71. Three identical metal balls, each of the radius r are placed touching each other on a horizontal surface such that an equilateral triangle is formed when centres of three balls are joined. The centre of the mass of the system is located at
(a) line joining centres of any two balls
(b) centre of one of the balls
(c) horizontal surface
(d) point of intersection of the medians *(1999)*

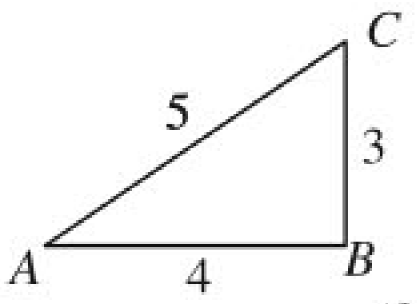
72. The moment of inertia of a disc of mass M and radius R about an axis, which is tangential to the circumference of the disc and parallel to its diameter is
(a) $\frac{5}{4}MR^2$ (b) $\frac{2}{3}MR^2$
(c) $\frac{3}{2}MR^2$ (d) $\frac{4}{5}MR^2$ *(1999)*

73. Find the torque of a force $\vec{F} = -3\hat{i} + \hat{j} + 5\hat{k}$ acting at the point $\vec{r} = 7\hat{i} + 3\hat{j} + \hat{k}$
(a) $-21\hat{i} + 4\hat{j} + 4\hat{k}$ (b) $-14\hat{i} + 34\hat{j} - 16\hat{k}$
(c) $14\hat{i} - 38\hat{j} + 16\hat{k}$ (d) $4\hat{i} + 4\hat{j} + 6\hat{k}$. *(1997)*

74. The centre of mass of system of particles does not depend on
(a) position of the particles
(b) relative distances between the particles
(c) masses of the particles
(d) forces acting on the particle. *(1997)*

75. A couple produces
(a) linear and rotational motion
(b) no motion
(c) purely linear motion
(d) purely rotational motion. *(1997)*

76. The ABC is a triangular plate of uniform thickness. The sides are in the ratio shown in the figure. I_{AB}, I_{BC} and I_{CA} are the moments of inertia of the plate about AB, BC and CA respectively. Which one of the following relations is correct?
(a) $I_{AB} + I_{BC} = I_{CA}$
(b) I_{CA} is maximum
(c) $I_{AB} > I_{BC}$
(d) $I_{BC} > I_{AB}$.

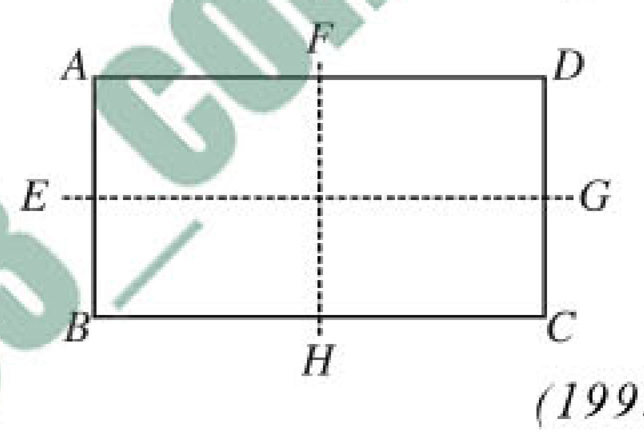


(1995)

77. What is the torque of the force $\vec{F} = 2\hat{i} - 3\hat{j} + 4\hat{k}$ N acting at the point $\vec{r} = 3\hat{i} + 2\hat{j} + 3\hat{k}$ m about origin?
(a) $-6\hat{i} + 6\hat{j} - 12\hat{k}$ (b) $-17\hat{i} + 6\hat{j} + 13\hat{k}$
(c) $6\hat{i} - 6\hat{j} + 12\hat{k}$ (d) $17\hat{i} - 6\hat{j} - 13\hat{k}$. *(1995)*

78. A solid spherical ball rolls on a table. Ratio of its rotational kinetic energy to total kinetic energy is
(a) $\frac{1}{2}$ (b) $\frac{1}{6}$ (c) $\frac{7}{10}$ (d) $\frac{2}{7}$. *(1994)*

79. In a rectangle $ABCD$ ($BC = 2AB$). The moment of inertia is minimum along axis through
(a) BC
(b) BD
(c) HF
(d) EG



(1993)

80. A solid sphere, disc and solid cylinder all of the same mass and made of the same material are allowed to roll down (from rest) on the inclined plane, then
(a) solid sphere reaches the bottom first
(b) solid sphere reaches the bottom last
(c) disc will reach the bottom first
(d) all reach the bottom at the same time *(1993)*

81. The speed of a homogenous 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) $\sqrt{\frac{4}{3}gh}$ *(1992)*

82. If a sphere is rolling, the ratio of the translational energy to total kinetic energy is given by
(a) 7 : 10 (b) 2 : 5
(c) 10 : 7 (d) 5 : 7 *(1991)*

