$a = \dfrac{V(\rho - \sigma)g}{V\rho} = \dfrac{(\rho - \sigma)g}{\rho}$

$\left(\dfrac{0.4 - 1}{0.4}\right)g = -\dfrac{3}{2}g$

If h be the depth upto which ball sink, then

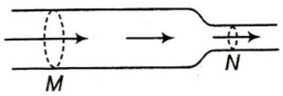
$0 - v^2 = 2 \times \left(\dfrac{-3}{2}g\right) \times h$

$\Rightarrow\ 2g \times 9 = 3gh$

$\therefore\quad h = 6\ \text{cm}$

37 **(c)**

The velocity of flow will increases if cross-section decreases and $vice - versa$



$ie,\ \ A_1v_1 = A_2v_2$

or $\ \ A_v = \text{constant}$

Therefore, the rate of liquid flow will be greater at N than at M.

38 **(d)**

In a turbulent flow, the velocity of the liquid in contact with the walls of the tube is equal is critical velocity.

39 **(b)**

The volume of liquid displaced by floating ice

$V_D = \frac{M}{\sigma_L}$

Volume of water formed by melting ice, $V_F = \frac{M}{\sigma_W}$

If $\sigma_L > \sigma_W$, then $\frac{M}{\sigma_L} < \frac{M}{\sigma_W}$ $i.e. V_D < V_F$

$i.e.$ volume of liquid displaced by floating ice will be lesser than water formed and so the level if liquid will rise

40 **(c)**

Since the wire frame is dipped in liquid, therefore its membrane has two free surfaces. Total length of square wire frame in contact of membrane

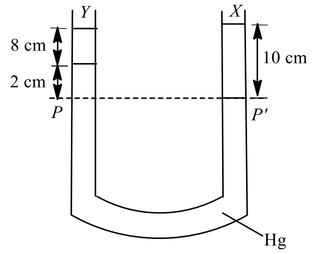
$= 2 \times \text{perimeter of square} = 2 \times 4L = 8L$

Hence, force acting on a frame

$F = Tl = T \times 8L = 8L$

41 **(a)**

As shown in figure, in the two arms of a tube pressure remains same on surface PP'.

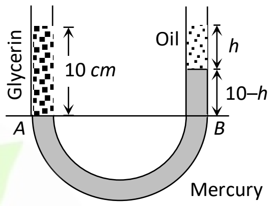


Hence, $8 \times \rho_y \times g \times 2 \times \rho_{Hg} \times g = 10 \times \rho_x \times g$

$\therefore 8\rho_y + 2 \times 113.6 = 10 \times 3.36$

or $\ \rho_y = \frac{36.6 - 27.2}{8} = 0.8\ \text{g cc}^{-1}$

42 **(d)**



At the condition of equilibrium

Pressure at point A = Pressure at point B

$P_A = P_B \Rightarrow 10 \times 1.3 \times g$

$= h \times 0.8 \times g + (10 - h) \times 13.6 \times g$

By solving we get $h = 9.6\ cm$

43 **(c)**

Vertical distance covered by water before striking ground$= (H - h)$. Time taken is, $t = \sqrt{2(H-h)g}$;

Horizontal velocity of water coming out of hole at $P, u = \sqrt{2gh}$

$\therefore$ Horizontal range

$= ut = \sqrt{2gh} = \sqrt{2(H-g)/g}$

$= 2\sqrt{h(H-h)}$

44 **(c)**

According to the Berboulli's theorem the total energy (pressure energy, potential energy and kinetic energy) of an incompressible and non viscous fluid in steady flow through a pipe remains constant throughout the flow.

$ie,\quad p + \rho gh + \dfrac{1}{2}\rho v^2 = \text{constant}.$

So, it is clear that Bernouli's theorem is a consequence of the law of conservation of energy.

45 **(a)**

Here, the free liquid surface between the plates will be cylindrical which is curved along one axis (parallel to the plates). The radius of curvature of meniscus, $R = r/2$. For cylindrical surface

$$p_0 - p = \frac{S}{R} = \frac{S}{r/2} = \frac{2S}{r}$$

$$\therefore p = p_0 - \frac{2S}{r}$$

46 **(b)**

When a ball is given anticlockwise rotation along with linear motion towards RHS then it will have maximum flight

47 **(d)**

Velocity of efflux $v = \sqrt{2gh}$

But $h\rho g = p$

$$\therefore \ hg = \frac{p}{\rho}$$

$$\therefore \ v = \sqrt{\frac{2p}{\rho}}$$

$$= \sqrt{\frac{2 \times 6.4 \times 10^5}{800}} \text{ms}^{-1}$$

$$= 40 \text{ ms}^{-1}$$

48 **(b)**

When a number of small droplets coalesce to form a bigger drop surface energy is released because its surface area decreases.

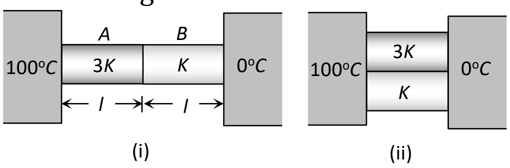
49 **(a)**

Using Pascal's law

$$P_1 = P_2 \Rightarrow \frac{F_1}{\left(\frac{\pi d_1^2}{4}\right)} = \frac{F_2}{\left(\frac{\pi d_2^2}{4}\right)} \Rightarrow F_2 = \frac{d_2^2}{d_1^2} F_1$$

Thermal Properties of Matter

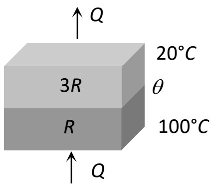
1. If the temperature of the sun were to increase from T to $2T$ and its radius from R to $2R$, when the ratio of radiant energy received on earth to what it was previously, will be
   a) 4 b) 16 c) 32 d) 64
2. A composite rod made of copper ($\alpha = 1.8 \times 10^{-5}\ \mathrm{K}^{-1}$) and steel ($\alpha = 1.2 \times 10^{-5}\ \mathrm{K}^{-1}$) is heated. Then
   a) It bends with steel on concave side
   b) It bends with copper on concave side
   c) It does not expand
   d) Data is insufficient
3. Heat travels through vacuum by
   a) Radiation b) Conduction c) Convection d) None of these
4. Two rods A and B are of equal lengths. Their ends are kept between the same temperature and their area of cross-sections are A_1 and A_2 and thermal conductivities K_1 and K_2. The rate of heat transmission in the two rods will be equal, if
   a) $K_1A_2 = K_2A_1$ b) $K_1A_1 = K_2A_2$ c) $K_1 = K_2$ d) $K_1A_1^2 = K_2A_2^2$
5. Two conducting rods A and B of same length and cross-sectional area are connected (i) In series (ii) In parallel as shown. In both combination a temperature difference of 100°C is maintained. If thermal conductivity of A is $3K$ and that of B is K then the ratio of heat current flowing in parallel combination to that flowing in series combination is



   a) $\frac{16}{3}$ b) $\frac{3}{16}$ c) $\frac{1}{1}$ d) $\frac{1}{3}$
6. 0.1 m^3 of water at 80°C is mixed with 0.3m^3 of water at 60°C. The final temperature of the mixture is
   a) 65°C b) 70°C c) 60°C d) 75°C
7. An amount of water of mass 20 g at 0°C is mixed with 40 g of water 10°C, final temperature of the mixture is
   a) 5°C b) 0°C c) 20°C d) 6.66°C
8. 540 g of ice at 0°C is mixed with 540 g of water at 80°C. The final temperature of the mixture is
   a) 0°C b) 40°C c) 80°C d) Less than 0°C
9. Two spheres made of same substance have diameters in the ratio 1 : 2. Their thermal capacities are in the ratio of
   a) 1 : 2 b) 1 : 8 c) 1 : 4 d) 2 : 1

10. A gas undergoes an adiabatic change. Its specific heat in the process is
a) Zero b) 1 c) ∞ d) None of these

11. In the following figure, two insulating sheets with thermal resistances R and $3R$ as shown in figure. The temperature θ is



a) 20°C b) 60°C c) 75°C d) 80°C

12. On Centigrade scale the temperature of a body increases by 30°.The increase in temperature on Fahrenheit scale is
a) 50° b) 40° c) 30° d) 54°

13. The absolute zero temperature in Fahrenheit scale is
a) $-273°F$ b) $-32°F$ c) $-460°F$ d) $-132°F$

14. When vapour condenses into liquid
a) It absorbs heat
b) It liberates heat
c) Its temperature increases
d) Its temperature decreases

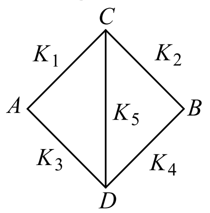
15. A pendulum clock keeps correct time at 0°C. Its mean coefficient of linear expansions is α/°C, then the loss in seconds per day by the clock if the temperature rises by t°C is
a) $\dfrac{\frac{1}{2}\alpha t \times 864000}{1-\frac{\alpha t}{2}}$ b) $\frac{1}{2}\alpha t \times 86400$ c) $\dfrac{\frac{1}{2}\alpha t \times 86400}{\left(1-\frac{\alpha t}{2}\right)^2}$ d) $\dfrac{\frac{1}{2}\alpha t \times 86400}{1+\frac{\alpha t}{2}}$

16. The lengths and radii of two rods made of same material are in the ratios 1:2 and 2:3 respectively. If the temperature difference between the ends for the two rods be the same, then in the steady state, the amount of heat flowing per second through them will be in the ratio
a) 1 : 3 b) 4 : 3 c) 8 : 9 d) 3 : 2

17. If the ratio of densities of two substances is 5 : 6 and that of the specific heats is 3 : 5. Then the ratio between heat capacities per unit volume is
a) 1 : 1 b) 2 : 1 c) 1 : 2 d) 1 : 3

18. Two spheres made of same material have radii in the ratio 1:2. Both are at same temperature. Ratio of heat radiation energy emitted per second by them is
a) 1 : 2 b) 1 : 8 c) 1 : 4 d) 1 : 16

19. Five rods of same dimensions are arranged as shown in figure. They have thermal conductivities K_1, K_2, K_3, K_4 and K_5. When points A and B are maintained at different temperature, no heat would flow through central rod, if



a) $K_1K_4 = K_2\,K_3$
b) $K_1 = K_4$ and $K_2 = K_3$
c) $\dfrac{K_1}{K_4} = \dfrac{K_2}{K_3}$
d) $K_1K_2 = K_3K_4$.

20. Two rods of different materials having coefficient of thermal expansions α_1 and α_2 and Young's moduli Y_1 and Y_2 respectively are fixed between two rigid walls. The rods are heated, such that they undergo the same increase in temperature. There is no bending of rods. If $\alpha_1/\alpha_2=2/3$ and stresses developed in the two rods are equal, then $\frac{Y1}{Y2}$ is
a) 3/2 b) 1 c) 2/3 d) 1/2

21. The ratio of thermal conductivity of two rods of different material is 5:4. The two rods of same area of cross-section and same thermal resistance will have the lengths in the ratio

a) 4 : 5 b) 9 : 1 c) 1 : 9 d) 5 : 4

22. The coefficient of thermal conductivity of a rod depends on

a) Area b) Length

c) Material of rod d) Temperature difference

23. Mode of transmission of heat, in which heat is carried by the moving particles, is

a) Radiation b) Conduction c) Convection d) Wave motion

24. The Fahrenheit and Kelvin scales of temperature will give the same reading at

a) -40 b) 313 c) 574.25 d) 732.75

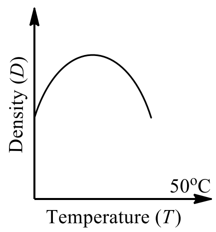
25. Two walls of thicknesses d_1 and d_2 and thermal conductivities k_1 and k_2 are in contact. In the steady state, if the temperatures at the outer surfaces are T_1 and T_2, the temperature at the common wall is

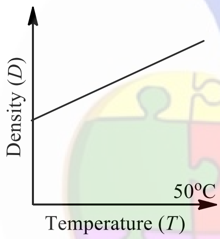
a) $\frac{k_1T_1d_2 + k_2T_2d_1}{k_1d_2 + k_2d_1}$ b) $\frac{k_1T_1 + k_2d_2}{d_1 + d_2}$ c) $\left(\frac{k_1d_1 + k_2d_2}{T_1 + T_2}\right)T_1T_2$ d) $\frac{k_1d_1T_1 + k_2d_2T_2}{k_1d_1 + k_2d_2}$

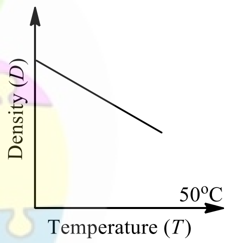
26. Two uniform brass rods A and B of lengths l and $2l$ and radii $2r$ and r respectively are heated to the same temperature. The ratio of the increase in the volumes of A to that of B is

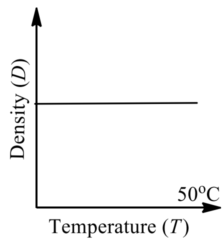
a) 1: 1 b) 1: 2 c) 2: 1 d) 1: 4

27. Which one of the figure gives the temperature dependence of density water correctly?

a) 

b) 

c) 

d) 

28. On a new scale of temperature (which is linear) and called the W scale, the freezing and boiling points of water are $39^o\ W$ and 239^oW respectively. What will be the temperature on the new scale, corresponding to a temperature of 39°C on the Celsius scale

a) 200^oW b) 139^oW c) 78^oW d) 117^oW

29. The SI unit of mechanical equivalent of heat is

a) $Joule \times Calorie$ b) $Joule/Calorie$ c) $Calorie \times Erg$ d) $Erg/Calorie$

30. The two ends of a rod of length L and a uniform cross-sectional area A are kept at two temperature T_1 and T_2 $(T_1 > T_2)$. The rate of heat transfer, $\frac{dQ}{dt}$, through the rod in a steady state is given by

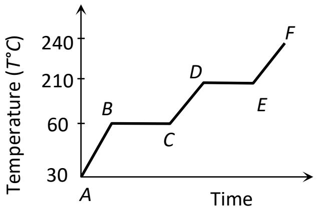
a) $\frac{dQ}{dt} = \frac{kL(T_1 - T_2)}{A}$ b) $\frac{dQ}{dt} = \frac{k(T_1 - T_2)}{LA}$ c) $\frac{dQ}{dt} = kLA(T_1 - T_2)$ d) $\frac{dQ}{dt} = \frac{kA(T_1 - T_2)}{L}$

31. Which of the following is the correct device for the detection of thermal radiation

a) Constant volume thermometer b) Liquid-in-glass thermometer

c) Six's maximum and minimum thermometer d) Thermopile

32. A solid substance is at 30°C. To this substance heat energy is supplied at a constant rate. Then temperature versus time graph is as shown in the figure. The substance is in liquid state for the portion (of the graph)



a) BC b) CD c) ED d) EF

33. In a steady state of thermal conduction, temperature of the ends A and B of a 20 cm long rod are 100°C and 0°C respectively. What will be the temperature of the rod at a point at a distance of 6 cm from the end A of the rod

a) −30°C b) 70°C c) 5°C d) None of the above

34. Wires A and B have identical lengths and have circular cross-section. The radius of A is twice the radius of B $i.e.\ r_A = 2r_B$. For a given temperature difference between the two ends, both wires conduct heat at the same rate. The relation between the thermal conductivities is given by

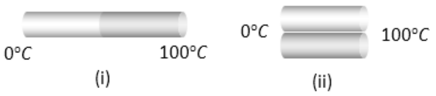
a) $K_A = 4K_B$ b) $K_A = 2K_B$ c) $K_A = K_B/2$ d) $K_A = K_B/4$

35. Absolute zero ($0\ K$) is that temperature at which

a) Matter ceases to exist b) Ice melts and water freezes

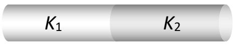
c) Volume and pressure of a gas becomes zero d) None of these

36. Two identical square rods of metal are welded end to end as shown in figure (i), 20 calories of heat flows through it in 4 minutes. If the rods are welded as shown in figure (ii), the same amount of heat will flow through the rods in



a) 1 minute b) 2 minutes c) 4 minutes d) 16 minutes

37 If two metallic plates of equal thicknesses and thermal conductivities K_1 and K_2 are put together face to face and a common plate is constructed, then the equivalent thermal conductivity of this plate will be



a) $\frac{K_1K_2}{K_1+K_2}$ b) $\frac{2K_1K_2}{K_1+K_2}$ c) $\frac{(K_1^2+K_2^2)^{3/2}}{K_1K_2}$ d) $\frac{(K_1^2+K_2^2)^{3/2}}{2K_1K_2}$

38. The coefficient of volume expansion of a liquid is $49 \times 10^{-5} \mathrm{K}^{-1}$. Calculate the fractional change in its density when the temperature is raised by 30°C.

a) 7.5×10^{-3} b) 3.0×10^{-3} c) 1.5×10^{-2} d) 1.1×10^{-3}

39. Total energy emitted by a perfectly black body is directly proportional to T^n where n is

a) 1 b) 2 c) 3 d) 4

40. On heating, the temperature at which water has minimum volume is

a) 0°C b) 4°C c) 4K d) 100°C

1 **(d)**

From Stefan law, the energy radiated by sun is given by. $P = \sigma e A T^4$, assuming e=1 for sun.

In Ist case, $P_1 = \sigma e \times 4\pi R^2 \times T^4$

In 2nd case, $P_2 = \sigma e \times 4\pi(2R^2) \times (2T^4)$

$= \sigma e \times 4\pi R^2 \times T^4 \times 64 = 64P_1$

The rate at which energy is received by earth is,

$$E = \frac{P}{4\pi R_{SE}^2} \times A_E$$

where A_E= area of earth

R_{SE}= distance between sun and earth

So, In Ist case, $E_1 = \frac{P_1}{4\pi R_{SE}^2} \times A_E$

$$E_2 = \frac{P_2}{4\pi R_{SE}^2} \times A_E = 64E_1$$

2 **(a)**

If l_t be length of rod at t°C and l_0 at 0°C, then

$$l_t = l_0(1 + \alpha t)$$

Where α is coefficient of linear expansion.

$\Rightarrow l_t$ is proportional to α. Since $\alpha_c > \alpha_s$, therefore copper will expand more, so rod bends with copper on convex side and steel on concave side.

3 **(a)**

4 **(b)**

$\left(\frac{Q}{t}\right)_1 = \frac{K_1A_1(\theta_1-\theta_2)}{l}$ and $\left(\frac{Q}{t}\right)_2 = \frac{K_2A_2(\theta_1-\theta_2)}{l}$

Given $\left(\frac{Q}{t}\right)_1 = \left(\frac{Q}{t}\right)_2 \Rightarrow K_1A_1 = K_2A_2$

5 **(a)**

Heat current $H = \frac{\Delta\theta}{R} \Rightarrow \frac{H_P}{H_S} = \frac{R_S}{R_P}$

In first case : $R_S = R_1 + R_2 = \frac{l}{(3K)A} + \frac{l}{KA} = \frac{4}{3}\frac{l}{KA}$

In second case : $R_P = \frac{R_1R_2}{R_1+R_2} = \frac{\frac{1}{(3K)A}\times\frac{l}{KA}}{\left(\frac{l}{(3K)A}+\frac{l}{KA}\right)} = \frac{l}{4KA}$

$$\therefore \frac{H_P}{H_S} = \frac{\frac{4l}{3KA}}{\frac{l}{4KA}} = \frac{16}{3}$$

6 **(a)**

Let the final temperature of the mixture be t.

Heat lost by water

at 80°C $\quad = ms\Delta t$

$= 0.1 \times 10^3 \times s_{\text{water}} \times (80° - t)$ $(\because m = V \times d = 0.1 \times 10^3\text{kg})$

Heat against by water at 60°C

$= 0.3 \times 10^3 \times s_{\text{water}} \times (t - 60°)$

According to principle of Calorimetry,

Heat lost = Heat against

$0.1 \times 10^3 \times S_{\text{water}} \times (80° - t) = 0.3 \times 10^3 \times S_{\text{water}} \times (t - 60°)$

or $\quad (80° - t) = 3 \times (t - 60°)$

or $\quad 4t = 260°\text{C}$

or $\quad t = 65°\text{C}$

7 **(d)**

Let θ be the temperature of the mixture.