83. A particle of mass m = 5 is moving with a uniform speed $v = 3\sqrt{2}$ in the XOY plane along the line $Y = X + 4$. The magnitude of the angular momentum of the particle about the origin is
(a) 60 units (b) $40\sqrt{2}$ units
(c) zero (d) 7.5 units *(1991)*

84. A fly wheel rotating about fixed axis has a kinetic energy of 360 joule when its angular speed is 30 radian/sec. The moment of inertia of the wheel about the axis of rotation is
(a) 0.6 kgm^2 (b) 0.15 kgm^2
(c) 0.8 kgm^2 (d) 0.75 kgm^2 *(1990)*

85. The moment of inertia of a body about a given axis is 1.2 kgm^2. Initially, the body is at rest. In order to produce a rotational kinetic energy of 1500 joule, an angular acceleration of 25 radian/sec^2 must be applied about that axis for a duration of
(a) 4 s (b) 2 s
(c) 8 s (d) 10 s *(1990)*

86. Moment of inertia of a uniform circular disc about a diameter is I. Its moment of inertia about an axis perpendicular to its plane and passing through a point on its rim will be
(a) $5I$ (b) $3I$
(c) $6I$ (d) $4I$ *(1990)*

87. A solid homogenous sphere of mass M and radius is moving on a rough horizontal surface, partly rolling and partly sliding. During this kind of motion of this sphere
(a) total kinetic energy is conserved
(b) the angular momentum of the sphere about the point of contact with the plane is conserved
(c) only the rotational kinetic energy about the centre of mass is conserved
(d) angular momentum about the centre of mass of conserved
(1988)

88. A ring of mass m and radius r rotates about an axis passing through its centre and perpendicular to its plane with angular velocity ω. Its kinetic energy is
(a) $\frac{1}{2}mr^2\omega^2$ (b) $mr\omega^2$
(c) $mr^2\omega^2$ (d) $\frac{1}{2}mr\omega^2$ *(1988)*

Answer Key

1.	(b)	**2.**	(a)	**3.**	(*)	**4.**	(c)	**5.**	(b)	**6.**	(a)	**7.**	(d)	**8.**	(d)	**9.**	(c)	**10.**	(b)
11.	(c)	**12.**	(c)	**13.**	(b)	**14.**	(a)	**15.**	(b)	**16.**	(d)	**17.**	(a)	**18.**	(c)	**19.**	(b)	**20.**	(d)
21.	(b)	**22.**	(a)	**23.**	(c)	**24.**	(b)	**25.**	(a)	**26.**	(d)	**27.**	(c)	**28.**	(a)	**29.**	(a)	**30.**	(a)
31.	(b)	**32.**	(d)	**33.**	(d)	**34.**	(b)	**35.**	(c)	**36.**	(a)	**37.**	(d)	**38.**	(d)	**39.**	(a)	**40.**	(b)
41.	(d)	**42.**	(a)	**43.**	(d)	**44.**	(d)	**45.**	(a)	**46.**	(c)	**47.**	(a)	**48.**	(d)	**49.**	(b)	**50.**	(c)
51.	(d)	**52.**	(c)	**53.**	(c)	**54.**	(b)	**55.**	(c)	**56.**	(c)	**57.**	(c)	**58.**	(a)	**59.**	(c)	**60.**	(c)
61.	(b)	**62.**	(b)	**63.**	(b)	**64.**	(d)	**65.**	(b)	**66.**	(a)	**67.**	(a)	**68.**	(b)	**69.**	(a)	**70.**	(b)
71.	(d)	**72.**	(a)	**73.**	(c)	**74.**	(d)	**75.**	(d)	**76.**	(d)	**77.**	(d)	**78.**	(d)	**79.**	(d)	**80.**	(a)
81.	(a)	**82.**	(d)	**83.**	(a)	**84.**	(c)	**85.**	(b)	**86.**	(c)	**87.**	(b)	**88.**	(a)				

EXPLANATIONS

1. **(b) :** $m = 3$ kg, $r = 40$ cm $= 40 \times 10^{-2}$ m, $F = 30$ N

Moment of inertia of hollow cylinder about its axis
$= mr^2 = 3 \text{ kg} \times (0.4)^2 \text{ m}^2 = 0.48 \text{ kg m}^2$

The torque is given by,
$\tau = I\alpha$

where I = moment of inertia,
α = angular acceleration

In the given case, $\tau = rF$, as the force is acting perpendicularly to the radial vector.

$$\therefore \quad \alpha = \frac{\tau}{I} = \frac{Fr}{mr^2} = \frac{F}{mr} = \frac{30}{3 \times 40 \times 10^{-2}} = \frac{30 \times 100}{3 \times 40}$$

$\alpha = 25$ rad s^{-2}

2. **(a) :** Initial angular momentum $= I\omega_1 + I\omega_2$

Let ω be angular speed of the combined system.