Heat gained by water at 0°C = Heat lost by water at 10°C

$c\, m_1\, (\theta - 0) = c\, m_2(10 - \theta)$

$$\theta = \frac{400}{60} = 6.66°\text{C}$$

8 **(a)**

Heat absorbed by 540 g of ice at 0°C to melt out = 540× 80 cal. This is exactly what is available in 540 g of water at 80°C to cool down to 0°C

9 **(b)**

Thermal capacity = Mass × Specific heat

Due to same material both spheres will have same specific heat. Also mass = Volume (V) × Density(ρ)

∴ Ratio of thermal capacity

$$= \frac{m_1}{m_2} = \frac{V_1\rho}{V_2\rho} = \frac{\frac{4}{3}\pi r_1^3}{\frac{4}{3}\pi r_2^3} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{1}{2}\right)^3 = 1:8$$

10 **(a)**

$$c = \frac{\Delta Q}{m.\Delta T} = \frac{\Delta Q}{m \times 0} = 0$$

11 **(d)**

For the two sheets $H_1 = H_2[H =$ Rate of heat flow]

$$\Rightarrow \frac{(100 - \theta)}{R} = \frac{(\theta - 20)}{3R} \Rightarrow \theta = 80°\text{C}$$

12 **(d)**

The degree Celsius (°C) scale was devised by dividing the range of temperature between the freezing and boiling temperature of pure water at standard atmospheric conditions into 100 equals parts.
For Fahrenheit scale.
Boiling point=212°F,
Freezing point=32°
$\therefore$ Difference of 100°C = difference of $(212° - 32°) = 180°F$
$\therefore$ Difference of $30° = \frac{180}{100} \times 30 = 54°$

13 **(c)**
$$\frac{F-32}{9} = \frac{K-273}{5} \Rightarrow \frac{F-32}{9} = \frac{0-273}{5}$$
$\Rightarrow F = -459.4°F = -460°F$

14 **(b)**
In vapor to liquid phase transition, heat liberates

15 **(b)**
Loss in time per second $\frac{\Delta T}{T} = \frac{1}{2}\alpha\Delta\theta = \frac{1}{2}\alpha(t-0)$
$\Rightarrow$ loss in time per day
$$\Delta t = \left(\frac{1}{2}\alpha t\right)t = \frac{1}{2}\alpha t \times (24 \times 60 \times 60)$$
$$= \frac{1}{2}\alpha t \times 86400$$

16 **(c)**
$$\frac{Q}{t} = \frac{KA(\theta_1 - \theta_2)}{l} \Rightarrow \frac{Q}{t} \propto \frac{A}{l} \propto \frac{r^2}{l}$$
[As $(\theta_1 - \theta_2)$ and K are constant]
$$\Rightarrow \frac{\left(\frac{Q}{t}\right)_1}{\left(\frac{Q}{t}\right)_2} = \frac{r_1^2}{r_2^2} \times \frac{l_2}{l_1} = \frac{4}{9} \times \frac{2}{1} = \frac{8}{9}$$

17 **(c)**
Heat capacity/volume $= c \times \frac{m}{V} = c \times \rho$
Desired ratio $= \frac{c_1\rho_1}{c_2\rho_1} = \frac{3}{5} \times \frac{5}{6} = 1 : 2$

18 **(c)**
$Q = A\varepsilon\sigma T^4 \Rightarrow Q \propto A \propto r^2 \quad [\because T = \text{constant}]$
$$\Rightarrow \frac{Q_1}{Q_2} = \frac{r_1^2}{r_2^2} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$$

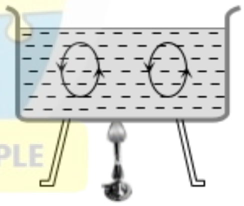
19 **(a)**
The equivalent electrical circuit, figure in these cases is of Wheatstone bridge. No current would flow through central rod CD when the bridge is balanced. The condition for balanced Wheatstone bridge is $\frac{P}{Q} = \frac{R}{S}$ (in terms of resistances)
$\frac{1/K_1}{1.K_2} = \frac{1/K_3}{1/K_4}$ or $\frac{K_2}{K_1} = \frac{K_4}{K_3}$
Or $K_1K_4 = K_2K_3$

20 **(a)**
Thermal stress is a measure of the internal distribution of force per unit area within body that is applied to the body, in the form of heat
Thermal stress$=Y\alpha\Delta T$
Where Y is Young's modulus, α the coefficient of linear expansion and ΔT the change in temperature
Both the rods are heated,
$\therefore \quad Y_1\alpha_1\Delta T_1 = Y_2\alpha_2\Delta T_2$
Since, $\quad \Delta T_1 = \Delta T_2$
$\Rightarrow \quad \frac{Y_1}{Y_2} = \frac{\alpha_2}{\alpha_1} = \frac{3}{2}$

21 **(d)**
Given $A_1 = A_2$ and $\frac{K_1}{K_2} = \frac{5}{4}$
$$\because R_1 = R_2 \Rightarrow \frac{l_1}{K_1A} = \frac{l_2}{K_2A} \Rightarrow \frac{l_1}{l_2} = \frac{K_1}{K_2} = \frac{5}{4}$$

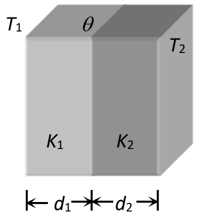
22 **(c)**

23 **(c)**
In convection hot particles move upward (due to low density) and light particle move downward (due to high density)



24 **(c)**
Let $F = K - X$
As $\frac{F-32}{9} = \frac{K-273}{5}$
$$\therefore \frac{x-32}{9} = \frac{x-273}{5}$$
$9x - 2457 = 5x - 160$
$4x - 2457 + 160 = 0$
$$x = \frac{2297}{4} = 574.25°$$

25 **(a)**
In series both walls have same rate of heat flow. Therefore
$$\frac{dQ}{dt} = \frac{K_1A(T_1 - \theta)}{d_1} = \frac{K_2A(\theta - T_2)}{d_2}$$
$\Rightarrow K_1d_2(T_1 - \theta) = K_2d_1(\theta - T_2)$



$$\Rightarrow \theta = \frac{K_1 d_2 T_1 + K_2 d_1 T_2}{K_1 d_2 + K_2 d_1}$$

26 **(c)**

For brass rod A

Volume $V_1 = \pi(2r)^2 \times l$ ...(i)

For volume expansion

$$V'_1 = V_1((1+\gamma\Delta t)$$

$\Rightarrow$ $V'_1 - V_1 \propto V_1$

Or $\Delta V_1 \propto V_1$ ...(ii)

Similarly, for brass rod B

Volume $V_2 = \pi(r)^2 \times 2l$ ...(iii)

and $\Delta V_2 \propto V_2$ ...(iv)

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

$$\frac{V_1}{V_2} = \frac{\pi 4r^2 l}{\pi r^2 2l} = \frac{2}{1}$$

From eqs. (ii) and (iv),

$$\frac{\Delta V_1}{\Delta V_2} = \frac{2}{1}$$

27 **(a)**

Anomalous density of water is given by (a). It has maximum density at 4°C.

28 **(d)**

$$\frac{X - LFP}{UFP - LFP} = \text{constant}$$

Where $X =$ Any given temperature on that scale

L. F. P. = Lower fixed point (Freezing point)

U. F. P. = Upper fixed point (Boiling point)

$$\frac{W - 39}{239 - 39} = \frac{39 - 0}{100 - 0}$$

$$\Rightarrow \frac{W - 39}{200} = \frac{39}{100} \Rightarrow W = 78 + 39 \Rightarrow W = 117^oW$$

29 **(b)**

$$J = \frac{W}{Q} = \frac{Joule}{cal}$$

30 **(d)**

31 **(d)**

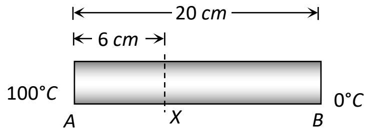
A thermopile is a sensitive instrument, used for detection of heat radiation and measurement of their intensity

32 **(b)**

In the given graph CD represents liquid state

33 **(b)**

In steady state, temperature gradient = constant



$$\Rightarrow \frac{(\theta_A - \theta_x)}{6} = \frac{(\theta_A - \theta_B)}{20} \Rightarrow (100 - \theta_x)$$

$$= \frac{6}{20} \times (100 - 0)$$

$\Rightarrow \theta_x = 70$°C

34 **(d)**

$$\frac{Q}{t} = \frac{KA\Delta\theta}{l} \Rightarrow \frac{K_A}{K_B} = \frac{A_B}{A_A} = \left(\frac{r_B}{r_A}\right)^2 = \frac{1}{4} \Rightarrow K_A = \frac{K_B}{4}$$

35 **(c)**

We know that $P = P_0(1 + \gamma t)$ and $V = V_0(1 + \gamma t)$

And $\gamma = (1/273)/$°C for $t = -273$°C, we have $P = 0$ and $V = 0$

Hence, at absolute zero, the volume and pressure of the gas become zero

36 **(a)**

$\frac{Q}{t} = \frac{KA\Delta\theta}{l} \Rightarrow \frac{\Delta\theta}{(l/KA)} = \frac{\Delta\theta}{R}$ [$R =$ Thermal resistance]

$\Rightarrow t \propto R$ [$\because Q$ and $\Delta\theta$ are same]

$$\Rightarrow \frac{t_p}{t_s} = \frac{R_P}{R_S} = \frac{R/2}{2R} = \frac{1}{4} \Rightarrow t_P = \frac{t_S}{4} = \frac{4}{4} = 1\text{min}$$

[Series resistance $R_S = R_1 + R_2$ and parallel resistance $R_P = \frac{R_1 R_1}{R_2 + R_2}$]

37 **(b)**

In series, $R_{eq} = R_1 + R_2 \Rightarrow \frac{2l}{K_{eq}A} = \frac{l}{K_1 A} + \frac{l}{K_2 A}$

$$\Rightarrow \frac{2}{K_{eq}} = \frac{1}{K_1} + \frac{1}{K_2} \Rightarrow K_{eq} = \frac{2K_1K_2}{K_1 + K_2}$$

38 **(c)**

Variations of density with temperature is given by

$$\rho' = \frac{\rho}{1+\gamma\Delta\theta}$$

Fraction change is

$$\frac{\rho' - \rho}{\rho} = \left[\frac{1}{1+49\times10^{-5}\times30} - 1\right]$$

$$= 1.5 \times 10^{-2}$$

39 **(d)**

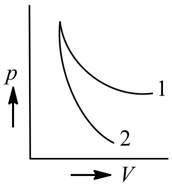
40 **(b)**

Water has maximum density at 4°C so at this temperature, it has minimum volume.

Thermodynamics

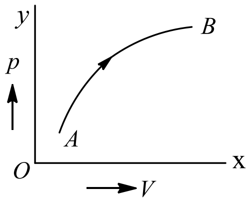
RED ZONE

1. If an ideal gas is compressed isothermally then
   a) No work is done against gas
   b) Heat is released by the gas
   c) The internal energy of gas will increase
   d) Pressure does not change
2. In an adiabatic process, the state of a gas is changed from p_1, V_1, T_1 to p_2, V_2, T_2. Which of the following relation is correct?
   a) $T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$
   b) $p_1 V_1^{\gamma-1} = p_2 V_2^{\gamma-1}$
   c) $T_1 p_1^{\gamma} = T_2 V_2^{\gamma}$
   d) $T_1 V_1^{\gamma} = T_2 V_2^{\gamma}$
3. During an adiabatic expansion of 2 moles of a gas, the change in internal energy was found $-50J$. The work done during the process is
   a) Zero
   b) $100J$
   c) $-50J$
   d) $50J$
4. 100 g of water is heated from30°C to 50°C.Ignoring the slight expansion of the water, the change in its internal energy is
   (Specific heat of water is 4184 J/kg/K)
   a) 8.4 kJ
   b) 84 kJ
   c) 2.1 kJ
   d) 4.2 kJ
5. $p - V$ plots for two gases during adiabatic processes are shown in figure. Plots 1 and 2 should correspond respectively to



   a) He and O_2
   b) O_2 and He
   c) He and Ar
   d) O_2 and N_2
6. When heat is given to a gas in an isothermal change, the result will be
   a) External work done
   b) Rise in temperature
   c) Increase in internal energy
   d) External work done and also rise in temp.
7. Pressure-temperature relationship for an ideal gas undergoing adiabatic change is ($\gamma = C_p/C_v$)
   a) PT^{γ} = constant
   b) $PT^{-1+\gamma}$ = constant
   c) $P^{\gamma-1}T^{\gamma}$ = constant
   d) $P^{1-\gamma}T^{\gamma}$ = constant

8. Figure shows a thermodynamical process on one moles a gas. How does the work done in the process change with time?

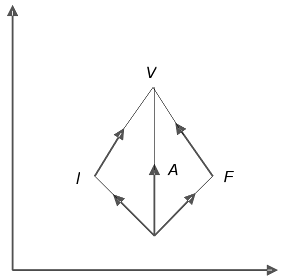


a) Decrease continuously
b) Increases continuously
c) Remains constant
d) First increase and then decreases

9. A gas at pressure 6×10^5 Nm^{-2} and volume 1 m^3 and its pressure falls to 410^5 Nm^{-2}, When its volume is 3m^3. Given that the indicator diagram is a straight line, work done by the system is

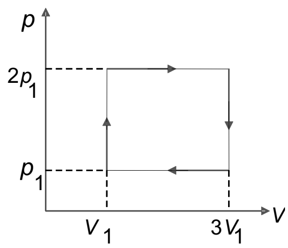
a) 6×10^5 J
b) 3×10^5 J
c) 4×10 J
d) 10×10^5 J

10. In the given p-V diagram, I is the initial state and F is the final state
The gas goes from I to F by
(i) IAF (ii) IBF (iii) ICF
The heat absorbed by gas is



a) The same in all three processes
b) The same in (i) and (ii)
c) Greater in (i) than in (ii)
d) Greater in (iii) than in (ii)

11. Work done in the given cyclic process is



a) p_1V_1
b) $3p_1V_1$
c) $2p_1V_1$
d) zero

12. A gas expands adiabatically at constant pressure, such that its temperature $T \propto \frac{1}{\sqrt{V}}$. The value of C_p/C_v of the gas is

a) 1.30
b) 1.50
c) 1.67
d) 2.00

13. A mass of dry air at NTP. is compressed to $\frac{1}{20}$ th of its original volume suddenly. If $\gamma = 1.4$, the final pressure would be

a) 20 atm
b) 66.28 atm
c) 30 atm
d) 150 atm

14. If a system undergoes contraction of volume then the work done by the system will be

a) Zero
b) Negligible
c) Negative
d) Positive

15. A gas is suddenly expanded such that its final volume becomes 3 times its initial volume. If the specific heat at constant volume of the gas is $2R$, then the ratio of initial to final pressure is nearly equal to

a) 5
b) 6.5
c) 7
d) 3.5

16. For an ideal gas, in an isothermal process

a) Heat content remains constant
b) Heat content and temperature remain constant
c) Temperature remains constant
d) None of the above

17. The phenomenon of sound propagation in air is

a) Isothermal process
b) Isobaric process
c) Adiabatic process
d) None of these

18. For an adiabatic expansion of a perfect gas, the value of $\frac{\Delta P}{P}$ is equal to

a) $-\sqrt{\gamma}\frac{\Delta V}{V}$
b) $-\frac{\Delta V}{V}$
c) $-\gamma\frac{\Delta V}{V}$
d) $-\gamma^2\frac{\Delta V}{V}$

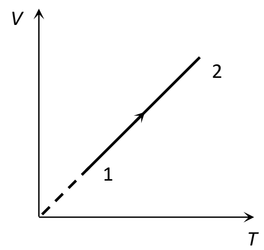
19. The pressure inside a tyre is 4 atm at 27°C. If the tyre burts suddenly, new temperature will be ($\gamma = 7/5$)

a) $300\ (4)^{7/2}$
b) $300(4)^{2/7}$
c) $300\ (2)^{7/2}$
d) $300\ (4)^{-2/7}$

20. First law of thermodynamics is given by

a) $dQ = dU + PdV$
b) $dQ = dU \times PdV$
c) $dQ = (dU + dV)P$
d) $dQ = PdU + dV$

21. Volume versus temperature graph of two moles of helium gas is as shown in figure. The ratio of heat absorbed and the work done by the gas in process 1-2 is

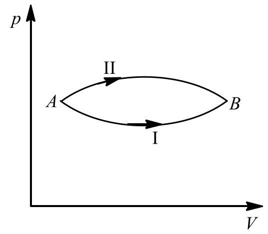


a) 3
b) $\frac{5}{2}$
c) $\frac{5}{3}$
d) $\frac{7}{2}$

22. In a cyclic process, work done by the system is

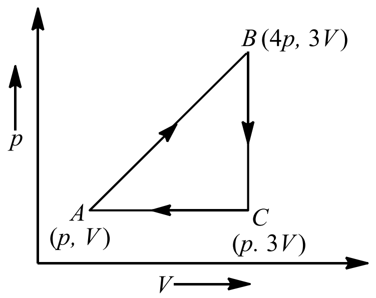
a) Zero
b) Equal to heat given to the system
c) More than the heat given to system
d) Independent of heat given to the system

23. A system goes from *A* to *B* *via* two processes I and II as shown in figure. If ΔU_1 and ΔU_2 are the changes in internal energies in the processes I and II respectively, then



a) $\Delta U_1 = \Delta U_2$
b) Relation between ΔU_1 and ΔU_2 cannot be determined
c) $\Delta U_2 > \Delta U_1$
d) $\Delta U_2 < \Delta U_1$

24. A sample of ideal monoatomic gas is taken round the cycle *ABCA* as shown in the figure. The work done during the cycle is

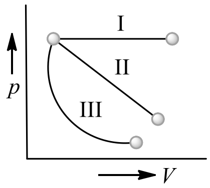


a) $3pV$
b) Zero
c) $9pv$
d) $6pv$

25. 500 J of heat energy is removed from 4 moles of a monoatomic ideal gas at constant volume. The temperature drops by

a) 40°C
b) 30°C
c) 10°C
d) 0°C

26. As shown in figure three $p-V$ diagrams. In which case, work done is minimum

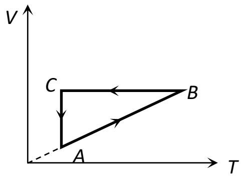


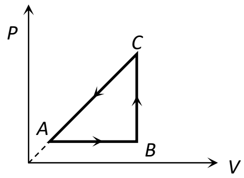
a) I b) II c) III d) Cannot say

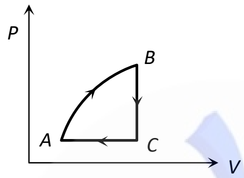
27. A refrigerator works between temperature of melting ice and room temperature (17°C). The amount of energy in kWh that must be supplied to freeze 1 kg of water at 0°C is

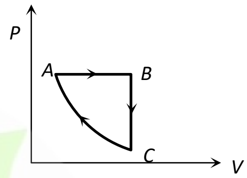
a) 1.4 b) 1.8 c) 0.058 d) 2.5

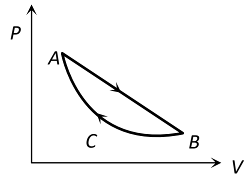
28. A cyclic process $ABCA$ is shown in the V-T diagram. Process on the P-V diagram is



a) 

b) 

c) 

d) 

29. During an isothermal expansion of an ideal gas

a) Its internal energy decreases
b) Its internal energy does not change
c) The work done by the gas is equal to the quantity of heat absorbed by it
d) Both (b) and (c) are correct

30. A mono atomic gas is supplied the heat Q very slowly keeping the pressure constant. The work done by the gas will be

a) $\frac{2}{3}Q$ b) $\frac{3}{5}Q$ c) $\frac{2}{5}Q$ d) $\frac{1}{5}Q$

31. Which is the correct statement

a) For an isothermal change $PV =$ Constant
b) In an isothermal process the change in internal energy must be equal to the work done
c) For an adiabatic change $\frac{P_2}{P_1} = \left(\frac{V_2}{V_1}\right)^{\gamma}$, where γ is the ratio of specific heats
d) In an adiabatic process work done must be equal to the heat entering the system