Final angular momentum $= 2I\omega$

$\therefore$ According to conservation of angular momentum

$$I\omega_1 + I\omega_2 = 2I\omega \text{ or } \omega = \frac{\omega_1 + \omega_2}{2}$$

Initial rotational kinetic energy

$$E = \frac{1}{2} I(\omega_1^2 + \omega_2^2)$$

Final rotational kinetic energy

$$E_f = \frac{1}{2}(2I)\omega^2 = \frac{1}{2}(2I)\left(\frac{\omega_1 + \omega_2}{2}\right)^2 = \frac{1}{4} I(\omega_1 + \omega_2)^2$$

$\therefore$ Loss of energy $\Delta E = E_i - E_f$

$$= \frac{I}{2}(\omega_1^2 + \omega_2^2) - \frac{I}{4}(\omega_1^2 + \omega_2^2 + 2\omega_1\omega_2)$$

$$= \frac{I}{4}\left[\omega_1^2 + \omega_2^2 - 2\omega_1\omega_2\right] = \frac{I}{4}(\omega_1 - \omega_2)^2$$

3. **(*) :** Centre of gravity of a body is the point at which the total gravitational torque on body is zero. Centre of mass and centre of gravity coincides only for symmetrical bodies.

Hence statements (1) and (2) are incorrect.

A couple of a body produces rotational motion only.

Hence statement (3) is incorrect.

Mechanical advantage greater than one means that the system will require a force that is less than the load in order to move it.

Hence statement (4) is correct.

*None of the given options is correct.

4. **(c) :** Here, $m_A = m$, $m_B = 2m$

Both bodies A and B have equal kinetic energy of rotation

$$k_A = k_B \Rightarrow \frac{1}{2} I_A \omega_A^2 = \frac{1}{2} I_B \omega_B^2$$

$$\Rightarrow \frac{\omega_A^2}{\omega_B^2} = \frac{I_B}{I_A} \quad \text{...(i)}$$

Ratio of angular momenta,

$$\frac{L_A}{L_B} = \frac{I_A\omega_A}{I_B\omega_B} = \frac{I_A}{I_B} \times \sqrt{\frac{I_B}{I_A}} \quad \text{[Using eqn. (i)]}$$

$$= \sqrt{\frac{I_A}{I_B}} < 1 \quad (\because I_B > I_A)$$

$\therefore \; L_B > L_A$

5. **(b) :** $$\frac{E_{\text{Sphere}}}{E_{\text{Cylinder}}} = \frac{\frac{1}{2} I_s \omega_s^2}{\frac{1}{2} I_c \omega_c^2} = \frac{I_s \omega_s^2}{I_c \omega_c^2}$$

Here, $I_s = \frac{2}{5} mR^2$, $I_c = \frac{1}{2} mR^2$

$\omega_c = 2\omega_s$

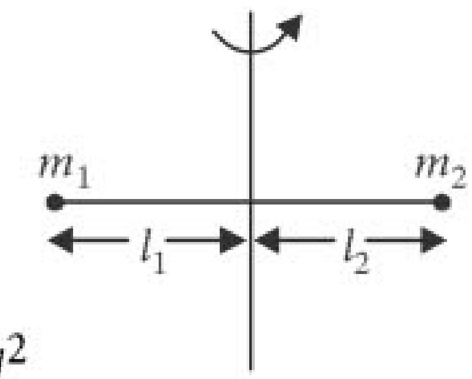
$$\frac{E_{\text{Sphere}}}{E_{\text{Cylinder}}} = \frac{\frac{2}{5} mR^2 \times \omega_s^2}{\frac{1}{2} mR^2 \times (2\omega_s)^2} = \frac{4}{5} \times \frac{1}{4} = \frac{1}{5}$$

6. **(a) :** Here, $l_1 + l_2 = l$

Centre of mass of the system,

$$l_1 = \frac{m_1 \times 0 + m_2 \times l}{m_1 + m_2} = \frac{m_2 l}{m_1 + m_2}$$

$$l_2 = l - l_1 = \frac{m_1 l}{m_1 + m_2}$$



Required moment of inertia of the system,

$I = m_1 l_1^2 + m_2 l_2^2$

$$= (m_1 m_2^2 + m_2 m_1^2) \frac{l^2}{(m_1 + m_2)^2}$$

$$= \frac{m_1 m_2 (m_1 + m_2) l^2}{(m_1 + m_2)^2} = \frac{m_1 m_2}{m_1 + m_2} l^2$$