32. One mole of an ideal monoatomic gas is heated at a constant pressure of 1 atm from 0°C to 100°C. Work done by the gas is

a) 8.31×10^{3} J b) 8.31×10^{-3} J c) 8.31×10^{-2} J d) 8.31×10^{2} J

33. A monoatomic ideal gas, initially at temperature T_1 is enclosed in a cylinder fitted with a frictionless piston. The gas is allowed to expand adiabatically to a temperature T_2 by releasing the piston suddenly. If L_1, L_2 are the lengths of the gas column before and after expansion respectively, then T_1/T_2 is given by

a) $(L_1/L_2)^{2/3}$ b) (L_1/L_2) c) L_1/L_2 d) $(L_2/L_1)^{2/3}$

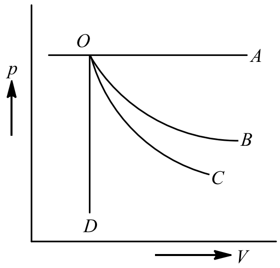
34. A gas $\left(\gamma = \frac{5}{3}\right)$, expands isobarically. The percentage of heat supplied that increases thermal energy and that is involved in doing work for expansion is

a) l40: 60 b) 60: 40 c) 50: 50 d) 25: 30

35. A system is given 300 calories of heat and it does 600 *joules* of work. How much does the internal energy of the system change in this process ($J = 4.18 joules/cal$)

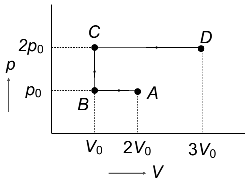
a) 654 *joule* b) 156.5 *joule* c) -300 *joule* d) -528.2 *joule*

36. A graph of pressure *versus* volume for an ideal gas for different processes is as shown. In the graph curve OC represents



a) Isochoric process　b) Isothermal process　c) Isobaric process　d) Adiabatic process

37. $p-V$ diagram of an ideal gas is as shown in figue. Work done by the gas in the process $ABCD$ is



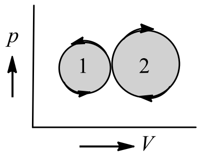
a) $4\ p\ V_0$　b) $2\ p_0\ V_0$　c) $3\ p_0\ V_0$　d) $p_0\ V_0$

38. The temperature of the system decreases in the process of

a) Free expansion　b) Adiabatic expansion

c) Isothermal expansion　d) Isothermal compression

39. In the indicator diagram, net amount of work done will be



a) Positive　b) Zero　c) Infinity　d) Negative

40. The adiabatic Bulk modulus of a perfect gas at pressure is given by

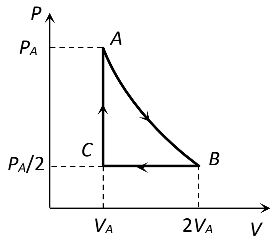
a) P　b) $2P$　c) $P/2$　d) γP

41. When an ideal gas ($\gamma = 5/3$) is heated under constant pressure, then what percentage of given heat energy will be utilised in doing external work

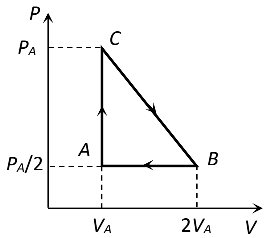
a) 40%　b) 30%　c) 60%　d) 20%

42. Three moles of an ideal gas $\left(C_P = \frac{7}{2}R\right)$ at pressure P_A and temperature T_A is isothermally expanded to twice its initial volume. It is then compressed at constant pressure to its original volume. Finally the gas is compressed at constant volume to its original pressure P_A. The correct P-V and P-T diagrams indicating the process are

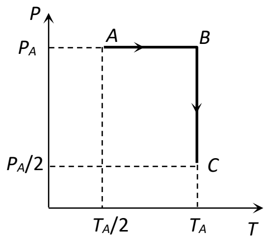
a)



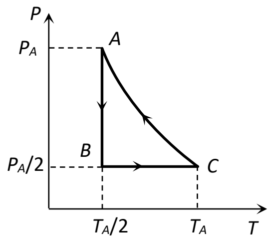
b)



c)



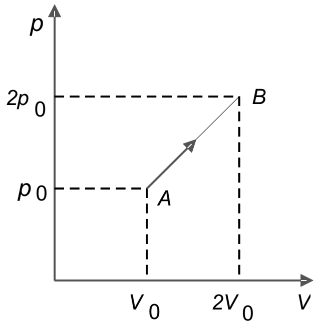
d)



43. In an isochoric process if $T_1 = 27°C$ and $T_2 = 127°C$, then P_1/P_2 will be equal to

a) 9/59　b) 2/3　c) 3/4　d) None of these

44. The p-V diagram of 2 g of helium gas for a certain process $A \to B$ is shown in the figure. What is the heat given to the gas during the process $A \to B$?



a) $4p_0V_0$ b) $6p_0V_0$ c) $4.5p_0V_0$ d) $2p_0V_0$

45. When a small amount of heat ΔQ is added to an enclosed gas, then increase in internal energy and external work done are related as

a) $mC_v\Delta T = Q + p\Delta V$ b) $\Delta Q = mC_v\Delta T + p\Delta V$ c) $mC_v = \Delta Q + p\Delta V$ d) $\Delta Q = mC_p\Delta T + p\Delta V$

46. For an isothermal expansion of a perfect gas, the value of $\frac{\Delta P}{P}$ is equal

a) $-\gamma^{1/2}\frac{\Delta V}{V}$ b) $-\frac{\Delta V}{V}$ c) $-\gamma\frac{\Delta V}{V}$ d) $-\gamma^2\frac{\Delta V}{V}$

47. A gas for which $\gamma = 1.5$ is suddenly compressed to the $\frac{1}{4}$ th of the initial volume. Then the ratio of the final to the initial pressure is

a) $1:6$ b) $1:8$ c) $1:4$ d) $8:1$

48. The volume of an ideal diatomic gas is doubled isothermally, the internal energy

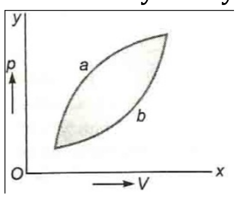
a) Is doubled b) Is halved

c) Is increased four times d) Remains unchanged

49. The work done in which of the following process is zero?

a) Isothermal process b) Adiabatic process c) Isochoric process d) None of these

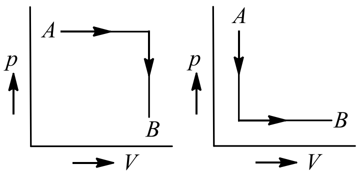
50. Figure shows two processes a and b for a given sample of a gas, if $\Delta Q_1, \Delta Q_2$ are the amounts of heat absorbed by the system in the two cases, and $\Delta U_1, \Delta U_2$ are changes in internal energies respectively, then



a) $\Delta Q_1 = \Delta Q_2, ;\ \Delta U_1 = \Delta U_2$ b) $\Delta Q_1 > \Delta Q_2;\ \Delta U_1 > \Delta U_2$

c) $\Delta Q_1 < \Delta Q_2;\ \Delta U_1 < \Delta U_2$ d) $\Delta Q_1 > \Delta Q_2;\ \Delta U_1 = \Delta U_2$

51. In figure two indicator diagrams are shown. If the amounts of work done in the two cases are W_1 and W_2 respectively, then



a) $W_1 = W_2$ b) $W_1 > W_2$ c) $W_1 < W_2$ d) Cannot say

52. In adiabatic expansion

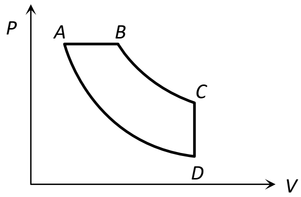
a) $\Delta U = 0$ b) $\Delta U =$ negative c) $\Delta U =$ positive d) $\Delta W =$ zero

53. We consider a thermodynamic system. If ΔU represents the increase in its internal energy and W the work done by the system, which of the following statements is true?

a) $\Delta U = -W$ in an adiabatic process b) $\Delta U = W$ in an isothermal process

c) $\Delta U = -W$ in an isothermal process d) $\Delta U = W$ in an adiabatic process

54. In pressure-volume diagram given below, the isochoric, isothermal, and isobaric parts respectively, are



a) BA, AD, DC b) DC, CB, BA c) AB, BC, CD d) CD, DA, AB

55. The volume of air increases by 5%, in its adiabatic expansion. The percentage decrease in its pressure will be

a) 5% b) 6% c) 7% d) 8%

56. When a gas expands adiabatically

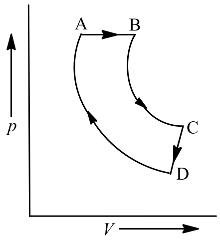
a) No energy is required for expansion

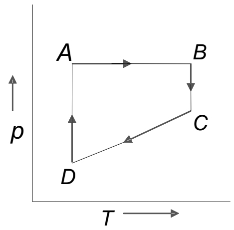
b) Energy is required and it comes from the wall of the container of the gas

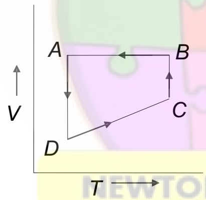
c) Internal energy of the gas is used in doing work

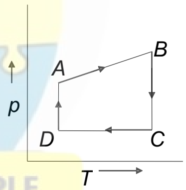
d) Law of conservation of energy does not hold

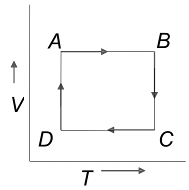
57. A cyclic process $ABCDA$ is shown below in the given p-V diagram. In the following answers the one that represents the same process as in p-V diagram



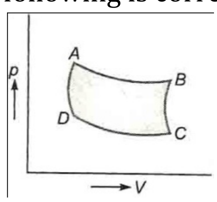
a) 

b) 

c) 

d) 

58. In the indicator diagram T_a, T_b, T_c, T_d represent temperature of gas at A, B, C, D respectively. Which of the following is correct relation?

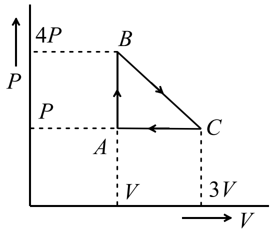


a) $T_a = T_b = T_c = T_d$ b) $T_a \neq T_b \neq T_c \neq T_d$

c) $T_a = T_b$ and $T_c = T_d$ d) None of these

59. An ideal gas is taken around the cycle $ABCA$ as shown in the $P - V$ diagram

The total work done by the gas during the cycles is

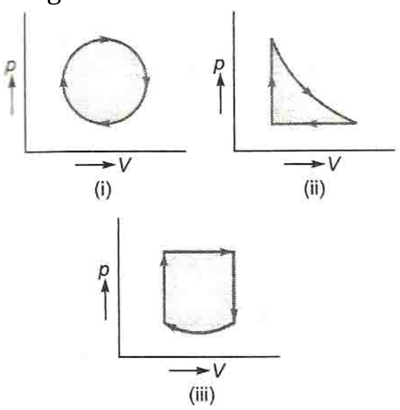


a) PV b) $2PV$ c) $4PV$ d) $3PV$

60. The thermodynamic process in which no work is done on or by the gas is
a) Isothermal process b) Adiabatic process c) Cyclic process d) Isochoric process

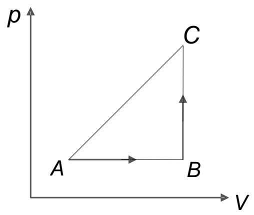
61. An ideal gas is allowed to expand freely against a vacuum in a rigid insulated container. The gas undergoes
a) An increase in its internal energy
b) A decrease in its internal energy
c) Neither an increase nor a decrease in its temperature or internal energy
d) A decrease in temperature

62. What is the nature of change in internal energy in the following three thermodynamical processes shown in figure?



a) ΔU is positive in all the three cases
b) ΔU is negative in all the three cases
c) ΔU is positive for (i), negative for (ii), zero for (iii)
d) $\Delta U = 0$, in all the cases

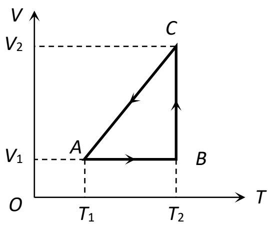
63. The p-V diagram of a system undergoing thermodynamic transformation is shown in figure. The work done by the system in going from $A \to B \to C$ is 30 J, and 40 J heat is given to the system. The change in internal energy between A and C is



a) 10 J b) 70 J c) 84 J d) 134 J

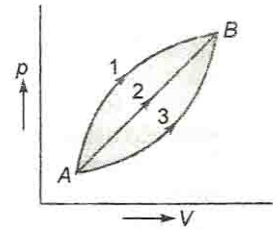
64. The slopes of isothermal and adiabatic curves are related as
a) Isothermal curve slope = adiabatic curve slope
b) Isothermal curve slope = $\gamma \times$ adiabatic curve slope
c) Adiabatic curve slope = $\gamma \times$ isothermal curve slope
d) Adiabatic curve slope = $1/2 \times$ isothermal curve slope

65. A cyclic process for 1 mole of an ideal gas is shown in figure in the V-T, diagram. The work done in AB, BC and CA respectively



a) $0, RT_2 \ln\left(\frac{V_1}{V_2}\right), R(T_1 - T_2)$
b) $R(T_1 - T_2), 0, RT_1 \ln\frac{V_1}{V_2}$
c) $0, RT_2 \ln\left(\frac{V_2}{V_1}\right), R(T_1 - T_2)$
d) $0, RT_2 \ln\left(\frac{V_2}{V_1}\right), R(T_2 - T_1)$

66. In figure a certain mass of gas traces three paths 1, 2, 3 from state A to state B. If work done by the gas along three paths are W_1, W_2, W_3 respectively, then



a) $W_1 < W_2 < W_3$ b) $W_1 = W_2 = W_3$ c) $W_1 > W_2 > W_3$ d) Cannot say

67. The volume of an ideal gas is 1 litre and its pressure is equal to $72 cm$ of mercury column. The volume of gas is made 900 cm^3 by compressing it isothermally. The stress of the gas will be

a) 8 cm (mercury) b) 7 cm (mercury) c) 6 cm (mercury) d) 4 cm (mercury)

68. In a thermodynamic system working substance is ideal gas, its internal energy is in the form of

a) Kinetic energy only b) Kinetic and potential energy
c) Potential energy d) None of these

69. Adiabatic modulus of elasticity of a gas is $2.1 \times 10^5 \mathrm{Nm}^{-2}$. What will be its isothermal modulus of elasticity? $\left(\frac{C_p}{C_v} = 1.4\right)$

a) 1.2×10^5 Nm^{-2} b) 4×10^5 Nm^{-2} c) 1.5×10^5 Nm^{-2} d) 1.8×10^5 Nm^{-2}

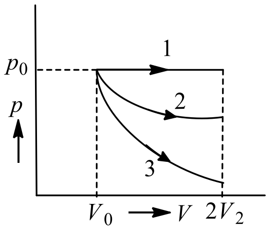
70. The temperature of a hypothetical gas increases to $\sqrt{2}$ times when compressed adiabatically to half the volume. Its equation can be written as

a) $PV^{3/2}$ = constant b) $PV^{5/2}$ = constant c) $PV^{7/3}$ = constant d) $PV^{4/3}$ = constant

71. The isothermal bulk modulus of a perfect gas at normal pressure is

a) $1.013 \times 10^5 N/m^2$ b) $1.013 \times 10^6 N/m^2$ c) $1.013 \times 10^{-11} N/m^2$ d) $1.013 \times 10^{11} N/m^2$

72. A gas is expanded from volume V_0 to $2V_0$ under three different processes, in figure process 1 is isobaric process, process 2 is isothermal and process 3 is adiabatic. Let $\Delta U_1, \Delta U_2$ and ΔU_3 be the change in internal energy of the gas in these three processes. Then



a) $\Delta U_1 > \Delta U_2 > \Delta U_3$ b) $\Delta U_1 < \Delta U_2 < \Delta U_3$ c) $\Delta U_2 < \Delta U_1 > \Delta U_3$ d) $\Delta U_2 < \Delta U_3 < \Delta U_1$

73. A gas is suddenly compressed to ¼ th of its original volume at normal temperature. The increase in its temperature is ($\gamma = 1.5$)

a) 273 K b) 573 K c) 373 K d) 473 K

74. In a reversible isochoric change

a) $\Delta W = 0$ b) $\Delta Q = 0$ c) $\Delta T = 0$ d) $\Delta U = 0$

75. Initial pressure and volume of a gas are P and V respectively. First it is expanded isothermally to volume $4V$ and then compressed adiabatically to volume V. The final pressure of gas will be (given $\gamma = 3/2$)

a) $1P$ b) $2P$ c) $4P$ d) $8P$

: HINTS AND SOLUTIONS :

1 **(b)**
In isothermal process, heat is released by the gas to maintain the constant temperature

2 **(a)**
For adiabatic process

$$P_1 V_1^{\gamma} = p_2 V_2$$

$$\frac{RT_1}{V_1} V_1^{\gamma} = \frac{RT_2}{V_2} V_2^{\gamma}$$

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

3 **(d)**
For adiabatic forces $\Delta W = -\Delta U$ $[\because \Delta Q = 0]$
$\Rightarrow \Delta W = -(-50) = +50 J$

4 **(a)**
As work done=0

$\Delta U = mc\Delta T$

$= 100 \times 10^{-3} \times 4184 \times (50 - 30)$

=84 kJ

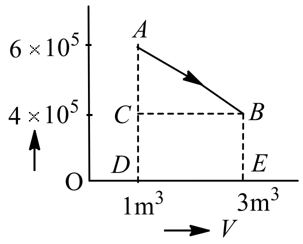
5 **(b)**
As is clear from figure,
Slope of curve 2 > Slope of curve 1
$(\gamma p)_2 = (\gamma p)_1$
$\gamma_2 > \gamma_1$
As $\gamma_{He} > \gamma O_2$
$\therefore$ adiabatic curve 2 corresponds to helium and adiabatic curve 1 corresponds to oxygen

6 **(a)**
In isothermal change, temperature remains constant,
Hence $\Delta U = 0$
Also from $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta Q = \Delta W$

7 **(d)**
$PV^{\gamma} = \text{constant} \Rightarrow P\left(\frac{RT}{P}\right)^{\gamma} = \text{constant}$

8 **(b)**
As work done in process = area under the curve, which increases continuously

9 **(a)**



Work done by the system
= area under $p - V$ diagram
= area of rectangle $BCDE$+ area of ΔABC
$= 4 \times 10^5 \times 2 + \frac{2 \times 10^5 \times 2}{2}$
$W = 10 \times 10^5$ J

10 **(d)**
Initial and final states are same an all the process

Hence, $\Delta U = 0$ in each case

By $p\Delta V = \Delta Q = \Delta W$ = Area enclosed by curve with volume axis

$\because$ $(Area)_1 < (Area)_2 < (Area)_3$

$\Rightarrow$ $Q_1 < Q_2 < Q_3$

11 **(c)**
For cyclic process p-V curve is closed curve and area enclosed by closed path represent the work done.

12 **(b)**
For adiabatic expansion, we have the formula

$$pV^{\gamma} = \text{constant} \quad \text{...(i)}$$

Gas equation is ,

$$pV=RT$$

$\Rightarrow$ $$p = \frac{RT}{V} \quad \text{...(ii)}$$

From Eqs. (i) and (ii), we obtain

$$\left(\frac{RT}{V}\right) V^{\gamma} = \text{constant}$$

$\Rightarrow$ $TV^{\gamma-1} = \text{constant}$ ...(iii)

But $T \propto \frac{1}{\sqrt{V}}$ (given)

as $TV^{1/2} = \text{constant}$ ...(iv)

Thus, using Eqs. (iii) and (iv) togther, we get

$$\gamma - 1 = \frac{1}{2}$$

or $$\gamma = \frac{3}{2} = 1.5$$

$$\Rightarrow \quad \frac{C_p}{C_v} = 1.5$$

13 **(b)**

From $p_2 V_2^\gamma = p_1 V_1^\gamma$

$$p_2 = p_1 \left(\frac{V_1}{V_2}\right)^\gamma = 1\left(\frac{V_1}{1/20V_1}\right)^{1.4}$$

$= 66.28$ atm

14 **(c)**

$\Delta W = P\Delta V$, here ΔV is negative so ΔW will be negative

15 **(a)**

As gas is suddenly expanded so it is an adiabatic process,

ie, $\quad pV^\gamma = constant$

or $\quad p_1 V_1^\gamma = p_2 V_2^\gamma$

Given, $V_2 = 3V_1, C_V = 2R$

$\therefore \quad C_P = 2R + R = 3R$

$$\Rightarrow \quad \gamma = \frac{C_P}{C_V} = \frac{3R}{2R} = 1.5$$

$$\therefore \quad \frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^\gamma = (3)^{1.5} = 5.1 \approx 5$$

16 **(c)**

In isothermal process temperature remains constant

17 **(b)**

Velocity of sound in air increases (v_t) with increase in temperature$[v_t = v_0 + 0.61t]$but is independent of pressure variation.

18 **(c)**

PV^γ = constant : Differentiating both sides

$$P_\gamma V^{\gamma-1} dV + V^\gamma dP = 0 \Rightarrow \frac{dP}{P} = -\gamma \frac{dV}{V}$$

19 **(d)**

In adiabatic operation (*eg*, bursing of tyre)

$$p_2^{(1-\gamma)} T_2^\gamma = p_1^{(1-\gamma)} T_1^\gamma$$

$$T_2 = T_1 \left(\frac{p_1}{p_2}\right)^{(1-\gamma)/\gamma}$$

$$= 300\left(\frac{4}{1}\right)^{\left(\frac{1-7/5}{7/5}\right)} = 300(4)^{-2/7}$$

20 **(a)**

$\Delta Q = \Delta U + \Delta W$ and $\Delta W = P\Delta V$

21 **(b)**

$V.T.$ graph is a straight line passing through origin.

Hence, $V \propto T$ or P = constant

$\therefore \ \Delta Q = nC_P \Delta T$ and $\Delta U = nC_V \Delta T$

Also $\Delta W = \Delta Q - \Delta U = \mu(C_P - C_V)\Delta T$

$$\therefore \frac{\Delta Q}{\Delta W} = \frac{nC_P \Delta T}{n(C_P - C_V)\Delta T} = \frac{C_P}{C_P - C_V} = \frac{1}{1 - \frac{C_V}{C_P}}$$

$\frac{C_V}{C_P} = \frac{3}{5}$ for helium gas. Hence $\frac{\Delta Q}{\Delta W} = \frac{1}{1-3/5} = \frac{5}{2}$

22 **(b)**

For cyclic forces $\Delta U = 0$, So, $\Delta Q = \Delta W$

23 **(a)**

The change in internal energy does not depend upon path followed by the process. It only depends on initial and final states.

Hence, $\quad \Delta U_1 = \Delta U_2$

24 **(a)**

The work done=area of p-Vgraph

=area of triangle ABC

$= \frac{1}{2} \times 3p \times 2V = 3pV$

25 **(c)**

For monoatomic gas,

$$C_v = \frac{3}{2}R = \frac{3}{2} \times 8.31 \text{ Jmol}^{-1}{}^\circ\text{C}^{-1}$$

$Q = 500$ J, $n = 4\theta = ?$

$$\theta = \frac{Q}{nC_v} = \frac{500}{4 \times \frac{3}{2} \times 8.31} = 10^\circ\text{C}$$

26 **(c)**

Area under curve III is minimum. Therefore, work done is minimum

27 **(c)**

$T_2 = 0^\circ\text{C} = 273$ K, $T_1 = 17^\circ\text{C} = 17 + 273 = 290$ K

$$\text{COP} = \frac{Q_2}{W} = \frac{T_2}{T_1 - T_2}$$

$$\frac{80 \times 1000 \times 4.2}{W} = \frac{273}{290 - 273} = \frac{273}{17}$$

$$W = \frac{80 \times 1000 \times 4.2 \times 17}{273} \text{ J}$$

$$W = \frac{33.6 \times 17 \times 10^4}{273 \times 3.6 \times 10^5} \text{ kWh} = 0.058 \text{ kWh}$$

28 **(c)**

From the given VT diagram

In process $AB, V \propto T \Rightarrow$ Pressure is constant (As quantity of the gas remains same)

In process $BC, V =$ Constant and in process CA, $T =$ constant

$\therefore$ These processes are correctly represented on PV diagram by graph (c)

29 **(d)**

In an ideal gas, the internal energy depends only upon the temperature of the gas. When an ideal gas undergoes an isothermal change, there is no change in its internal energy ($\Delta U = 0$)

From first law of thermodynamics

$\Delta U = Q - W$

For isothermal change $\Delta U = 0$

$\therefore \quad Q = W$

Hence, in an isothermal process in an ideal gas the heat absorbed by the gas is entirely used in the work done by the gas.

30 **(c)**

$$\Delta Q = \Delta U + \Delta W \Rightarrow \Delta W = (\Delta Q)_P - \Delta U$$
$$= (\Delta Q)_P \left[1 - \frac{(\Delta Q)_V}{(\Delta Q)_P}\right]$$
$$= (\Delta Q)_P \left[1 - \frac{C_V}{C_P}\right] = Q\left[1 - \frac{3}{5}\right] = \frac{2}{5} Q$$

$\because (\Delta Q)_P = Q$ and $\gamma = \frac{5}{3}$ for monoatomic gas

31 **(a)**

Since $PV = RT$ and $T =$ constant

$\therefore PV =$ constant

32 **(d)**

$dW = dQ - dU$

$= C_2(T_2 - T_1) - C_v[T_2 - T_1]$

$= R[T_2 - T_1]$

$= 8.31 \times 100 = 8.31 \times 10^2$ J

33 **(d)**

During adiabatic expansion

$TV^{\gamma-1} =$ constant of $T_2 V_2^{\gamma-1} = T_1 V_1^{\gamma-1}$

$$\frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1}$$

For monoatomic gas, $\gamma = 5/3$

$$\frac{T_1}{T_2} = \left(\frac{AL_2}{AL_1}\right)^{5/3-1} = \left(\frac{L_2}{L_1}\right)^{2/3}$$

34 **(b)**

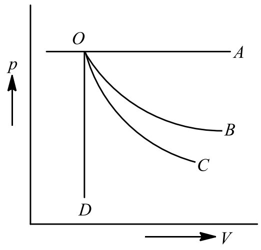
$$\frac{Q_1}{Q_2} = \frac{C_V dT}{p\, dT} = \frac{\frac{3}{2}R}{R} = \frac{3}{2} \text{ that is } 60:40.$$

35 **(a)**

$J\Delta Q = \Delta U + \Delta W, \Delta U = J\Delta Q - \Delta W$

$\Delta U = 4.18 \times 300 - 600 = 654$ *joule*

36 **(d)**



(i)Curve OA represents isobaric process (since pressure is constant). Since, the slope of adiabatic process is more steeper than isothermal process.

(ii)Curve OB represents isothermal process.

(iii)Curve OC represents adiabatic process.

(iv)Curve OD represents isochoric process.

(since volume is constant).

37 **(c)**

$W_{AB} = -p_0 V_0$

$W_{BC} = 0$

$W_{CD} = 4\, p_0 V_0$

$W_{ABCD} = W_{AB} + W_{BC} + W_{CD}$

$= -p_0 V_0 + 0 + 4p_0 V_0 = 3p_0 V_0$

38 **(b)**

In adiabatic expansion of a gas system, gas expands, so temperature of the system decreases.

39 **(a)**

Figure shows that loop 1 is anticlockwise, therefore W_1 is negative, loop 2 is clockwise, therefore W_2 is positive.

Also, loop 2 is bigger

$\therefore \quad W_2 > W_1$

Hence, $W = -W_1 + W_2$ →positive

40 **(d)**

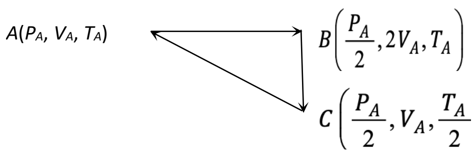
Adiabatic Bulk modulus $E_\phi = \gamma P$

41 **(a)**

$$\Delta Q = \Delta U + \Delta W \Rightarrow \frac{\Delta W}{\Delta Q} = 1 - \frac{\Delta U}{\Delta Q} = 1 - \frac{\mu C_V dT}{\mu C_P dT}$$
$$\Rightarrow \frac{\Delta W}{\Delta Q} = 1 - \frac{C_V}{C_P} = 1 - \frac{3}{5} = \frac{2}{5} = 0.4$$

42 **(a)**

Let the process start from initial pressure P_A, volume V_A and temperature T_A



(i) Isothermal expansion ($PV =$ constant) at temperature T_A to twice the initial volume V_A

(ii) Compression at constant pressure $\frac{P_A}{2}$ to original volume $V_A (i.e. V \propto T)$

(iii) Isochoric process (at volume V_A) to initial condition $(i.e. P \propto T)$

43 **(c)**

At constant volume $P \propto T \Rightarrow \frac{P_1}{P_2} = \frac{T_1}{T_2} \Rightarrow \frac{P_1}{P_2} = \frac{300}{400} = \frac{3}{4}$

44 **(b)**

Change in internal energy from A to B is

$$\Delta U = \frac{f}{2} nR\Delta T = \frac{f}{2}(p_f V_f - p_i V_i)$$

$$= \frac{3}{2}(2p_0 \times 2V_0 - p_0 \times V_0) = \frac{9}{2} p_0 V_0$$

Work done in process A to B is equal to the area covered by the graph with volume axis, *ie,*

$$W_{A\to B} = \frac{1}{2}(p_0 + 2p_0) \times (2V_0 - V_0) = \frac{3}{2} p_0 V_0$$

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

$$= \frac{9}{2} p_0 V_0 + \frac{3}{2} p_0 V_0 = 6 p_0 V_0$$

45 **(b)**

$\Delta Q = \Delta U + \Delta W = mC_v(\Delta T) + p(\Delta V)$

46 **(b)**

Differentiate $PV =$ constant $w.r.t. V$

$\Rightarrow P\Delta V + V\Delta P = 0 \Rightarrow \frac{\Delta P}{P} = -\frac{\Delta V}{V}$

47 **(d)**

Here, $\gamma = 1.5, V_2 = \frac{1}{4} V_1$; $\frac{p_2}{p_1} = ?$

As compression is sudden/adiabatic,

$\therefore\ p_2 V_2^\gamma = p_1 V_1^\gamma$

$\frac{p_2}{p_1} = \left(\frac{V_1}{V_2}\right)^\gamma = (4)^{1.5} = 8$

48 **(d)**

No change in the internal energy of ideal gas, but for real gas internal energy increases because work is done against intermolecular forces.

49 **(c)**

Isochoric process takes place at constant volume.

Since, there is no change of volume $(\Delta V = 0)$ therefore

$W = p\,\Delta V = 0$

50 **(d)**

As initial and final states in the two processes are same. Therefore, $\Delta U_1 = \Delta U_2$. As area under curve $a >$ area under curve b, therefore, $\Delta W_1 > \Delta W_2$

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

$\therefore\ \Delta Q_1 > \Delta Q_2$

51 **(b)**

As work done = area under the $p - V$ diagram

$\therefore\ W_1 > W_2$

52 **(b)**

In case of adiabatic expansion $\Delta W =$ positive and $\Delta Q = 0$

From FLOT $\Delta Q = \Delta U + \Delta W \Rightarrow \Delta U = -\Delta W$, $i.e.$, ΔU will be negative

53 **(a)**

An isothermal process is a constant temperature process. In this process, $T =$ constant or $\Delta T = 0$.

$\therefore \qquad \Delta U = nC_V\,\Delta T = 0$

An adiabatic process is defined as one with no heat transfer into or out of a system. Therefore, $\Delta Q = 0$. From the first law of thermodynamics.

$$W = -\Delta U$$

or $\qquad \Delta U = -W$

54 **(d)**

Process CD is isochoric as volume is constant, process DA is isothermal as temperature constant and process AB is isobaric as pressure is constant

55 **(c)**

$PV^\gamma = K$ or $P\gamma V^{\gamma-1} dV + dP.V^\gamma = 0$

$\Rightarrow \frac{dP}{P} = -\gamma \frac{dV}{V}$ or $\frac{dP}{P} \times 100 = -\gamma\left(\frac{dV}{V} \times 100\right)$

$= -1.4 \times 5 = 7\%$

56 **(c)**

$\Delta Q = \Delta U + \Delta W = 0 \Rightarrow \Delta W = -\Delta U$

If ΔW is positive $i.e.$, gas does work then ΔU should be negative meaning internal energy is used in doing work

57 **(a)**

In *p-V* diagrams process *AB* is isobaric process in which pressure remains constant *ie*, *p*=constant at all temperatures.

Process *BC* is isothermal process in which, temperature remains constant *ie*, *T*=constant.

Process *CD* is isochoric process in which volume remains constant *ie, p-T* diagram *CD* is a straight line passing through origin.

Process AD is adiabatice process which corresponds to process AD in p-T diagram.

Hence, the correct p-T diagram is shown in option (a).

58 **(c)**

AB and CD are isothermal curves therefore $T_a = T_b$ and $T_c = T_d$ but all the four temperatures are not equal

59 **(d)**

$W = \frac{1}{2} 2V.3P = 3PV$

60 **(d)**

In case of no work done W=0 than volume expersion V=0. So, the volume remains zero V=0. This process is called isochoric process.

61 **(c)**

For vacuum, pressure p=0

Hence, work done $= p\Delta V = 0$

According to first law of thermodynamics

$$Q = \Delta U + p\Delta V$$

$$\therefore \qquad Q = \Delta U$$

Hence the gas undergoes neither an increase nor a decrease in its temperature or internal energy.

62 **(d)**

As indicator diagram if all the three cases are closed curves, representing cyclic changes, therefore, U = const and $\Delta U = 0$ in all the cases

63 **(a)**

Since, work is done by the system, so it is positive. Therefore,

$\Delta W = 30\text{J}$

Heat given to the system,

$\Delta Q = 40\text{J}$

According to first law of thermodynamics, change in internal energy is given by

$\Delta U = \Delta Q - \Delta W$

$= 43 - 30 = 10$ J

64 **(c)**

For Isothermal process PV = constant

$\Rightarrow \left(\frac{dP}{dV}\right) = \frac{-P}{V}$ = Slope of Isothermal curve

For adiabatic PV^{γ} = constant

$\Rightarrow \frac{dP}{dV} = \frac{-\gamma P}{V}$ = Slope of adiabatic curve

Clearly, $\left(\frac{dP}{dV}\right)_{\text{adibatic}} = \gamma \left(\frac{dP}{dV}\right)_{\text{Isothermal}}$

65 **(c)**

Process AB is isochoric, $\therefore W_{AB} = P\,\Delta V = 0$

Process BC is isothermal $\therefore W_{BC} = RT_2.\ln\left(\frac{V_2}{V_1}\right)$

Process CA is isobaric

$\therefore W_{CA} = P\Delta V = R\Delta T = R(T_1 - T_2)$

[Negative sign is taken because of compression]

66 **(c)**

As work done by the gas = area under the $p - V$ curve, therefore $W_1 > W_2 > W_3$

67 **(a)**

For isothermal process $P_1V_1 = P_2V_2$

$\Rightarrow P_2 = \frac{P_1V_1}{V_2} = \frac{72 \times 1000}{900} = 80\ cm$

Stress $\Delta P = P_2 - P_1 = 80 - 72 = 8cm$

68 **(a)**

Ideal gas possess only kinetic energy

69 **(c)**

$\frac{E_s}{E_T} = \gamma = \frac{C_P}{C_V} = 1.4$

$$\frac{2.1 \times 10^5}{E_T} = 1.4$$

$$\text{or} \quad E_T = \frac{2.1 \times 10^5}{1.4}$$

$$= 1.5 \times 10^5\ \text{Nm}^{-2}$$

70 **(a)**

$TV^{\gamma-1}$ = constant

$\therefore \frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1}$ or $\left(\frac{1}{2}\right)^{\gamma-1} = \sqrt{\frac{1}{2}}$

$\therefore\ \gamma - 1 = \frac{1}{2}$ or $\gamma = \frac{3}{2}$ $\quad \therefore PV^{3/2}$ = constant

71 **(a)**

$E_\theta = P = 1.013 \times 10^5 N/m^2$

72 **(a)**

Process 1 is isobaric (p = constant) expansion

Hence, temperature of gas will increase

$\therefore\ \Delta U_1$ = negative

Process 2 is an adiabatic expansion

$\therefore\ \Delta U_2 = 0$

Process 3 is an adiabatic expansion

Hence, temperature of gas will fall

$\therefore\ \Delta U_3$ = constant

$\therefore\ \Delta U_1 > \Delta U_2 > \Delta U_3$

73 **(a)**

For adiabatic process

$$TV^{\gamma-1} = \text{constant}$$

$\therefore \quad T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$

$\Rightarrow \quad \frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1}$

Given , $V_1 = V, V_2 = \frac{V}{4}, \gamma = 1.5$

$\therefore \frac{T_1}{T_2} = \left(\frac{V/4}{V}\right)^{1.5-1} = \left(\frac{1}{4}\right)^{0.5} = -\frac{1}{2}$

$\Rightarrow \quad T_2 = 2T_1$

The change in temperature is given by

$T_2 - T_1 = 2T_1 - T_1 \Rightarrow T_1 = 273\text{ K}$

74 **(a)**

$\Delta V = 0 \Rightarrow P\Delta V = 0 \Rightarrow \Delta W = 0$

75 **(b)**

In isothermal process $P_1 V_1 = P_2 V_2$

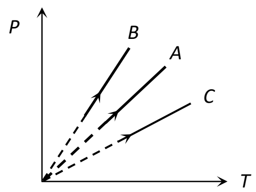
$\Rightarrow PV = P_2 \times 4V \;\; \therefore P_2 = \frac{P}{4}$

In adiabatic process

$P_2 V_2^{\gamma} = P_3 V_3^{\gamma} \Rightarrow \frac{P}{4} \times (4V)^{1.5} = P_3 V^{1.5} \Rightarrow P_3 = 2P$

Kinetic Theory of Gases

1. An ideal gas ($\gamma = 1.5$) is expanded adiabatically. How many times has the gas to be expanded to reduce the root mean square velocity of molecules 2.0 times?
   a) 4 times b) 16 times c) 8 times d) 2 times
2. If number of molecules of H_2 are double than that of O_2, then ratio of kinetic energy of hydrogen and that of oxygen at 300 K is
   a) 1 : 1 b) 1 : 2 c) 2 : 1 d) 1 : 16
3. The absolute temperature of a gas is determined by
   a) The average momentum of the molecules b) The velocity of sound in the gas
   c) The number of molecules in the gas d) The mean square velocity of the molecules
4. If the rms velocity of a gas is v ,then
   a) $v^2T =$ constant b) $v^2/T =$ constant
   c) $vT^2 =$ constant d) v is independent of T
5. When an air bubble of radius $'r'$ rises from the bottom to the surface of a lake, its radius becomes $5r/4$ (the pressure of the atmosphere is equal to the 10 m height of water column). If the temperature is constant and the surface tension is neglected, the depth of the lake is
   a) 3.53 m b) 6.53 m c) 9.53 m d) 12.53 m
6. Two gases A and B having same pressure p, volume V and absolute temperature T are mixed. If the mixture has the volume and temperature as V and T respectively, then the pressure of the mixture is
   a) $2p$ b) p c) $\frac{p}{2}$ d) $4p$
7. In the relation $n = \frac{PV}{RT}, n =$
   a) Number of molecules b) Atomic number c) Mass number d) Number of moles
8. Pressure versus temperature graph of an ideal gas at constant volume V of an ideal gas is shown by the straight line A. Now mass of the gas is doubled and the volume is halved, then the corresponding pressure versus temperature graph will be shown by the line

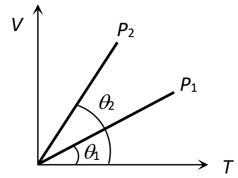


   a) A b) B c) C d) None of these
9. 10 moles of an ideal monoatomic gas at 10°C is mixed with 20 moles of another monoatomic gas at 20°C. Then the temperature of the mixture is
   a) 15.5°C b) 15°C c) 16°C d) 16.6°C

10. If C_p and C_v denote the specific heats of nitrogen per unit mass at constant pressure and constant volume respectively, then

a) $C_p - C_v = R/28$ b) $C_p - C_v = R/14$ c) $C_p - C_v = R$ d) $C_p - C_v = 28R$

11. The figure shows the volume V versus temperature T graphs for a certain mass of a perfect gas at two constant pressures of P_1 and P_2. What inference can you draw from the graphs



a) $P_1 > P_2$
b) $P_1 < P_2$
c) $P_1 = P_2$
d) No interference can be drawn due to insufficient information

12. The pressure is exerted by the gas on the walls of the container because

a) It loses kinetic energy
b) It sticks with the walls
c) On collision with the walls there is a change in momentum
d) It is accelerated towards the walls

13. If the degree of freedom of a gas are f, then the ratio of two specific heats C_P/C_V is given by

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

14. The ratio of root mean square velocity of O_3 and O_2 is

a) 1: 1 b) 2: 3 c) 3: 2 d) $\sqrt{2} : \sqrt{3}$

15. 1 mol of gas occupies a volume of 200 mL at 100 mm pressure. What is the volume occupied by two moles of gas at 400 mm pressure and at same temperature?