7. **(d) :** Time taken by the body to reach the bottom when it rolls down on an inclined plane without slipping is given by

$$t = \sqrt{\frac{2l\left(1 + \frac{k^2}{R^2}\right)}{g \sin\theta}}$$

Since g is constant and l, R and $\sin\theta$ are same for both

$$\therefore\ \frac{t_d}{t_s}=\frac{\sqrt{1+\frac{k_d^2}{R^2}}}{\sqrt{1+\frac{k_s^2}{R^2}}}=\sqrt{\frac{1+\frac{R^2}{2R^2}}{1+\frac{2R^2}{5R^2}}}$$

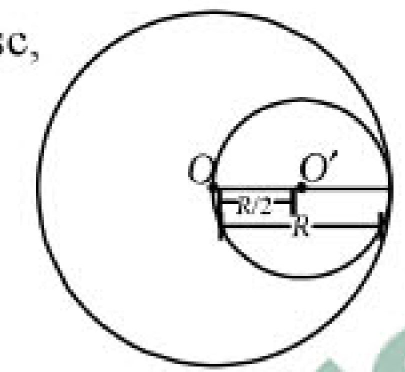
$$\left(\because k_d=\frac{R}{\sqrt{2}},k_s=\sqrt{\frac{2}{5}}R\right)$$

$$=\sqrt{\frac{3}{2}\times\frac{5}{7}}=\sqrt{\frac{15}{14}}\ \Rightarrow\ t_d>t_s$$

Hence, the sphere gets to the bottom first.

8. **(d) :** Mass per unit area of disc $=\frac{M}{\pi R^2}$

Mass of removed portion of disc,



$$M'=\frac{M}{\pi R^2}\times\pi\left(\frac{R}{2}\right)^2=\frac{M}{4}$$

Moment of inertia of removed portion about an axis passing through centre of disc O and perpendicular to the plane of disc,

$$I'_O=I_{O'}+M'd^2$$

$$=\frac{1}{2}\times\frac{M}{4}\times\left(\frac{R}{2}\right)^2+\frac{M}{4}\times\left(\frac{R}{2}\right)^2$$

$$=\frac{MR^2}{32}+\frac{MR^2}{16}=\frac{3MR^2}{32}$$

When portion of disc would not have been removed, the moment of inertia of complete disc about centre O is

$$I_O=\frac{1}{2}MR^2$$

So, moment of inertia of the disc with removed portion is

$$I=I_O-I'_O=\frac{1}{2}MR^2-\frac{3MR^2}{32}=\frac{13MR^2}{32}$$

9. **(c) :** Given, $r=50\text{ cm}=0.5\text{ m}, \alpha=2.0\text{ rad s}^{-2}, \omega_0=0$

At the end of 2 s,

Tangential acceleration, $a_t=r\alpha=0.5\times2=1\text{ m s}^{-2}$

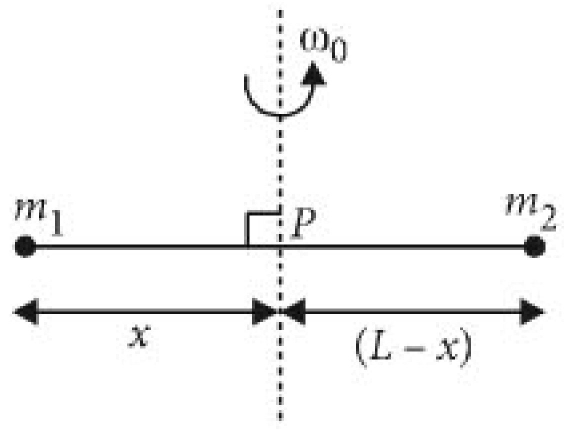
Radial acceleration, $a_r=\omega^2r=(\omega_0+\alpha t)^2r$

$=(0+2\times2)^2\times0.5=8\text{ m s}^{-2}$

$\therefore$ Net acceleration,

$$a=\sqrt{a_t^2+a_r^2}=\sqrt{1^2+8^2}=\sqrt{65}\approx8\text{ m s}^{-2}$$

10. **(b) :**



Moment of inertia of the system about the axis of rotation (through point P) is

$$I=m_1x^2+m_2(L-x)^2$$

By work energy theorem,

Work done to set the rod rotating with angular velocity ω_0 = Increase in rotational kinetic energy

$$W=\frac{1}{2}I\omega_0^2=\frac{1}{2}[m_1x^2+m_2(L-x)^2]\omega_0^2$$

For W to be minimum, $\frac{dW}{dx}=0$

i.e. $\frac{1}{2}[2m_1x+2m_2(L-x)(-1)]\omega_0^2=0$

or $m_1x-m_2(L-x)=0$ $(\because\omega_0\neq0)$

or $(m_1+m_2)x=m_2L$ or $x=\frac{m_2L}{m_1+m_2}$

11. **(c) :** Here,

Speed of the automobile,

$$v=54\text{ km h}^{-1}=54\times\frac{5}{18}\text{ m s}^{-1}=15\text{ m s}^{-1}$$

Radius of the wheel of the automobile, $R=0.45$ m

Moment of inertia of the wheel about its axis of rotation, $I=3\text{ kg m}^2$

Time in which the vehicle brought to rest, $t=15$ s

The initial angular speed of the wheel is

$$\omega_i=\frac{v}{R}=\frac{15\text{ m s}^{-1}}{0.45\text{ m}}=\frac{1500}{45}\text{rad s}^{-1}=\frac{100}{3}\text{ rad s}^{-1}$$

and its final angular speed is

$\omega_f=0$ (as the vehicle comes to rest)

$\therefore$ The angular retardation of the wheel is

$$\alpha=\frac{\omega_f-\omega_i}{t}=\frac{0-\frac{100}{3}}{15\text{ s}}=-\frac{100}{45}\text{ rad s}^{-2}$$

The magnitude of required torque is

$$\tau=I|\alpha|=(3\text{ kg m}^2)\left(\frac{100}{45}\text{rad s}^{-2}\right)$$

$$=\frac{20}{3}\text{ kg m}^2\text{s}^{-2}=6.66\text{ kg m}^2\text{s}^{-2}$$

12. **(c) :** For the conservation of angular momentum about origin, the torque $\vec{\tau}$ acting on the particle will be zero.

By definition, $\vec{\tau} = \vec{r} \times \vec{F}$

Here, $\vec{r} = 2\hat{i} - 6\hat{j} - 12\hat{k}$ and $\vec{F} = \alpha\hat{i} + 3\hat{j} + 6\hat{k}$

$$\therefore \quad \vec{\tau} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & -6 & -12 \\ \alpha & 3 & 6 \end{vmatrix}$$

$$= \hat{i}(-36+36) - \hat{j}(12+12\alpha) + \hat{k}(6+6\alpha)$$

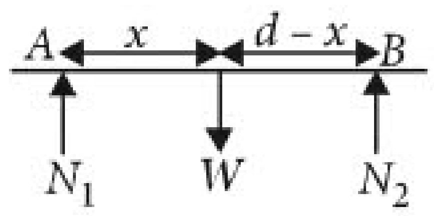
$$= -\hat{j}(12+12\alpha) + \hat{k}(6+6\alpha)$$

But $\vec{\tau} = 0$

$\therefore \quad 12 + 12\alpha = 0$ or $\alpha = -1$

and $6 + 6\alpha = 0$ or $\alpha = -1$

13. (b) : Given situation is shown in figure.



N_1 = Normal reaction on A

N_2 = Normal reaction on B

W = Weight of the rod

In vertical equilibrium,

$N_1 + N_2 = W$ ...(i)

Torque balance about centre of mass of the rod,

$N_1 x = N_2(d - x)$

Putting value of N_2 from equation (i)

$N_1 x = (W - N_1)(d - x)$

$\Rightarrow \quad N_1 x = Wd - Wx - N_1 d + N_1 x$

$\Rightarrow \quad N_1 d = W(d - x)$

$$\therefore \quad N_1 = \frac{W(d-x)}{d}$$

14. (a) : According to law of conservation of angular momentum

$mvr = mv'r'$

$$v_0 R_0 = v\left(\frac{R_0}{2}\right);\ v = 2v_0 \qquad \text{...(i)}$$

$$\therefore \quad \frac{K_0}{K} = \frac{\frac{1}{2}mv_0^2}{\frac{1}{2}mv^2} = \left(\frac{v_0}{v}\right)^2$$

$$\text{or} \quad \frac{K}{K_0} = \left(\frac{v}{v_0}\right)^2 = (2)^2 \qquad \text{(Using (i))}$$

$K = 4K_0 = 2mv_0^2$

15. (b) : Net moment of inertia of the system,

$I = I_1 + I_2 + I_3$

The moment of inertia of a shell about its diameter,

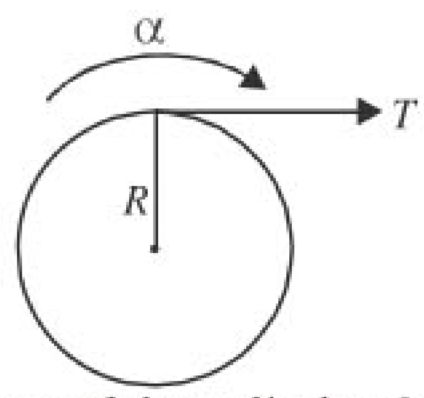
$$I_1 = \frac{2}{3}mr^2$$

The moment of inertia of a shell about its tangent is given by

$$I_2 = I_3 = I_1 + mr^2 = \frac{2}{3}mr^2 + mr^2 = \frac{5}{3}mr^2$$

$$\therefore \quad I = 2\times\frac{5}{3}mr^2 + \frac{2}{3}mr^2 = \frac{12mr^2}{3} = 4mr^2$$