a) 50 mL b) 100 mL c) 200 mL d) 400 mL

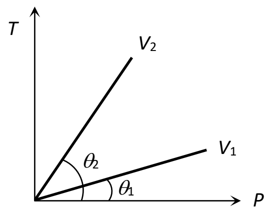
16. Molecules of a gas behave like

a) Inelastic rigid sphere
b) Perfectly elastic non-rigid sphere
c) Perfectly elastic rigid sphere
d) Inelastic non-rigid sphere

17. For an ideal gas of diatomic molecules

a) $C_p = \frac{5}{2}R$ b) $C_v = \frac{3}{2}R$ c) $C_p - C_v = 2R$ d) $C_p = \frac{7}{2}R$

18. From the following $P - T$ graph what inference can be drawn



a) $V_2 > V_1$ b) $V_2 < V_1$ c) $V_2 = V_1$ d) None of the above

19. The root mean square speed of the molecules of a diatomic gas is v. When the temperature is doubled, the molecules dissociate into two atoms. The new root mean square speed of the atom is

a) $\sqrt{2}v$ b) v c) $2v$ d) $4v$

20. At what temperature, the mean kinetic energy of O_2 will be the same for H_2 molecules at -73℃

a) 127℃ b) 527℃ c) -73℃ d) -173℃

21. The relation between the gas pressure P and average kinetic energy per unit volume E is

a) $P = \frac{1}{2}E$ b) $P = E$ c) $P = \frac{3}{2}E$ d) $P = \frac{2}{3}E$

22. For hydrogen gas $C_P - C_V = a$ and for oxygen gas $C_P - C_V = b$. So the relation between a and b is given by

a) $a = 16b$ b) $b = 16a$ c) $a = 4b$ d) $a = b$

23. For a gas at a temperature T the root-mean-square velocity v_{rms}, the most probable speed v_{mp}, and the average speed v_{av} obey the relationship

a) $v_{av} > v_{rms} > v_{mp}$ b) $v_{rms} > v_{av} > v_{mp}$ c) $v_{mp} > v_{av} > v_{rms}$ d) $v_{mp} > v_{rms} > v_{av}$

24. The ratio of the molar heat capacities of a diatomic gas at constant pressure to that at constant volume is

a) $\frac{7}{2}$ b) $\frac{3}{2}$ c) $\frac{3}{5}$ d) $\frac{7}{5}$

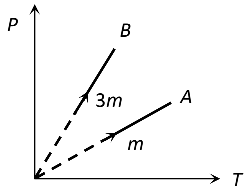
25. A monoatomic gas molecule has

a) Three degrees of freedom b) Four degrees of freedom
c) Five degrees of freedom d) Six degrees of freedom

26. If the ratio of vapour density for hydrogen and oxygen is $\frac{1}{16}$, then under constant pressure the ratio of their rms velocities will be

a) $\frac{4}{1}$ b) $\frac{1}{4}$ c) $\frac{1}{16}$ d) $\frac{16}{1}$

27. Two different masses m and $3m$ of an ideal gas are heated separately in a vessel of constant volume, the pressure P and absolute temperature T, graphs for these two cases are shown in the figure as A and B. The ratio of slopes of curves B to A is



a) 3 : 1 b) 1 : 3 c) 9 : 1 d) 1 : 9

28. The temperature of a gas is -68°C. At what temperature will the average kinetic energy of its molecules be twice that of at -68°C?

a) 137°C b) 127°C c) 100°C d) 105°C

29. The translational kinetic energy of gas molecule for one mole of the gas is equal to

a) $\frac{3}{2}RT$ b) $\frac{2}{3}RT$ c) $\frac{1}{2}RT$ d) $\frac{2}{3}KT$

30. The average kinetic energy of hydrogen molecules at 300 K is E. At the same temperature, the average kinetic energy of oxygen molecules will be

a) $E/4$ b) $E/16$ c) E d) $4E$

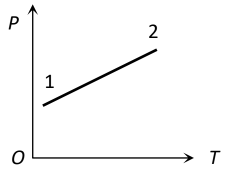
31. O_2 gas is filled in a vessel. If pressure is doubled, temperature becomes four times, how many times its density will become

a) 2 b) 4 c) $\frac{1}{4}$ d) $\frac{1}{2}$

32. At 0 K which of the following properties of a gas will be zero

a) Kinetic energy b) Potential energy c) Vibrational energy d) Density

33. A pressure P-absolute temperature T diagram was obtained when a given mass of gas was heated. During the heating process from the state 1 to state 2 the volume



a) Remained constant b) Decreased c) Increased d) Changed erratically

34. A real gas behaves like an ideal gas if its
a) Pressure and temperature are both high b) Pressure and temperature are both low
c) Pressure is high and temperature is low d) Pressure is low and temperature is high

35. If γ is the ratio of specific heats and R is the universal gas constant, then the molar specific heat at constant volume C_v is given by
a) γR b) $\frac{(\gamma-1)R}{\gamma}$ c) $\frac{R}{\gamma-1}$ d) $\frac{\gamma R}{\gamma-1}$

36. A diatomic gas molecule has translational, rotational and vibrational degrees of freedom. The C_P/C_V is
a) 1.67 b) 1.4 c) 1.29 d) 1.33

37. Molecular motion shows itself as
a) Temperature b) Internal Energy c) Friction d) Viscosity

38. A polyatomic gas with n degrees of freedom has a mean energy per molecule given by (N is Avogadro's number)
a) $\frac{nkT}{N}$ b) $\frac{nkT}{2N}$ c) $\frac{nkT}{2}$ d) $\frac{3kT}{2}$

39. Boyle's law holds for an ideal gas during
a) Isobaric changes b) Isothermal changes c) Isochoric changes d) Isotonic changes

40. The pressure and volume of saturated water vapour are P and V respectively. It is compressed isothermally thereby volume becomes $V/2$, the final pressure will be
a) More than $2P$ b) P c) $2P$ d) $4P$

41. In Boyle's law what remains constant
a) PV b) TV c) $\frac{V}{T}$ d) $\frac{P}{T}$

42. The degrees of freedom of a molecule of a triatomic gas are
a) 2 b) 4 c) 6 d) 8

43. One mole of monoatomic gas and three moles of diatomic gas are put together in a container. The molar specific heat (in J K^{-1} mol^{-1}) at constant volume is ($R = 8.3$ J K^{-1} mol^{-1})
a) 18.7 b) 18.9 c) 19.2 d) None of these

44. Suppose ideal gas equation follows VP^3 = constant. Initial temperature and volume of the gas are T and V respectively. If gas expands to 27 V then its temperature will become
a) T b) $9T$ c) 27 T d) $T/9$

45. The temperature of the hydrogen at which the average speed of its molecules is equal to that of oxygen molecules at a temperature of 31°C, is
a) −216°C b) −235°C c) −254°C d) −264°C

46. A mixture of 2 moles of helium gas (atomic mass = 4 amu), and 1 mole of argon gas (atomic mass = 40amu) is kept at 300K in a container. The ratio of the rms speeds $\left[\frac{V_{rms}(\text{helium})}{V_{rms}(\text{argon})}\right]$ is
a) 0.32 b) 0.45 c) 2.24 d) 3.16

47. If the internal energy of n_1 moles of He at temperature 10 T is equal to the internal energy of n_2 mole of hydrogen at temperature 6 T. the ratio of $\frac{n_1}{n_2}$ is

a) $\frac{3}{5}$ b) 2 c) 1 d) $\frac{5}{3}$

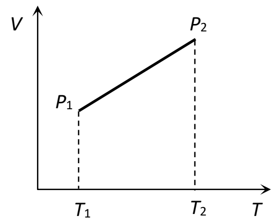
48. In kinetic theory of gases, which of the following statements regarding elastic collisions of the molecules is wrong
a) Kinetic energy is lost in collisions
b) Kinetic energy remains constant in collision
c) Momentum is conserved in collision
d) Pressure of the gas remains constant in collisions

49. The ratio of the vapor densities of two gases at a given temperature is 9: 8. The ratio of the rms velocities of their molecules is
a) $3: 2\sqrt{2}$ b) $2\sqrt{2}: 3$ c) 9: 8 d) 8: 9

50. On any planet, the presence of atmosphere implies (C_{rms} = root mean square velocity of molecules and V_e = escape velocity)
a) $C_{rms} << V_e$ b) $C_{rms} > V_e$ c) $C_{rms} = V_e$ d) $C_{rms} = 0$

51. $r.m.s.$ velocity of nitrogen molecules at NTP is
a) 492 m/s b) 517 m/s c) 546 m/s d) 33 m/s

52. From the following $V - T$ diagram we can conclude



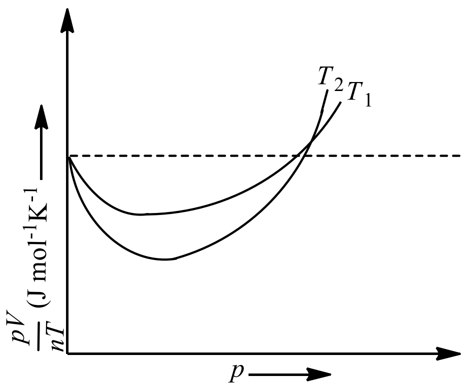
a) $P_1 = P_2$ b) $P_1 > P_2$ c) $P_1 < P_2$ d) None of these

53. In Vander Waal's equation a and b represent $\left(P + \frac{a}{V^2}\right)(V - b) = RT$
a) Both a and b represent correction in volume
b) Both a and b represent adhesive force between molecules
c) a represents adhesive force between molecules and b correction in volume
d) a represents correction in volume and b represents adhesive force between molecules

54. At the same temperature and pressure and volume of two gases, which of the following quantities is constant
a) Total number of molecules
b) Average kinetic energy
c) Root mean square velocity
d) Mean free path

55 A closed vessel is maintained at a constant temperature. It is first evacuated and then vapour is injected into it continuously. The pressure of the vapour in the vessel
a) Increases continuously
b) First increases and then remains constant
c) First increases and then decreases
d) None of the above

56. The figure below shows the plot of $\frac{pV}{nT}$ *versus* p for oxygen gas at two different temperatures.



Read the following statements concerning the above curves.

I. The dotted line corresponds to the ideal gas behavior

II. $T_1 > T_2$

III. The value of $\frac{pV}{nT}$ at the point where the curves meet on the y-axis is the same for all gases.

a) (i) only b) (i) and (ii) only c) All of these d) None of these

57. If one mole of a monoatomic gas $\left(\gamma = \frac{5}{3}\right)$ is mixed with one mole of a diatomic gas $\left(\gamma = \frac{7}{5}\right)$, the value of γ for the mixture is

a) 1.40 b) 1.50 c) 1.53 d) 3.07

58. A gas mixture consists of 2 moles of oxygen and 4 moles of argon at temperature T. Neglecting all vibrational moles, the total internal energy of the system is

a) 4 RT b) 15 RT c) 9 RT d) 11 RT

: HINTS AND SOLUTIONS :

1 **(b)**

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}} \quad \text{or} \quad v_{\text{rms}} \propto \sqrt{T}$$

v_{rms} is to reduce two times, *ie*, the temperature of the gas will have to reduce force times or

$$\frac{T'}{T} = \frac{1}{4}$$

During adiabatic process,

$$TV^{\gamma-1} = T'V'^{\gamma-1}$$

or $$\frac{V'}{V} = \left(\frac{T}{T'}\right)^{\frac{1}{\gamma-1}}$$

$$= (4)^{\frac{1}{1.5-1}} = 4^2 = 16$$

$\therefore \quad V' = 16\,V$

2 **(a)**

K.E. is function of temperature. So $\frac{E_{H_2}}{E_{O_2}} = \frac{1}{1}$

3 **(d)**

Since $v_{rms} \propto \sqrt{T}$. Also mean square velocity $\overline{v^2} = v_{rms}^2$

4 **(b)**

RMS velocity is given by

$$v = \sqrt{\frac{3kT}{m}} \quad \text{or} \quad v^2 = \frac{3kT}{m}$$

For a gas, k and m are constants.

$\therefore \quad \frac{v^2}{T}$ =constant

5 **(c)**

According to Boyle's law

$(P_1V_1)_{\text{At top of the lake}} = (P_2V_2)_{\text{At the bottom of the lake}}$

$$\Rightarrow P_1V_1 = (P_1 + h)V_2 \Rightarrow 10 \times \frac{4}{3}\pi\left(\frac{5r}{4}\right)^3$$

$$\Rightarrow (10 + h) \times \frac{4}{3}\pi r^3 \Rightarrow h = \frac{610}{64} = 9.53m$$

6 **(a)**

The total pressure exerted by a mixture of non-reacting gases occupying a vessel is equal to the sum of the individual pressure which each gas exert if it alone occupied the same volume at a given temperature.

For two gases,

$$p = p_1 + p_2 = p + p = 2p$$

7 **(d)**

8 **(b)**

$$P = \frac{\mu RT}{V} = \frac{mRT}{MV} \quad \left(\mu = \frac{m}{M}\right)$$

So, at constant volume pressure-versus temperature graph is a straight line passing through origin with slope $\frac{mR}{MV}$. As the mass is doubled and volume is halved slope becomes four times. Therefore, pressure versus temperature graph will be shown by the line B

9 **(d)**

$n_1 C_v \Delta T_1 = n_2 C_v \Delta T_2$

$10 \times (T - 10) = 20(20 - T)$

$T - 10 = 40 - 2T$

$3T = 50 \Rightarrow T = 16.6°\text{C}$

10 **(a)**

Mayer Formula

11 **(a)**

$\because \theta_1 < \theta_2 \Rightarrow \tan\theta_1 < \tan\theta_2 \Rightarrow \left(\frac{V}{T}\right)_1 < \left(\frac{V}{T}\right)_2$

Form $PV = \mu RT; \frac{V}{T} \propto \frac{1}{P}$

Hence $\left(\frac{1}{P}\right)_1 < \left(\frac{1}{P}\right)_2 \Rightarrow P_1 > P_2$

12 **(c)**

Pressure, $P = \frac{F}{A} = \frac{1}{A}.\frac{\Delta p}{\Delta t}$ [Δp = change in momentum]

13 **(a)**

$$\frac{C_P}{C_V} = \gamma = 1 + \frac{2}{f}$$

14 **(d)**

Root mean square velocity of gas molecules

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

or $$v_{\text{rms}} \propto \frac{1}{\sqrt{M}}$$

or $$\frac{v_{O_3}}{v_{O_2}} = \sqrt{\frac{M_{O_2}}{M_{O_3}}}$$

Here, $M_{O_2} = 32$, $M_{O_3} = 48$

$\therefore$ $$\frac{v_{O_3}}{v_{O_2}} = \sqrt{\frac{32}{48}} = \frac{\sqrt{2}}{\sqrt{3}}$$

15 **(b)**

Given, $p_1 = 100$ mm, $V_1 = 200$ mL and $p_2 = 400$ mm

From Boyle' Law

$$p_1V_1 = p_2V_2$$

$$V_2 = \frac{p_1V_1}{p_2}$$

$$= \frac{100 \times 200}{400}$$

$$V_2 = 50 \text{ mL}$$

Volume of 2 mol gas$=2 \times 50 = 100$ mL

16 **(c)**

Molecules of ideal gas behaves like perfectly elastic rigid sphere

17 **(d)**

$$C_P = \left(\frac{f}{2}+1\right)R = \left(\frac{5}{2}+1\right)R = \frac{7}{2}R$$

18 **(a)**

As $\theta_2 > \theta_1 \Rightarrow \tan\theta_2 > \tan\theta_1 \Rightarrow \left(\frac{T}{P}\right)_2 > \left(\frac{T}{P}\right)_1$

Also from $PV = \mu RT; \frac{T}{P} \propto V \Rightarrow V_2 > V_1$

19 **(c)**

$v_{rms} = \sqrt{\frac{3RT}{M}}$. According to problem T will become $2T$ and M will becomes $M/2$ so the value of v_{rms} will increase by $\sqrt{4} = 2$times, $i.e.$, new root mean square velocity will be $2v$

20 **(c)**

Mean kinetic energy of molecule depends upon temperature only. For O_2 it is same as that of H_2 at the same temperature of $-73°C$

21 **(d)**

$$P = \frac{2}{3}E$$

22 **(d)**

$C_P - C_V = R$ and R is constant for all gases

23 **(b)**

$v_{rms} > v_{av} > v_{mp}$

24 **(d)**

$$C_V = \frac{5}{2}R \text{ and } C_p = \frac{7}{2}R$$

$$\therefore \qquad \gamma = \frac{C_p}{C_V} = \frac{7}{5}$$

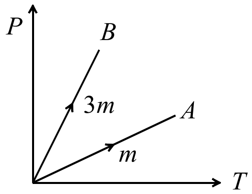
25 **(a)**

A monoatomic gas molecule has only three translational degrees of freedom

26 **(a)**

$$v_{rms} = \sqrt{\frac{3p}{\rho}} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{\rho_2}{\rho_1}} = \sqrt{\frac{16}{1}} = \frac{4}{1}$$

27 **(a)**



For a gas, $PV = \mu RT = \frac{m}{M}RT$

For graph A, $PV = \frac{m}{M}RT$

Slope of graph A,

$\left(\frac{P}{T}\right) = \frac{m}{M}\frac{R}{V}$ ...(i)

For graph B, $PV = \frac{3m}{M}RT$

Slope of graph B,

$\left(\frac{P}{T}\right) = \frac{3m}{M}\frac{R}{V}$ ...(ii)

$$\frac{\text{Slope of curve } B}{\text{Slope of curve } A} = \frac{\frac{3m}{M}\frac{R}{V}}{\frac{m}{M}\frac{R}{V}} = \frac{3}{1}$$

28 **(a)**

Average kinetic theory of one molecule is

$$E = \frac{3}{2} kT$$

where k is Boltzmann constant and T the absolute temperature.

Given, $T_1 = -68°C = 273 - 68 = 205$ K,

$E_1 = E, \quad E_2 = 2E$

$$\therefore \quad \frac{E_1}{E_2} = \frac{T_1}{T_2}$$

$$\Rightarrow \quad T_2 = \frac{T_1 E_2}{E_1}$$

$$\therefore \quad T_2 = \frac{205 \times 2E}{E} = 410 \text{ K}$$

29 **(a)**

Kinetic energy for 1 *mole gas* $E = \frac{f}{2} RT$

$$\Rightarrow E_{\text{Translation}} = \frac{3}{2} RT$$

[$\because$ For all gases translational degree of freedom $f = 3$]

30 **(c)**

$E \propto T$

31 **(d)**

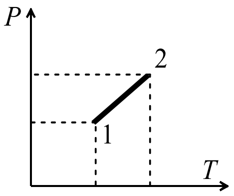
$$PV = \mu RT \Rightarrow P\left(\frac{m}{\rho}\right) = \mu RT \Rightarrow \rho \propto \frac{P}{T}$$

Since T becomes four times and P becomes twice so ρ becomes $\frac{1}{2}$ times

32 **(a)**

At $T = 0K, v_{rms} = 0$

33 **(c)**



$PV = \mu RT$

$\Rightarrow V \propto \frac{T}{P}$ ($\because$ μ and R are fixed)

Since, T increases rapidly and P increases slowly thus volume of the gas increases

34 **(d)**

35 **(c)**

From the Mayer's formula

$$C_p - C_V = R \qquad \text{...(i)}$$

and $\gamma = \frac{C_p}{C_V}$

$$\Rightarrow \quad \gamma C_V = C_p \qquad \text{...(ii)}$$

Substituting Eq. (ii) in Eq. (i) we get

$$\Rightarrow \quad \gamma C_V - C_V = R$$

$$C_V(\gamma - 1) = R$$

$$C_V = \frac{R}{\gamma - 1}$$

36 **(d)**

Degree of freedom $f = 3$ (Translatory)+2(rotatory)+1(vibratory) = 6

$$\Rightarrow \frac{C_P}{C_V} = \gamma = 1 + \frac{2}{f} = 1 + \frac{2}{6} = \frac{4}{3} = 1.33$$

37 **(b)**

38 **(c)**

Mean kinetic energy per molecule $E = \frac{f}{2}kT = \frac{n}{2}kT$

39 **(b)**

In isothermal changes, temperature remains constant

40 **(b)**

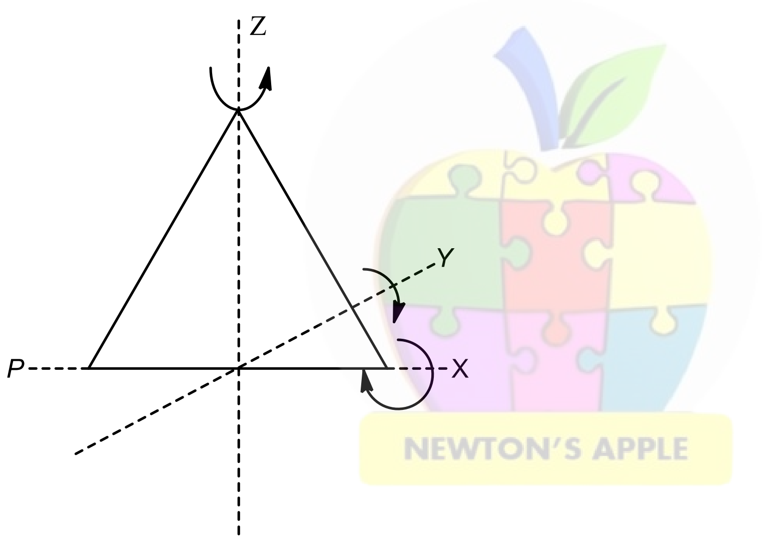
Saturated water vapour do not obey gas laws

41 **(a)**

According to Boyle's law PV = constant

42 **(c)**

As temperature requirement is not given so, the molecule of a triatomic gas has a tendency of rotating about any of three coordinate axes. So, it has 6 degrees of freedom; 3 translational and 3 rotational.



Thus,

(3 translational+3 rotational) at room temperature.

43 **(a)**

Ratio of specific heat for a monoatomic gas is $\frac{5}{3}$ and for diatomic gas is $\frac{7}{5}$.

Given, $n_1 = 1, n_2 = 3, n = 4$

$\therefore \quad \frac{n}{\gamma - 1} = \frac{n_1}{\gamma_1 - 1} + \frac{n_2}{\gamma_2 - 1}$

$\frac{4}{\gamma-1} = \frac{1}{\frac{5}{3}-1} + \frac{3}{\frac{7}{5}-1}$

$\Rightarrow \quad \frac{4}{\gamma-1} = \frac{3}{2} + \frac{15}{2} = 9$

$\therefore \quad 4 = 9\gamma - 9$

$\Rightarrow \quad 9\gamma = 13 \quad \Rightarrow \gamma = \frac{13}{9}$

Now, $\quad C_V(\gamma - 1) = R$

or $\quad C_V = \frac{R}{\gamma-1} = \frac{8.3}{\frac{13}{9}-1} = \frac{8.3\times9}{4}$

$\Rightarrow \quad C_V = 18.7 \text{ J mol}^{-1} - \text{K}^{-1}$

44 **(b)**

$VP^3 = \text{constant} = k \Rightarrow P = \frac{k}{V^{1/3}}$

Also $PV = \mu RT \Rightarrow \frac{k}{V^{1/3}}.V = \mu RT \Rightarrow V^{2/3} = \frac{\mu RT}{k}$

Hence $\left(\frac{V_1}{V_2}\right)^{2/3} = \frac{T_1}{T_2} \Rightarrow \left(\frac{V}{27V}\right)^{2/3} = \frac{T}{T_2} \Rightarrow T_2 = 9T$

45 **(c)**

$$v_{av} = \sqrt{\frac{8RT}{\pi M}} \Rightarrow T \propto M \quad [\because v_{av}, R \to \text{constant}]$$

$$\Rightarrow \frac{T_{H_2}}{T_{O_2}} = \frac{M_{H_2}}{M_{O_2}} \Rightarrow \frac{T_{H_2}}{(273+31)} = \frac{2}{32}$$

$\Rightarrow T_{H_2} = 19\,K = -254°\text{C}$

46 **(d)**

$$\frac{V_{rms\,He}}{V_{rms\,Ar}} = \frac{\sqrt{\frac{3RT}{m_{He}}}}{\sqrt{\frac{3RT}{m_{Ar}}}} = \sqrt{\frac{m_{Ar}}{m_{He}}} = \sqrt{\frac{40}{4}} = \sqrt{10} \approx 3.16$$

47 **(c)**

$n_1 C_{v1} \Delta T_1 = n_2 C_{v2} \Delta T_2$

$$\Rightarrow n_1 \times \frac{3}{2} R \times 10 = n_2 \times \frac{5}{2} R \times 6 \Rightarrow \frac{n_1}{n_2} = 1$$

48 **(a)**

In elastic collision kinetic energy is conserved

49 **(b)**

Root mean square speed

$$v_{\text{rms}} \propto \frac{1}{\sqrt{\rho}}$$

$$\therefore \qquad \frac{v_{\text{rms}_1}}{v_{\text{rms}_2}} = \sqrt{\frac{\rho_2}{\rho_1}}$$

Given, $\frac{\rho_1}{\rho_2} = \frac{9}{8}$

$$\Rightarrow \qquad \frac{v_{\text{rms}_1}}{v_{\text{rms}_2}} = \sqrt{\frac{8}{9}} = \frac{2\sqrt{2}}{3}$$

50 **(a)**

Since $c_{rms} << V_e$, hence molecules do not escape out

51 **(b)**

$$v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \times 8.3 \times 300}{28 \times 10^{-3}}} = 517 m/s$$

52 **(b)**

In case of given graph, V and T are related as $V = aT - b$, where a and b are constants.

From ideal gas equation, $PV = \mu RT$

We find $P = \frac{\mu RT}{aT - b} = \frac{\mu R}{a - b/T}$

Sinec $T_2 > T_1$, therefore $P_2 < P_1$

53 **(c)**

In Vander Waal's equation $\left(P + \frac{a}{V_2}\right)(V - b) = RT$

a represents intermolecular attractive force and b represents volume correction

54 **(b)**

Average kinetic energy $\propto$ Temperature

55 **(b)**

The molecules of a gas are in a state of random motion. They continuously collide against the walls of the container. Even at ordinary temperature and pressure, the number of molecular collisions with walls is very large. During each collision, certain momentum is transferred to the walls of the container. The pressure exerted by the gas is due to continuous bombardment of gas molecules against the walls of the container. Due to this continuous bombardment, the walls of the container experience a continuous force which is equal to the total momentum imparted to the walls per second. The average force experienced per unit area of the walls container determines the pressure exerted by the gas. This should be clear from the fact that although the molecular collisions are random the pressure remains constant.

56 **(c)**

1. The dotted line in the diagram shows that there is no derivation in the value of $\frac{pV}{nT}$ for different temperature T_1 and T_2 for increasing pressure so, this gas behaves ideally. Hence, dotted line corresponds to 'ideal' gas behavior.

2. At high temperature, the derivation of the gas is less and at low temperature the derivation of gas is more. In the graph, derivation for T_2 is greater than for T_1. Thus,

$$T_1 > T_2$$

3. Since, the two curves intersect at dotted line so, the value of $\frac{pV}{nT}$ at that point on the y-axis is same for all gases.

57 **(c)**

$$\gamma_{\text{max}} = \frac{\frac{\mu_1\gamma_1}{\gamma_1-1} + \frac{\mu_2\gamma_2}{\gamma_2-1}}{\frac{\mu_1}{\gamma_1-1} + \frac{\mu_2}{\gamma_2-1}}$$

$$= \frac{\frac{1\times\frac{5}{3}}{\left[\frac{5}{3}-1\right]} + \frac{1\times\frac{7}{5}}{\left[\frac{7}{5}-1\right]}}{\left[\frac{1}{\frac{5}{3}-1}\right] + \left[\frac{1}{\frac{7}{5}-1}\right]} = \frac{3}{2} = 1.5$$

58 **(d)**

Oxygen being a diatomic gas possesses 5 degrees of freedom, 3 translational and 2 rotational. Argon being monoatomic has 3 translational degrees of freedom.

Total energy of the system

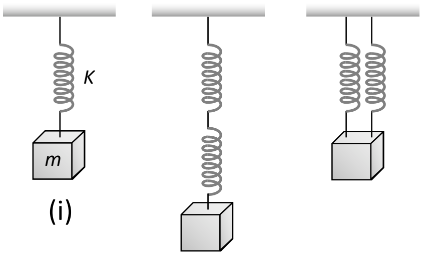
$$= E_{\text{oxygen}} + E_{\text{argon}}$$

$$= n_1 f_1 \left(\frac{1}{2}RT\right) + n_2 f_2 (\frac{1}{2}RT)$$

$$= 2 \times 5 \times \frac{1}{2} RT + 4 \times 3 \times \frac{1}{2} RT$$
$$= 5RT + 6RT = 11RT$$

Simple Harmonic Motion

1. A mass m is vertically suspended from a spring of negligible mass; the system oscillates with a frequency n. What will be the frequency of the system if a mass 4 m is suspended from the same spring
   a) $n/4$ b) $4n$ c) $n/2$ d) $2n$
2. Two particles P and Q start from origin and execute Simple Harmonic Motion along X-axis with same amplitude but with period 3 *seconds* and 6 *seconds* respectively. The ratio of the velocities of the velocities of P and Q when they meet is
   a) 1 :2 b) 2 :1 c) 2 :3 d) 3 :2
3. The total energy of a particle, executing simple harmonic motion is
   Where x is the displacement from the mean position?
   a) $\propto x$ b) $\propto x^2$ c) Independent of x d) $\propto x^{1/2}$
4. There is a simple pendulum hanging from the ceiling of a lift. When the lift is stand still, the time period of the pendulum is T. If the resultant acceleration becomes $g/4$, then the new time period of the pendulum is
   a) 0.8 T b) 0.25 T c) 2 T d) 4 T
5. If a body is executing simple harmonic motion then
   a) At extreme positions, the total energy is zero
   b) At equilibrium position, the total energy is in the form of potential energy
   c) At equilibrium position, the total energy is in the form of kinetic energy
   d) At extreme position, the total energy is infinite
6. Five identical springs are used in the following three configurations. The time periods of vertical oscillations in configurations (i), (ii) and (iii) are in the ratio



   a) $1 : \sqrt{2} : \frac{1}{\sqrt{2}}$ b) $2 : \sqrt{2} : \frac{1}{\sqrt{2}}$ c) $\frac{1}{\sqrt{2}} : 2 : 1$ d) $2 : \frac{1}{\sqrt{2}} : 1$
7. A simple pendulum has time period T. The bob is given negative charge and surface below it is given positive charge. The new time period will be
   a) Less than T b) Greater than T c) Equal to T d) Infinite

8. A particle of mass 200 g executes SHM. The restoring force is provided by a spring of force constant 80 N/m. The time period of oscillation is

a) 0.31 s b) 0.15 s c) 0.05 s d) 0.02 s

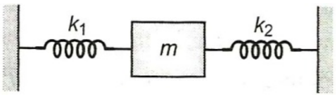
9. The time period of a simple pendulum in a lift descending with constant acceleration g is

a) $T = 2\pi\sqrt{\frac{l}{g}}$ b) $T = 2\pi\sqrt{\frac{l}{2g}}$ c) Zero d) Infinite

10. Displacement between maximum potential energy position and maximum kinetic energy position for a particle executing S.H.M. is

a) $-a$ b) $+a$ c) $\pm a$ d) $\pm a/4$

11. Two springs, of force constants k_1 and k_2, are connected to a mass m as shown. The frequency of the mass is f. If both k_1 and k_2 are made four times their original values, the frequency of oscillation becomes



a) $f/2$ b) $f/4$ c) $4f$ d) $2f$

12. The motion of a particle executing S.H.M. is given by $x = 0.01 \sin 100\pi(t + .05)$, where x is in $metres$ and time is in seconds. The time period is

a) 0.01 s b) 0.02 s c) 0.1 s d) 0.2 s

13. The pendulum bob has a speed of 3ms^{-1} at its lowest position. The pendulum is 0.5 m long. The speed of the bob, when the length makes an angle of 60° to the vertical will be ($g = 10\text{ ms}^{-2}$)

a) $\frac{1}{2}\text{ ms}^{-1}$ b) $\frac{1}{3}\text{ ms}^{-1}$ c) 3 ms^{-1} d) 2 ms^{-1}

14. A uniform spring of force constant k is cut into two pieces, the lengths of which are in the ratio 1: 2. The ratio of the force constants of the shorter and longer piece is

a) 1 : 2 b) 2 : 1 c) 1 : 3 d) 2 : 3

15. The displacement x(in metre) of a particle in simple harmonic motion is related to time t(in second) as

$$x = 0.01 \cos\left(\pi t + \frac{\pi}{4}\right)$$

The frequency of the motion will be

a) 0.5 Hz b) 1.0 Hz c) $\frac{\pi}{2}$ Hz d) π Hz

16. A particle is moving in a circle with uniform speed. Its motion is

a) Periodic and simple harmonic b) Periodic but no simple harmonic
c) A periodic d) None of the above

17. A simple pendulum is suspended from the ceiling of a lift. When the lift is at rest its time period is T. With what acceleration should the lift be accelerated upwards in order to reduce its period to $T/2$? (g is acceleration due to gravity)

a) 2 g b) 3 g c) 4 g d) g

18. Two simple harmonic motions are represented by

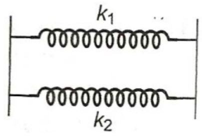
$$y_1 = 5[\sin 2\pi t + \sqrt{3}\cos 2\pi t]$$

and $$y_2 = 5\sin\left(2\pi t + \frac{\pi}{4}\right)$$

The ratio of their amplitudes is

a) 1: 1 b) 2: 1 c) 1: 3 d) $\sqrt{3}$: 1

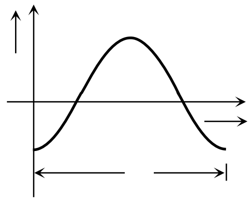
19. Two springs of force constant k_1 and k_2 are connected as shown.



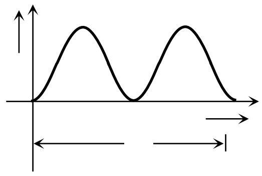
The effective spring constant k is

a) $k_1 + k_2$ b) $\frac{k_1}{k_2}$ c) $k_1 k_2$ d) $2k_1 k_2$

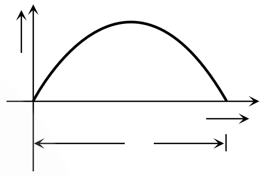
20. Acceleration A and time period T of a body in S.H.M. is given by a curve shown below. Then corresponding graph, between identic energy (K.E) and time t is correctly represented by



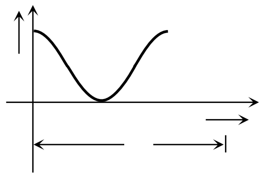
a)



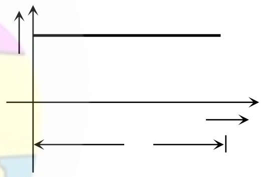
b)



c)



d)



21. The bob of a pendulum of length l is pulled aside from its equilibrium position through an angle θ and then released. The bob will then pass through its equilibrium position with a speed v, where v equals

a) $\sqrt{2gl(1 - \cos\theta)}$ b) $\sqrt{2gl(1 + \sin\theta)}$
c) $\sqrt{2gl(1 - \sin\theta)}$ d) $\sqrt{2gl(1 + \cos\theta)}$

22. A particle executes harmonic motion with an angular velocity and maximum acceleration of 3.5 rad/s and 7.5 m/s^2 respectively. The amplitude of oscillation is

a) 0.28 m b) 0.36 m c) 0.53 m d) 0.61 m

23. The total energy of a particle executing SHM is 80 J. What is the potential energy when the particle is at a distance of ¾ of amplitude from the mean position?

a) 60 J b) 10 J c) 40 J d) 45 J

24. Mark the wrong statement

a) All S.H.M.'s have fixed time period
b) All motions having same time period are S.H.M.
c) In S.H.M. total energy is proportional to square of amplitude
d) Phase constant of S.H.M. depends upon initial conditions

25. What is constant in S.H.M.

a) Restoring force b) Kinetic energy c) Potential energy d) Periodic time

26. If a watch with a wound spring is taken on to the moon, it

a) Runs faster b) Runs slower c) Does not work d) Shown no change

27. A particle has simple harmonic motion. The equation of its motion is $x = 5\sin\left(4t - \frac{\pi}{6}\right)$, where x is its displacement. If the displacement of the particle is 3 units, then it velocity is

a) $\frac{2\pi}{3}$ b) $\frac{5\pi}{6}$ c) 20 d) 16

28. What is the effect on the time period of a simple pendulum if the mass of the bob is doubled

a) Halved b) Doubled c) Becomes eight times d) No effect

29. Two simple harmonic motions are represented by the equations

$y_1 = 0.1 \sin\left(100\,\pi t + \frac{\pi}{3}\right)$ and $y_2 = 0.1 \cos \pi t$.

The phase difference of the velocity of particle 1, with respect to the velocity of particle 2 is

a) $\frac{-\pi}{6}$ b) $\frac{\pi}{3}$ c) $\frac{-\pi}{3}$ d) $\frac{\pi}{6}$

30. A body of mass 4 kg hangs from a spring and oscillates with a period 0.5 s on the removel of the body, the spring is shortented by

a) 6.3 cm b) 0.63 cm c) 6.25 cm d) 6.3 cm

31. The periodic time of a particle doing simple harmonic motion is 4 s. The taken by it to go from its mean position to half the maximum displacement (amplitude)

a) 2s b) 1s c) $\frac{2}{3}$s d) $\frac{1}{3}$s

32. The motion of a particle executing SHM is given by$x = 0.01 \sin 100p(t + 0.05)$, where x is in metre and time t is in second. The time period is

a) 0.2 s b) 0.1 s c) 0.02 s d) 0.01 s

33. A particle executes simple harmonic motion with a time period of 16 s. At time $t = 2$ s, the particle crosses the mean position while at $t = 4$ s, velocity is 4 ms^{-1}. The amplitude of motion in metre is

a) $\sqrt{2}\pi$ b) $16\sqrt{2}\pi$ c) $24\sqrt{2}\pi$ d) $\frac{32\sqrt{2}}{\pi}$

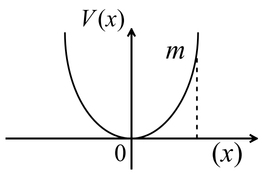
34. The acceleration of a particle performing SHM is 12 cms^{-2} at a distance of 3 cm from the mean position. Its time period is

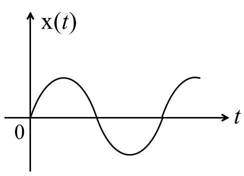
a) 2.0 s b) 3.14 s c) 0.5 s d) 1.0 s

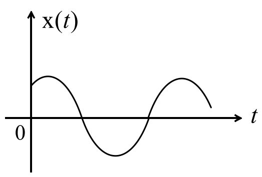
35. A body of mass 20 g connected to spring of constant k executes simple harmonic motion with a frequency of $\left(\frac{5}{\pi}\right)$ Hz. The value of spring constant is

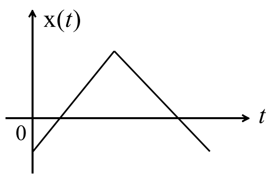
a) 4 Nm^{-1} b) 3 Nm^{-1} c) 2 Nm^{-1} d) 5 Nm^{-1}

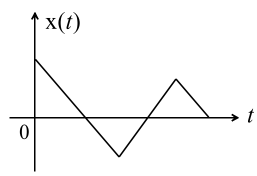
36. A particle of mass m is released from rest and follows a parabolic path as shown. Assuming that the displacement of the mass from the origin is small, which graph correctly depicts the position of the particle as a function of time



a) 

b) 

c) 

d) 

37. Two particles execute SHM of the same amplitude and frequency along the same straight line. If they pass one another when going in opposite directions, each time their displacement is half their amplitude, the phase difference between them is

a) $\frac{\pi}{3}$ b) $\frac{\pi}{4}$ c) $\frac{\pi}{6}$ d) $\frac{2\pi}{3}$

38. The velocity of simple pendulum is maximum at

a) Extremes b) Half displacement c) Mean position d) Every where

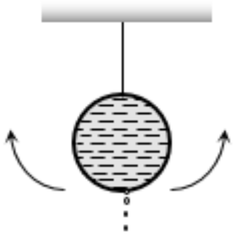
39. A simple pendulum has a length l and the mass of the bob is m. The bob is given a charge q coulomb. The pendulum is suspended between the vertical plates of a charged parallel plate capacitor. If E is the electric field strength between the plates, the time period of the pendulum is given by

a) $2\pi\sqrt{\frac{l}{g}}$ b) $2\pi\sqrt{\frac{l}{\sqrt{g+\frac{qE}{m}}}}$ c) $2\pi\sqrt{\frac{l}{\sqrt{g-\frac{qE}{m}}}}$ d) $2\pi\sqrt{\frac{l}{\sqrt{g^2+\left(\frac{qE}{m}\right)^2}}}$

40. The period of oscillation of a simple pendulum of length l suspended from the roof of a vehicle, which moves without friction down an inclined plane of inclination α is given by

a) $2\pi\sqrt{\frac{1}{g\cos\alpha}}$ b) $2\pi\sqrt{\frac{1}{g\sin\alpha}}$ c) $2\pi\sqrt{\frac{l}{g}}$ d) $2\pi\sqrt{\frac{1}{g\tan\alpha}}$

41. A simple pendulum is made of a body which is a hollow sphere containing mercury suspended by means of a wire. If a little mercury is drained off, the period of pendulum will



a) Remains unchanged
b) Increase
c) Decrease
d) Become erratic

42. The circular motion of a particle with constant speed is

a) Simple harmonic but not periodic b) Periodic and simple harmonic
c) Neither periodic nor simple harmonic d) Periodic but not simple harmonic

43. A particle is executing simple harmonic motion with frequency f. The frequency at which its kinetic energy change into potential energy is

a) $f/2$ b) f c) $2f$ d) $4f$

44. The average acceleration of a particle performing SHM over one complete oscillation is

a) $\frac{\omega^2 A}{2}$ b) $\frac{\omega^2 A}{\sqrt{2}}$ c) Zero d) $A\omega^2$

45. A particle of mass 1 kg is moving in SHM with an amplitude 0.02 m and a frequency of 60 Hz. The maximum force in newton acting on the particle is

a) $188\,\pi^2$ b) $144\pi^2$ c) $288\pi^2$ d) None of these

46. Two springs have spring constants K_A and K_B and $K_A > K_B$. The work required to stretch them by same extension will be

a) More in spring A b) More in spring B c) Equal in both d) Nothing can be said

1 **(c)**

$$n = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \Rightarrow n \propto \frac{1}{\sqrt{m}} \Rightarrow \frac{n_1}{n_2} = \sqrt{\frac{m_2}{m_1}}$$

$$\Rightarrow \frac{n}{n_2} = \sqrt{\frac{4m}{m}} \Rightarrow n_2 = \frac{n}{2}$$

2 **(b)**

The particle will meet at the mean position when P completes one oscillation and Q completes half an oscillation

So $\frac{v_P}{v_Q} = \frac{a\omega_P}{a\omega_Q} = \frac{T_Q}{T_P} = \frac{6}{3} = \frac{2}{1}$

3 **(c)**

In simple harmonic motion when a particle displaced to a position from its mean position then its kinetic energy gets converted in potential energy. Hence, total energy of particle remains constant or the total energy in simple harmonic motion does not depend is displacement x.