16. (d) :



Here, mass of the cylinder, $M = 50$ kg

Radius of the cylinder, $R = 0.5$ m

Angular acceleration, $\alpha = 2$ rev s^{-2}

$= 2 \times 2\pi$ rad s^{-2} $= 4\pi$ rad s^{-2}

Torque, $\tau = TR$

Moment of inertia of the solid cylinder about its axis, $I = \frac{1}{2}MR^2$

$\therefore$ Angular acceleration of the cylinder

$$\alpha = \frac{\tau}{I} = \frac{TR}{\frac{1}{2}MR^2}$$

$$T = \frac{MR\alpha}{2} = \frac{50\times0.5\times4\pi}{2} = 157 \text{ N}$$

17. (a) : Acceleration of the solid sphere slipping down the incline without rolling is

$a_{\text{slipping}} = g\sin\theta$ ...(i)

Acceleration of the solid sphere rolling down the incline without slipping is

$$a_{\text{rolling}} = \frac{g\sin\theta}{1+\frac{k^2}{R^2}} = \frac{g\sin\theta}{1+\frac{2}{5}}$$

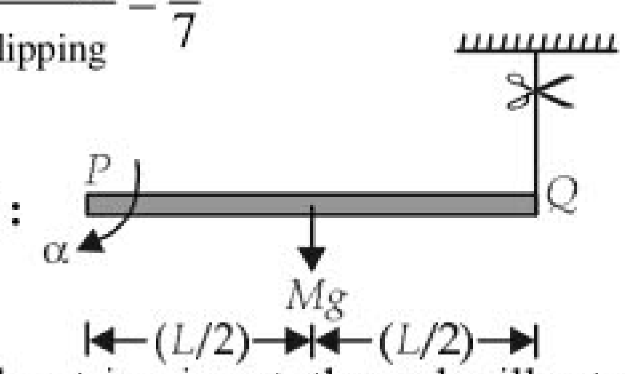
$$\left(\because \text{For solid sphere, } \frac{k^2}{R^2} = \frac{2}{5}\right)$$

$$= \frac{5}{7}g\sin\theta \qquad \text{...(ii)}$$

Divide eqn. (ii) by eqn. (i), we get

$$\frac{a_{\text{rolling}}}{a_{\text{slipping}}} = \frac{5}{7}$$

18. (c) :



When the string is cut, the rod will rotate about P. Let α be initial angular acceleration of the rod. Then

$$\text{Torque, } \tau = I\alpha = \frac{ML^2}{3}\alpha \qquad \text{...(i)}$$

(Moment of inertia of the rod about one end $= \frac{ML^2}{3}$)

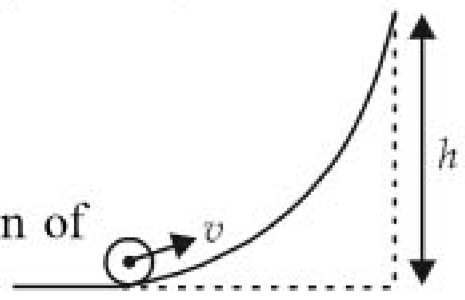
Also, $\tau = Mg\frac{L}{2}$ ...(ii)

Equating (i) and (ii), we get

$$Mg\frac{L}{2} = \frac{ML^2}{3}\alpha \text{ or } \alpha = \frac{3g}{2L}$$

19. (b) : The kinetic energy of the rolling object is converted into potential energy at height

$$h\left(=\frac{3v^2}{4g}\right)$$



So by the law of conservation of mechanical energy, we have

$$\frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2 = Mgh \qquad \left(\because \omega = \frac{v}{R}\right)$$

$$\frac{1}{2}Mv^2 + \frac{1}{2}I\left(\frac{v}{R}\right)^2 = Mg\left(\frac{3v^2}{4g}\right)$$

$$\frac{1}{2}I\frac{v^2}{R^2} = \frac{3}{4}Mv^2 - \frac{1}{2}Mv^2$$

$$\frac{1}{2}I\frac{v^2}{R^2} = \frac{1}{4}Mv^2 \quad \text{or} \quad I = \frac{1}{2}MR^2$$

Hence, the object is disc.

20. (d) : Let M and R be mass and radius of the ring and the disc respectively. Then,

Moment of inertia of ring about an axis passing through its centre and perpendicular to its plane is

$$I_{\text{ring}} = MR^2$$

Moment of inertia of disc about the same axis is

$$I_{\text{disc}} = \frac{MR^2}{2}$$

As $I = Mk^2$ where k is the radius of gyration

$\therefore$ $I_{\text{ring}} = Mk^2_{\text{ring}} = MR^2$ or $k_{\text{ring}} = R$

and $I_{\text{disc}} = Mk^2_{\text{disc}} = \frac{MR^2}{2}$ or $k_{\text{disc}} = \frac{R}{\sqrt{2}}$

$$\therefore \frac{k_{\text{ring}}}{k_{\text{disc}}} = \frac{R}{R/\sqrt{2}} = \frac{\sqrt{2}}{1}$$

$$k_{\text{ring}} : k_{\text{disc}} = \sqrt{2}:1$$

21. (b) : Moment of inertia of disc D_1 about an axis passing through its centre and normal to its plane is

$$I_1 = \frac{MR^2}{2} = \frac{(2\text{ kg})(0.2\text{ m})^2}{2} = 0.04\text{ kg m}^2.$$

Initial angular velocity of disc D_1, $\omega_1 = 50$ rad s^{-1}

Moment of inertia of disc D_2 about an axis passing through its centre and normal to its plane is

$$I_2 = \frac{(4\text{ kg})(0.1\text{ m})^2}{2} = 0.02\text{ kg m}^2$$

Initial angular velocity of disc D_2, $\omega_2 = 200$ rad s^{-1}

Total initial angular momentum of the two discs is

$$L_i = I_1\omega_1 + I_2\omega_2$$

When two discs are brought in contact face to face (one on the top of the other) and their axes of rotation coincident, the moment of inertia I of the system is equal to the sum of their individual moment of inertia.

$$I = I_1 + I_2$$

Let ω be the final angular speed of the system. The final angular momentum of the system is

$$L_f = I\omega = (I_1 + I_2)\omega$$

According to law of conservation of angular momentum, we get

$$L_i = L_f$$

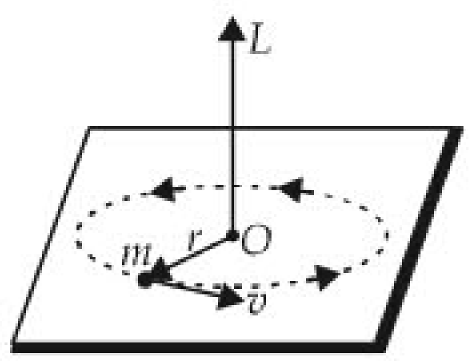
$$I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\omega$$

$$\omega = \frac{I_1\omega_1 + I_2\omega_2}{I_1 + I_2}$$

$$= \frac{(0.04\text{ kg m}^2)(50\text{ rad s}^{-1}) + (0.02\text{ kg m}^2)(200\text{ rad s}^{-1})}{(0.04 + 0.02)\text{ kg m}^2}$$

$$= \frac{(2+4)}{0.06}\text{ rad s}^{-1} = 100\text{ rad s}^{-1}$$

22. (a) : When a mass is rotating in a plane about a fixed point its angular momentum is directed along a line perpendicular to the plane of rotation.



23. (c) : As no external force acts on the system, therefore centre of mass will not shift.

24. (b) : Here, $m = 1000$ kg, $R = 90$ m, $\theta = 45°$

For banking, $\tan\theta = \frac{v^2}{Rg}$

or $v = \sqrt{Rg\tan\theta} = \sqrt{90 \times 10 \times \tan 45°} = 30\text{ m s}^{-1}$

25. (a) : Let x be the distance of centre O of equilateral triangle from each side.

Total torque about $O = 0$

$\Rightarrow$ $F_1x + F_2x - F_3x = 0$ or $F_3 = F_1 + F_2$

26. (d) : Force of friction provides the necessary centripetal force.

$$f \le \mu_s N = \frac{mv^2}{R}$$

$$v^2 \le \frac{\mu_s RN}{m}$$

$$v^2 \le \mu_s R g \qquad [\because N = mg]$$

or $\quad v \le \sqrt{\mu_s R g}$

$\therefore$ The maximum speed of the car in circular motion is

$$v_{max} = \sqrt{\mu_s R g}$$

27. (c) : As the system is initially at rest, therefore, initial angular momentum $L_i = 0$.
According to the principle of conservation of angular momentum, final angular momentum, $L_f = 0$.
$\therefore$ Angular momentum = Angular momentum of man is in opposite direction of platform.
i.e., $\quad mvR = I\omega$

or $\quad \omega = \dfrac{mvR}{I} = \dfrac{50 \times 1 \times 2}{200} = \dfrac{1}{2}\text{ rad s}^{-1}$

Angular velocity of man relative to platform is

$$\omega_r = \omega + \frac{v}{R} = \frac{1}{2} + \frac{1}{2} = 1\text{ rad s}^{-1}$$