4 **(c)**

Time period of a simple pendulum of length l, is given by

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

...(i)

Where, g is acceleration due to gravity.

When $g' = \frac{g}{4}$,

New, time period is

$$T' = 2\pi\sqrt{\frac{l}{g/4}}$$

...(ii)

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

$$\frac{T'}{T} = \sqrt{\frac{g}{g/4}} = 2$$

$\Rightarrow \quad T' = 2\,T$

Hence, new time period becomes twice of the original value.

5 **(c)**

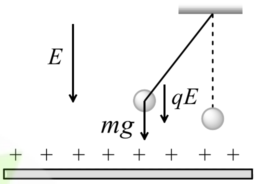
At equilibrium position, potential energy of the body is zero. So, the total energy at equilibrium position is completely kinetic energy.

6 **(a)**

$$T \propto \frac{1}{\sqrt{k}} \Rightarrow T_1 : T_2 : T_3 = \frac{1}{\sqrt{k}} : \frac{1}{\sqrt{k/2}} : \frac{1}{\sqrt{2k}} = 1 : \sqrt{2} : \frac{1}{\sqrt{2}}$$

7 **(a)**

In this case time period of pendulum becomes



$$T'' = 2\pi\sqrt{\frac{l}{\left(g + \frac{qE}{m}\right)}}$$

$\Rightarrow T'' < T$

8 **(a)**

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

$$= 2\pi\sqrt{\frac{0.2}{80}} = 0.315$$

9 **(d)**

This is the case of freely falling lift and in free fall of lift effective g for pendulum will be zero. So

$$T = 2\pi\sqrt{\frac{l}{0}} = \infty$$

10 **(c)**

Maximum potential energy position $y = \pm a$ and maximum kinetic energy position is $y = 0$

11 **(d)**

$$f = \frac{1}{2\pi}\sqrt{\frac{k_1+k_2}{m}}$$

and $\quad f' = \frac{1}{2\pi}.2\sqrt{\frac{k_1+k_2}{m}} = 2f$

12 **(b)**

$$\omega = \frac{2\pi}{T} = 100\pi \Rightarrow T = 0.02\ s$$

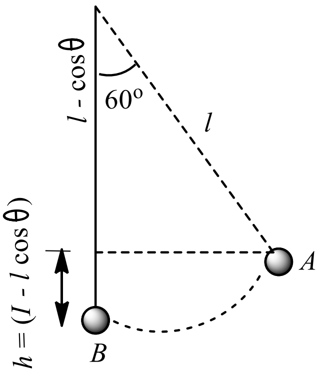
13 **(d)**

KE at the lowest position $= \frac{1}{2}\,mv^2$

$$= \frac{1}{2} m(3)^2 = \frac{9}{2} m$$

When the length makes an angle $\theta (= 60°)$ to the vertical, the bob of the pendulum will have both KE and PE. If v is the velocity of bob at this position and h is the height of the bob w.r.t. B, then total energy of the bob

$$= \frac{1}{2} mv^2 + mgh$$



But $\quad h = l - l\cos\theta$

$$= l(1 - \cos\theta)$$

$$= 0.5(1 - \cos 60°) = 0.5\left(1 - \frac{1}{2}\right) = \frac{1}{4}$$

$$E = \frac{1}{2} mv^2 + m \times 10 \times \frac{1}{4}$$

$$= \frac{1}{2} mv^2 + \frac{5}{2} m$$

According to law of conservation of energy

$$\frac{1}{2} mv^2 + \frac{5m}{2} = \frac{9}{2} m$$

$$\Rightarrow \quad \frac{1}{2} mv^2 = \frac{9}{2} m - \frac{5}{2} m = 2m$$

$$\therefore \quad u = 2 \text{ ms}^{-1}$$

14 **(b)**

Let k be the force constant of the shorter part of the spring of length$l/3$. In a complete spring, three springs are in series each of force constant k

$$k_1 = k/2 = \frac{3k}{2}$$

$$\therefore \quad \frac{k}{k_1} = \frac{3K}{3K/2} = 2 \text{ or } k : k_1 = 2 : 1$$

15 **(a)**

The standard equation in SHM is

$$x = a\cos(\omega t + \emptyset)$$

...(i)

Where a is amplitude, ω the angular velocity and $(\emptyset)$ the phase difference.

Also, $\omega = \frac{2\pi}{T}$ where T is periodic time.

So, Eq. (i) becomes

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

...(ii)

Given, equation is

$$x = 0.01\cos\left(\frac{2\pi t}{2} + \frac{\pi}{4}\right)$$

...(iii)

Comparing Eq. (ii) with Eq. (iii), we get

$$\frac{2\pi t}{T} = \frac{2\pi t}{2}$$

$$\Rightarrow \quad T = 2\text{s}$$

So, frequency $n = \frac{1}{T} = \frac{1}{2} = 0.5$ Hz

16 **(b)**

17 **(b)**

Time period of simple pendulum is given by

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

...(i)

When the lift is moving up with an acceleration a, then time period becomes

$$T' = 2\pi\sqrt{\frac{l}{g + a}}$$

Here, $\quad T' = \frac{T}{2}$

$$\Rightarrow \quad \frac{T}{2} = 2\pi\sqrt{\frac{l}{g + a}}$$

...(ii)

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

$$a = 3g$$

18 **(b)**

$$y_1 = 5[\sin 2\pi t + \sqrt{3}\cos 2\pi t]$$

$$= 10[\frac{1}{2}\sin 2\pi t + \frac{\sqrt{3}}{2}\cos 2\pi t\ ]$$

$$= 10[\cos\frac{\pi}{3}\sin 2\pi t + \sin\frac{\pi}{3}\cos 2\pi t]$$

$$= 10[(\sin 2\pi t + \frac{\pi}{3})]$$

$$\Rightarrow \quad A_1 = 10$$

Similarly, $\quad y_2 = 5\sin\left(2\pi t + \frac{\pi}{4}\right)$

$$\Rightarrow \quad A_2 = 5$$

Hence, $\quad \frac{A_1}{A_2} = \frac{10}{5} = \frac{2}{1}$

19 **(a)**

Effective spring constant of parallel combination

$$k_e = k_1 + k_2$$

20 **(a)**

In S.H.M. when acceleration is negative maximum or positive maximum, the velocity is zero so kinetic energy is also zero. Similarly for zero acceleration, velocity is maximum so kinetic energy is also maximum

21 **(a)**

When the bob of pendulum is brought to a position making an angle θ with the equilibrium position, then height of fall of pendulum will be, $h = l - l\cos\theta = l(1-\cos\theta)$.
Taking free fall of the
$u = 0, a = g, g = h = l(1-\cos\theta), v = ?$
Now, $v^2 = u^2 + 2gh = 0 + 2gl(1-\cos\theta)$
or $v = \sqrt{2gl(1-\cos\theta)}$

22 **(d)**

$$A_{\max} = a\omega^2 \Rightarrow a = \frac{A_{\max}}{\omega^2} = \frac{7.5}{(3.5)^2} = 0.61\ m$$

23 **(d)**

$\frac{1}{2}m\omega^2r^2 = 80\ J$;

PE$= \frac{1}{2}m\omega^2y^2 = \frac{1}{2}m\omega^2 \times \left(\frac{3}{4}r\right)^2$

$= \frac{9}{16}\left(\frac{1}{2}m\omega^2r^2\right) = \frac{9}{16} \times 80 = 45$ J

24 **(b)**

25 **(d)**

26 **(d)**

The time period of oscillation of a spring does not depend on gravity

27 **(d)**

From the given equation, $a = 5$ and $\omega = 4$

$\therefore v = \omega\sqrt{a^2 - y^2} = 4\sqrt{(5)^2 - (3)^2} = 16$

28 **(d)**

$T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow T \propto \sqrt{\frac{l}{g}}$, it is does not depend upon mass

29 **(a)**

Given,

$$y_1 = 0.1\sin(100\pi t + \frac{\pi}{3})$$

$\therefore \quad \frac{dy_1}{dt} = v_1 = 0.1 \times 100\pi\cos\left(100\pi t + \frac{\pi}{3}\right)$

or $\quad v_1 = 10\pi\sin\left(100\pi t + \frac{\pi}{3} + \frac{\pi}{2}\right)$

or $\quad v_1 = 10\pi\sin\left(100\pi t + \frac{5\pi}{6}\right)$

and $\quad y_2 = 0.1\cos\pi t$

$\therefore \quad \frac{dy_2}{dt} = v_2 = -0.1\sin\pi t = 0.1\sin(\pi t + \pi)$

Hence, phase difference

$$\Delta\emptyset = \emptyset_1 - \emptyset_2 = \left(100\pi t + \frac{5\pi}{6}\right) - (\pi t + \pi)$$

$= \frac{5\pi}{6} - \pi$ (at $t =$ 0)

$= -\frac{\pi}{6}$

30 **(c)**

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

$\because \quad mg = kx$

$\therefore \quad T = 2\pi\sqrt{\frac{x}{g}}$

$(0.5)^2 = 4\pi^2 \times \sqrt{\frac{x}{10}}$

$\frac{(0.5)^2 \times 9.8}{4 \times 3.14 \times 3.14} = x$

$x = 0.0621$ m

$x = 6.2$ cm

31 **(d)**

$y = A\sin\left(\frac{2\pi}{T}\right)t$

$\Rightarrow \quad \frac{A}{2} = A\sin\left(\frac{2\pi}{T}\right)t$

$\frac{\pi t}{2} = \frac{\pi}{6}$

$t = \frac{1}{3}$ s

32 **(c)**

$x = 0.01\sin 100\pi(t + 0.05)$

$= 0.01\sin(100\pi t + 5\pi)$

$\therefore$ Angular frequency $\omega = 100\pi = \frac{2\pi}{T}$

or $\quad T = \frac{2}{100} = 0.02$s

33 **(d)**

For simple harmonic motion, $y = a\sin\ \omega t$

$\therefore \quad y = a\sin\ \left(\frac{2\pi}{T}\right)t$

(at t=2 s)

$y_1 = a\sin\ \left[\left(\frac{2\pi}{16}\right) \times 2\right]$

$= a\sin\left(\frac{\pi}{4}\right) = \frac{a}{\sqrt{2}}$

...(i)

At t=4 s or after 2 s from mean position.

$y_1 = \frac{a}{\sqrt{2}}$, velocity=4 ms^{-1}

$\therefore$ Velocity $= \omega\sqrt{a^2 - y_1^2}$

or $\quad 4 = \left(\frac{2\pi}{16}\right)\sqrt{a^2 - \frac{a^2}{2}}$

[From Eq. (i)]

or $\quad 4 = \frac{\pi}{8} \times \frac{a}{\sqrt{2}}$

or $\quad a = \frac{32\sqrt{2}}{\pi}$ m

34 **(b)**

Acceleration, $a = -\omega^2 y = \frac{-4\pi^2}{T^2} y$

or $\quad T = \left(\frac{4\pi^2 y}{a}\right)^{1/2} = 2\pi\sqrt{\frac{y}{a}}$

$= 2 \times \frac{22}{7} \times \sqrt{\frac{3}{12}} = 3.14$

35 **(c)**

Mass (m)=20 g=0.02 kg

Frequency (f)=$\frac{5}{\pi}$ Hz

Time period of a loaded spring

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

Frequency $(f) = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

$$\frac{5}{\pi} = \frac{1}{2\pi}\sqrt{\frac{k}{0.02}}$$

or $\qquad 10 = \sqrt{\frac{k}{0.02}}$

or $\qquad 100 = \frac{k}{0.02}$

$\therefore \qquad k = 2\ \mathrm{Nm}^{-1}$

36 **(b)**

Motion given here is SHM starting from rest

37 **(d)**

Equation of simple harmonic wave is

$$y = A\sin(\omega t + \emptyset)$$

Here, $\quad y = \frac{A}{2}$

$\therefore \qquad A\sin(\omega t + \emptyset) = \frac{A}{2}$

So, $\quad \delta = \omega t + \emptyset = \frac{\pi}{6}$ or $\frac{5\pi}{6}$

So, the phase difference of the two particles when they are crossing each other at $y = \frac{A}{2}$ in opposite directions are

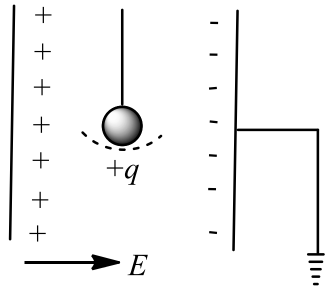
$$\delta = \delta_1 - \delta_2 = \frac{5\pi}{6} - \frac{\pi}{6} = \frac{2\pi}{3}$$

38 **(c)**

39 **(d)**

Time period of simple pendulum in air

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



When it is suspended between vertical plates of a charged parallel plate capacitor, then acceleration due to electric field,

$$a = \frac{qE}{m}$$

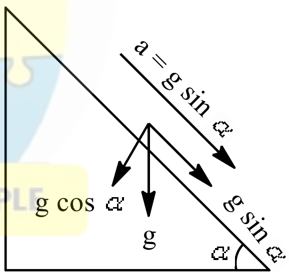
This acceleration is acting horizontally and acceleration due to gravity is acting vertically. So, effective acceleration

$$g' = \sqrt{g^2 + a^2} = \sqrt{g^2 + \left(\frac{qE}{m}\right)^2}$$

Hence, $\qquad T' = 2\pi\sqrt{\frac{l}{\sqrt{g^2 + \left(\frac{qE}{m}\right)^2}}}$

40 **(a)**

Time period $\qquad T = 2\pi\sqrt{\frac{l}{g_{\mathrm{eff}}}}$



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

41 **(b)**

When a little mercury is drained off, the position of $c.g.$ of ball falls ($w.r.t.$ fixed end) so that effective length of pendulum increases hence T increases

42 **(d)**

In a circular motion particle repeats after equal intervals of time. So particle motion on a circular path is periodic but not simple harmonic as it does not execute to and fro motion about a fixed point.

43 **(c)**

In S.H.M. frequency of K.E. and P.E.

= 2 × (Frequency of oscillating particle)

44 **(c)**

The average acceleration of a particle performing SHM over one complete oscillation is zero.

45 **(c)**

Maximum force= $m\omega^2 a = m4\pi v^2 a$

$= 1 \times 4\pi^2 \times (60)^2 \times 0.02 = 288\pi^2$

46 **(a)**

Work done in stretching $(W) \propto$ Stiffness of spring $(i.e. k)$

$\because k_A > k_B \Rightarrow W_A > W_B$ [For same extension]

Mechanical Waves

1. Quality of a musical note depends on
   a) Harmonics present
   b) Amplitude of the wave
   c) Fundamental frequency
   d) Velocity of sound in the medium
2. A cylindrical tube containing air is open at both ends. If the shortest length of the tube for resonance with a given fork is 2 cm, the next shortest length for resonance with the same fork will be
   a) 60 cm
   b) 40 cm
   c) 90 cm
   d) 80 cm
3. The fundamental frequency of a sonameter wire is v. if its radius is doubled and its tension becomes half, the material of the wire remains same, the new fundamental frequency will be
   a) V
   b) $\frac{v}{\sqrt{2}}$
   c) $\frac{v}{2}$
   d) $\frac{v}{2\sqrt{2}}$
4. A wave travelling in stretched string is described by the equation $y = \text{A}\sin(kx - \omega t)$.The maximum particle velocity is
   a) $A\omega$
   b) ω/k
   c) $d\omega/dk$
   d) x/t
5. The second overtone of an open pipe is in resonance with the first overtone of a closed pipe of length 2m. length of the open pipe is
   a) 4m
   b) 2m
   c) 8m
   d) 1m
6. When a sound wave of wavelength λ is propagating in a medium, the maximum velocity of the particle is equal to the velocity. The amplitude of wave is
   a) λ
   b) $\frac{\lambda}{2}$
   c) $\frac{\lambda}{2\pi}$
   d) $\frac{\lambda}{4\pi}$
7. The displacement of a particle is given by
   $x = 3\sin(5\pi t) + 4\cos(5\pi t)$
   The amplitude of the particle is
   a) 3
   b) 4
   c) 5
   d) 7
8. Oxygen is 16 times heavier than hydrogen. Equal volumes of hydrogen and oxygen are mixed. The ratio of speed of sound in the mixture to that in hydrogen is
   a) $\sqrt{8}$
   b) $\sqrt{\frac{2}{17}}$
   c) $\sqrt{\frac{1}{8}}$
   d) $\sqrt{\frac{32}{17}}$
9. If $y = 5\sin\left(30\pi t - \frac{\pi}{7} + 30°\right)$ $y \to mm, t \to s, x \to m$.for given progressive wave equation, phase difference between two vibrating particle having path difference 3.5 m would be
   a) $\pi/4$
   b) π
   c) $\pi/3$
   d) $\pi/2$
10. An observer is moving away from source of sound of frequency 100 Hz. This speed is 33 m/s. If speed of sound is 330 m/s, then the observed frequency is
    a) 90 Hz
    b) 100 Hz
    c) 91 Hz
    d) 110 Hz

11. Velocity of sound in air
I. increases with temperature
II. Decreases with temperature
III. Increase with pressure
IV. Is independent of pressure
V. Is independent of temperature
Choose the correct answer
a) Only I and II are true
b) Only I and III are true
c) Only II and III are true
d) Only I and IV are true

12. The equation of a wave on a string of liner mass density 0.04 $kgm^{-1}$is given by
$y = 0.02(m) \sin\left[2\pi\left(\frac{t}{0.04(s)} - \frac{x}{0.50(m)}\right)\right]$. the tension in the string is
a) 4.0N
b) 12.5N
c) 0.5N
d) 6.25N

13. Which of the following is not the transverse wave
a) X-rays
b) γ-rays
c) Visible light wave
d) Sound wave in gas

14. Three sound waves of equal amplitude have frequencies (v-1),v,(v+1). They superpose to give beat. The number of beats produced per second will be
a) 4
b) 3
c) 2
d) 1

15. If you set up the seventh harmonic on a string fixed at both ends, how many nodes and antinodes are set up in it
a) 8,7
b) 7,7
c) 8,9
d) 9,8

16. In a closed organ pipe the frequency of fundamental note is 50 Hz. The note of which of the following frequencies will not be emitted by it
a) 50 Hz
b) 100 Hz
c) 150 Hz
d) None of the above

17. The equation $y = 0.15 \sin 5x \cos 300t$, describes a stationary wave. The wavelength of the stationary wave is
a) Zero
b) 1.256 $metres$
c) 2.512 $metres$
d) 0.628 $metre$

18. Two tuning forks when sounded together produced 4 $beats/sec$. The frequency of one fork is 256. The number of beats heard increases when the fork of frequency 256 is loaded with wax. The frequency of the other fork is
a) 504
b) 520
c) 260
d) 252

19. A tuning fork of known frequency 256 Hz makes 5 beats/s with the vibrating string of a piano. The beat frequency decreases to 2 beats/s when the tension in the piano string is slightly increased. The frequency of the piano string before increasing the tension was
a) (256+2)Hz
b) (256-2)Hz
c) (256-5)Hz
d) (256+5)Hz

20. An open pipe is suddenly closed at one end with the result that the frequency of third harmonic of the closed pipe is found to be higher at 100 Hz. The fundamental frequency of the open pipe is
a) 200 Hz
b) 480 Hz
c) 240 Hz
d) 300 Hz

21. Of the following, the equation of plane progressive wave is
a) $y = r \sin \omega t$
b) $y = r \sin(\omega t - kx)$
c) $y = \frac{a}{\sqrt{r}} \sin(\omega t - kx)$
d) $y = \frac{a}{r} \sin(\omega t - kx)$

22. Water waves are
a) Longitudinal
b) Transverse
c) Both longitudinal and transverse
d) Neither longitudinal nor transverse

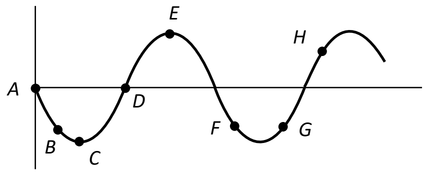
23. If at same temperature and pressure, the densities for two diatomic gases are respectively d_1 and d_2, then the ratio of velocities of sound in these gases will be
a) $\sqrt{\frac{d_2}{d_1}}$
b) $\sqrt{\frac{d_1}{d_2}}$
c) $d_1 d_2$
d) $\sqrt{d_1 d_2}$

24. If fundamental frequency of closed pipe is 50 Hz then frequency of 2^{nd} overtone is
a) 100 Hz
b) 50 Hz
c) 250 Hz
d) 150 Hz

25. Tuning fork F_1 has a frequency of 256 Hz and it is observed to produce 6 beats/second with another tuning fork F_2. When F_2 is loaded with wax, it still produces 6 beats/second with F_1. The frequency of F_2 before loading was

a) 253 Hz b) 262 Hz c) 250 Hz d) 259 Hz

26. The diagram below shows the propagation of a wave. Which points are in same phase



a) F, G b) C and E c) B and G d) B and F

27. A closed Prgan pipe and an open organ pipe of same length produce 2 beats/second while vibrating in their fundamental modes. The length of the open organ pipe is halved and that of closed pipe is doubled. Then the number of beats produced per second while vibrating in the fundamental mode is

a) 2 b) 6 c) 8 d) 7

28. A wave is reflected from a rigid support. The change in phase on reflection will be

a) $\pi/4$ b) $\pi/2$ c) π d) 2π

29. The displacement y of a wave travelling in the x -direction is given by $y = 10^{-4}\sin\left(600t - 2x + \frac{\pi}{3}\right)$ meters, where x is expressed in meters and t is second. The speed of the wave-motion, in ms^{-1}, is

a) 200 b) 300 c) 600 d) 1200

30. When a guitar string is sounded with a 440 Hz tuning fork, a beat frequency of 5 Hz is heard. If the experiment is repeated with a tuning fork of 437 Hz, the beat frequency is 8 Hz. The string frequency (Hz) is

a) 445 b) 435 c) 429 d) 448

31. At which temperature the speed of sound in hydrogen will be same as that of speed of sound in oxygen at 100°C

a) −148°C b) −212.5°C c) −317.5°C d) −249.7°C

32. Two waves are represented by $y_1 = a\sin\left(\omega t + \frac{\pi}{6}\right)$ and $y_2 = a\cos\omega t$. What will be their resultant amplitude

a) a b) $\sqrt{2}a$ c) $\sqrt{3}a$ d) $2a$

33. A transverse progressive wave on a stretched string has a velocity of $10ms^{-1}$ and a frequency of 100 Hz. The phase difference between two particles of the string which are 2.5 cm apart will be

a) $\pi/8$ b) $\pi/4$ c) $3\pi/8$ d) $\pi/2$

34. If the wave equation $y = 0.08\sin\frac{2\pi}{\lambda}(200t - x)$ then the velocity of the wave will be

a) $400\sqrt{2}$ b) $200\sqrt{2}$ c) 400 d) 200

35. If $\lambda_1, \lambda_2, \lambda_3$ are the wavelengths of the waves giving resonance with the fundamental, first and second overtones respectively of a closed organ pipe, then the ratio of $\lambda_1, \lambda_2, \lambda_3$ is

a) 1:3:5 b) 1:2:3 c) 5:3:1 d) $1:\frac{1}{3}:\frac{1}{5}$

36. In a resonance tube, using a tuning fork of frequency 325 Hz, two successive resonance length are observed as 25.4 cm and 77.4 cm respectively. The velocity of sound in air is

a) $338ms^{-1}$ b) $328ms^{-1}$ c) $330ms^{-1}$ d) $320ms^{-1}$

37. A wave of frequency 100 Hz is sent along a string towards a fixed end. When this wave travels back, after reflection, a node is formed at a distance of 10 cm from the fixed end of the string. The speeds of incident (and reflected) waves are

a) $5ms^{-1}$ b) $10ms^{-1}$ c) $20ms^{-1}$ d) $40ms^{-1}$

38. Which of the following do not require medium for transmission
a) Cathode ray
b) Electromagnetic wave
c) Sound wave
d) None of the above

39. A tuning fork arrangement (pair) produces 4 $beats/sec$ with one fork of frequency 288 Hz. A little wax is placed on the unknown fork and it then produces 2 $beats/sec$. The frequency of the unknown fork is
a) 286 Hz
b) 292 Hz
c) 294 Hz
d) 288 Hz

40. Beats are produced by two waves given by $y_1 = a \sin 2000\pi t$ and $y_2 a \sin 2008\pi t$. The number of beats heard per second is
a) Zero
b) One
c) Four
d) Eight

41. "Stationary waves" are so called because in them
a) The particles of the medium are not disturbed at all
b) The particles of the medium do not execute SHM
c) There occurs no flow of energy along the wave
d) The interference effect can't be observed

[redacted]

1 **(a)**

The quality of sound depends upon the number of harmonics present. Due to different number of harmonics present in two sounds, the shape of the resultant wave is also different

2 **(b)**

As the tube is open at both ends, therefore, next shortest length for resonance $= 2 \times 20 = 40$ cm.

3 **(d)**

Frequency of sonometer wire is given by

$$v = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

Where m is mass of string per unit length, and T is tension in the string.

Also, m=πr²d

R being radius of string per unit length, and T is tension in the string.

So,

$$v = \frac{1}{2l}\sqrt{\frac{T}{\pi r^2 d}}$$

Or

$$v \propto \frac{\sqrt{T}}{r}$$

Or

$$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}} \times \left(\frac{r_2}{r_1}\right)$$

Given, $r_2 = 2r_1, \quad T_2 = \frac{T_1}{2}, \quad v_1 = v$

Hence,

$$\frac{v}{v_2} = \sqrt{2} \times 2$$

Or

$$v_2 = \frac{v}{2\sqrt{2}}$$

4 **(a)**

Here, $y = A\sin(kx - \omega t)$

$$\frac{dy}{dt} = A\cos(kx - \omega t) \times (-\omega)$$

$$\left(\frac{dy}{dt}\right)_{\max} = A(-1)(-\omega) = A\omega$$

5 **(a)**

Second overtone of open pipe of length $\boldsymbol{l}$ is

$$v_0 = \frac{v}{2l} \quad \ldots \ldots (i)$$

First overtone of a close pipe is

$$v_c = \frac{v}{4l} = \frac{v}{4 \times 2} \ldots \ldots . . (ii)$$

Equating Eqs. (i) and (ii), we get

$$\frac{v}{2l} = \frac{v}{8} \Longrightarrow l = 4m$$

6 **(c)**

Given, $v_{\max} = v$

$\Longrightarrow \quad a\omega = v$

$$\Longrightarrow a \times 2\pi v = v\lambda \ \ or\ a = \frac{\lambda}{2\pi}$$

7 **(c)**

For the given super imposing waves

$a_1 = 3, a_2 = 4$ and phase difference $\phi = \frac{\pi}{2}$

$$\Rightarrow A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\pi/2} = \sqrt{(3)^2 + (4)^4}$$

$$= 5$$

8 **(b)**

Let one mole of each gas has same volumes as V. when they are mixed, then density of mixture is

$$\rho_{mixture} = \frac{mass\ of\ O_2 + mass\ of\ H_2}{volume\ of\ O_2 + volume\ of\ H_2}$$

$$= \frac{32 + 2}{V + V}$$

$$= \frac{34}{2V} = \frac{17}{V}$$

Also, $\rho_{H_2} = \frac{2}{V}$

Now, velocity $v = \left(\frac{\gamma p}{\rho}\right)^{1/2}$

Or

$$v \propto \frac{1}{\sqrt{\rho}}$$

$$\therefore \frac{v_{mixture}}{V_{H_2}} = \sqrt{\left(\frac{\rho_{H_2}}{\rho_{mixture}}\right)}$$

$$= \sqrt{\left(\frac{2/v}{17/v}\right)} = \sqrt{\left(\frac{2}{17}\right)}$$

9 **(d)**

Given,

$y = 5\sin\left(30\pi t - \frac{\pi}{7}x + 30°\right)$ ... (i)

Now,

$y = a\sin\left(\frac{2\pi t}{T} - \frac{2\pi x}{\lambda} + \phi\right)$ ... (ii)

On comparing Eqs. (i) and (ii)

$$\frac{2\pi x}{\lambda} = \frac{\pi x}{7}$$

$\Rightarrow \quad \lambda = 14m$

We know that relation between phase difference and path difference

$$\Delta\phi = \frac{2\pi}{\lambda} \times \Delta x = \frac{2\pi}{14} \times 3.5$$

$$\Rightarrow \Delta\phi = \frac{\pi}{2}$$

10 **(a)**

$$n' = n\left(\frac{v - v_O}{v}\right) = \left(\frac{330 - 33}{330}\right) \times 100 = 90\ Hz$$

11 **(d)**

Speed of sound $v \propto \sqrt{T}$ and it is independent of pressure

12 **(d)**

$$T = \mu v^2 = \mu\frac{\omega^2}{k^2} = 0.04\frac{\left(\frac{2\pi}{0.004}\right)^2}{\left(\frac{2\pi}{0.50}\right)^2} = 6.25N$$

13 **(d)**

14 **(c)**

Maximum number of beats =v+1-(v-1)=2

15 **(a)**

String will vibrate in 7 loops so it will have 8 nodes 7 antinodes.

Number of harmonics = Number of loops = Number of antinodes ⇒ Number of antinodes = 7

Hence number of nodes = Number of antinodes + 1

$= 7 + 1 = 8$

16 **(b)**

Only odd harmonics are present

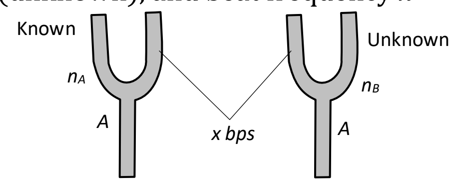
17 **(b)**

On comparing the given equation with standard equation

$$\frac{2\pi}{\lambda} = 5 \Rightarrow \lambda = \frac{6.28}{5} = 1.256m$$

18 ©

Suppose two tuning forks are named A and B with frequencies $n_A = 256\ Hz$ (known), $n_B = ?$ (unknown), and beat frequency $x = 4\ bps$.



Frequency of unknown tuning fork may be

$n_B = 256 + 4 = 260\ Hz$ and $n_B = 256 - 4 = 252\ Hz$

It is given that on sounding waxed fork A (fork of frequency 256 Hz) and fork B, number of beats (beat frequency) increases. It means that with decrease in frequency of A, the difference in new frequency of A and the frequency of B has increased. This is possible only when the frequency of A while decreasing is moving away from the frequency of B.

This is possible only if $n_B = 260\ Hz$.

Alternate method : It is given $n_A = 256\ Hz, n_B = ?$

And $x = 4\ bps$

Also after loading A ($i.e.\ n_A \downarrow$), beat frequency ($i.e.\ x$) increases (↑).

Apply these informations in two possibilities to known the frequency of unknown tuning fork.

$n_A \downarrow - n_B = x$ ...(i)

$n_B - n_A \downarrow = x \uparrow$ ...(ii)

It is obvious that equation (i) is wrong (ii) is correct so

$n_B = n_A + x = 256 + 4 = 260\ Hz$

19 ©

$v_1 = 256$ Hz

For tuning for $v_1 - v_1 = \pm 5$,

v_2 = frequency of piano

$v_2 = (256 + 5)$Hz or $(256 - 5)$Hz

When tension is increased, the bear frequency decreases to 2 beats/s.

If we assume that the frequency of piano string is 261 Hz, then on increasing tension, frequency, more than 261 Hz. But it is given that beat frequency decreases to 2, therefore, 261 is not possible.

Hence, 251 Hz i.e., 256-5 was the frequency of piano string before increasing tension.

20 **(a)**

Frequency of third harmonic of closed pipe

$$n_1 = \frac{3v}{4l}$$

Fundamental frequency of open pipe

$$n_2 = \frac{2}{2l}$$

As $n_1 - n_2 = 100$

$$\frac{v}{4l} = 100$$

$$\therefore \frac{v}{2l} = 200 \text{ Hz}$$

21 **(b)**
The position f such a wave changes in two dimensional plane with time. Therefore, (b) represents the correct equation.

22 ©
Water waves are transverse as well as longitudinal in nature

23 **(a)**
Speed of sound $v = \sqrt{\frac{\gamma P}{d}} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{d_2}{d_1}}$ [$\because$ P-constant]

24 ©
Frequency of 2^{nd} overtone $n_3 = 5n_1 = 5 \times 50 = 250Hz$

25 **(b)**
$n_A =$ Known frequency $= 256\ Hz, n_B = ?$
$x = 6\ bps$, which remains the same after loading.
Unknown tuning fork F_2 is loaded so $n_B \downarrow$
Hence $n_A - n_B \downarrow = x \quad \rightarrow$ Wrong ...(i)
$n_B \downarrow - n_A = x \quad \rightarrow$ ...(ii)
$\Rightarrow n_B = n_A + x = 256 + 6 = 262\ Hz$

26 **(d)**
Points B and F are in same phase as they are λ distance apart

27 **(d)**
Given, $f_0 - f_c = 2$ ... (i)
Frequency of fundamental mode for a closed organ pipe,

$$f_c = \frac{v}{4L_c}$$

Similarly frequency of fundamental mode an open orgen pipe,

$$f_0 = \frac{v}{2L_0}$$

Given $L_c = L_0$
$\Longrightarrow f_0 = 2f_c$ ... (ii)
From Eqs. (i) and (ii), we get
$f_0 = 4Hz$
And $f_c = 2Hz$
When the length of the open pipe is halved, its frequency of fundamental mode is

$$f_0' = \frac{v}{2\left[\frac{L_0}{2}\right]}$$

$= 2f_0 = 2 \times 4Hz = 8Hz$
When the length of the closed pipe is doubled, its frequency of fundamental mode is

$$f_0' = \frac{v}{4(2L_c)}$$

$$= \frac{1}{2}f_c = \frac{1}{2} \times 2 = 1Hz$$

Hence, number of beats produced per second is
$f_0' = f' = 8 - 1 = 7$

28 **(c)**
After reflection from rigid support, a wave suffers a phase change of π

29 **(b)**

$$v = \frac{\omega}{k} = \frac{600}{2} = 300\text{ms}^{-2}$$

30 **(a)**
Frequency of string $= 440 \pm 5$
As frequency of tuning fork decreases beat frequency also increases, therefore, frequency of string $= 445\ Hz$

31 **(d)**
Speed of sound in gases is $v = \sqrt{\frac{\gamma RT}{M}} \Rightarrow T \propto M$
(Because v, γ-constant). Hence $\frac{T_{H_2}}{T_{O_2}} = \frac{M_{H_2}}{M_{O_2}}$

$$\Rightarrow \frac{T_{H_2}}{(273+100)} = \frac{2}{32} \Rightarrow T_{H_2} = 23.2K = -249.7°\text{C}$$

32 **(c)**

$$A = \sqrt{(a_1^2 + a_2^2 + 2a_1a_2\cos\phi)}$$

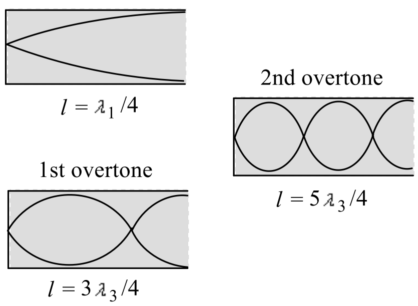
Putting $a_1 = a_2 = a$ and $\phi = \frac{\pi}{3}$, we get $A = \sqrt{3}a$

33 **(d)**
$v = n\lambda \Rightarrow \lambda = 10\ cm$
Phase difference $= \frac{2\pi}{\lambda} \times$ Path difference $=$
$\frac{2\pi}{10} \times 2.5 = \frac{\pi}{2}$

34 **(d)**
Comparing with standard wave equation
$y = a\sin\frac{2\pi}{\lambda}(vt - x)$, we get, $v = 200\ m/s$

35 **(d)**

As is clear from figure



$$l = \frac{\lambda_1}{4}, \lambda_2 = 4l$$

$$l = \frac{3\lambda_2}{4}, \lambda_2 = \frac{4l}{3}$$

$$l = \frac{5\lambda_3}{4}, \lambda_3 = \frac{4l}{5}$$

$$\therefore \quad \lambda_1 : \lambda_2 : \lambda_3 = 1 : \frac{1}{3} : \frac{1}{5}$$

36 **(a)**

$v = 2n(l_2 - l_1) = 2 \times 325(77.4 - 25.4)\text{cms}^{-1}$

$$= \frac{650 \times 52}{100}\ \text{ms}^{-1} = 338\ \text{ms}^{-1}$$

37 **(c)**

As fixed end is a node, therefore, distance between two consecutive nodes $= \frac{\lambda}{2} = 10$ cm

$\lambda = 20\ cm = 0.2\ m$

As $\ v = v\lambda$

$\therefore \quad v = 100 \times 0.2 = 20\ \text{ms}^{-1}$

38 **(b)**

EM waves do not require medium for their propagation

39 **(b)**

n_A = Known frequency $= 288\ cps, n_B = ?$

$x = 4\ bps$, which is decreasing (from 4 to 2) after loading $i.e. x \downarrow$

Unknown fork is loaded so $n_B \downarrow$

Hence $n_A - n_B \downarrow = x \downarrow \ \rightarrow$ Wrong

$n_B \downarrow - n_A \downarrow = x \downarrow \rightarrow$ Correct

$\Rightarrow n_B = n_A + x = 288 + 4 = 292\ Hz$

40 **(c)**

Number of beats per second= $n_1 \sim n_2$

$\omega_1 = 200\pi = 2\pi v_1$

$\Longrightarrow n_1 = 1000$

And $\omega_2 = 2008\pi = 2\pi n_2$

$\Longrightarrow n_2 = 1004$

Number of beats heard per second =1004-1000=4

41 **(c)**