Time taken by the man to complete one revolution is

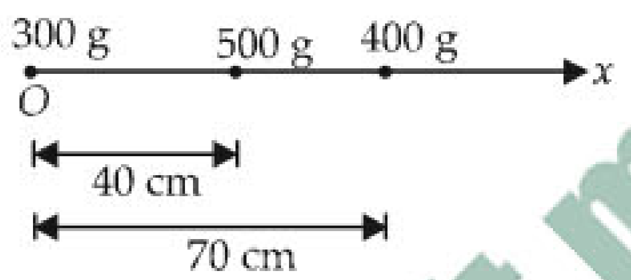
$$T = \frac{2\pi}{\omega_r} = \frac{2\pi}{1} = 2\pi\text{ s}$$

28. (a) : According to the theorem of parallel axes,

$$I = I_{CM} + Ma^2$$

As a is maximum for point B.
Therefore I is maximum about B.

29. (a) :



The distance of the centre of mass of the system of three masses from the origin O is

$$X_{CM} = \frac{m_1x_1 + m_2x_2 + m_3x_3}{m_1 + m_2 + m_3}$$
$$= \frac{300 \times 0 + 500 \times 40 + 400 \times 70}{300 + 500 + 400}$$
$$= \frac{500 \times 40 + 400 \times 70}{1200} = \frac{400\,[50 + 70]}{1200}$$
$$= \frac{50 + 70}{3} = \frac{120}{3} = 40\text{ cm}$$

30. (a) : Given : $\theta(t) = 2t^3 - 6t^2$

$$\therefore \frac{d\theta}{dt} = 6t^2 - 12t \Rightarrow \frac{d^2\theta}{dt^2} = 12t - 12$$

Angular acceleration, $\alpha = \dfrac{d^2\theta}{dt^2} = 12t - 12$

When angular acceleration (α) is zero, then the torque on the wheel becomes zero ($\because \tau = I\alpha$)

$\Rightarrow \quad 12t - 12 = 0 \quad$ or $\quad t = 1$ s

31. (b) : According to the theorem of parallel axes, the moment of inertia of the thin rod of mass M and length L about an axis passing through one of the ends is

$$I = I_{CM} + Md^2$$

where I_{CM} is the moment of inertia of the given rod about an axis passing through its centre of mass and perpendicular to its length and d is the distance between two parallel axes.

Here, $I_{CM} = I_0$, $d = \dfrac{L}{2}$

$$\therefore \quad I = I_0 + M\left(\frac{L}{2}\right)^2 = I_0 + \frac{ML^2}{4}$$

32. (d) : According to law of conservation of angular momentum

$$mvr = mv'r'$$
$$vr = v'\left(\frac{r}{2}\right)$$
$$v' = 2v \qquad \text{...(i)}$$
$$\therefore \quad \frac{K}{K'} = \frac{\frac{1}{2}mv^2}{\frac{1}{2}mv'^2} = \left(\frac{v}{v'}\right)^2$$

or $\quad \dfrac{K'}{K} = \left(\dfrac{v'}{v}\right)^2 = (2)^2 \qquad$ (Using (i))

$$K' = 4K$$

33. (d) : As no external torque is applied to the system, the angular momentum of the system remains conserved.

$$\therefore \quad L_i = L_f$$

According to given problem,

$$I_t\omega_i = (I_t + I_b)\omega_f$$

or $\quad \omega_f = \dfrac{I_t\omega_i}{(I_t + I_b)} \qquad$ ...(i)

Initial energy, $E_i = \dfrac{1}{2}I_t\omega_i^2 \qquad$ ...(ii)

Final energy, $E_f = \dfrac{1}{2}(I_t + I_b)\omega_f^2 \qquad$ ...(iii)

Substituting the value of ω_f from equation (i) in equation (iii), we get

Final energy, $E_f = \dfrac{1}{2}(I_t + I_b)\left(\dfrac{I_t\omega_i}{I_t + I_b}\right)^2 = \dfrac{1}{2}\dfrac{I_t^2\omega_i^2}{(I_t + I_b)} \qquad$ ...(iv)

Loss of energy, $\Delta E = E_i - E_f$

$$= \frac{1}{2}I_t\omega_i^2 - \frac{1}{2}\frac{I_t^2\omega_i^2}{(I_t + I_b)} \qquad \text{(Using (ii) and (iv))}$$

$$= \frac{\omega_i^2}{2}\left(I_t - \frac{I_t^2}{(I_t + I_b)}\right) = \frac{\omega_i^2}{2}\left(\frac{I_t^2 + I_b I_t - I_t^2}{(I_t + I_b)}\right)$$

$$= \frac{1}{2}\frac{I_b I_t}{(I_t + I_b)}\omega_i^2$$

34. (b) : As no external force is acting on the system, the centre of mass must be at rest *i.e.* $v_{CM} = 0$.

35. (c) : The coin will revolve with the record, if

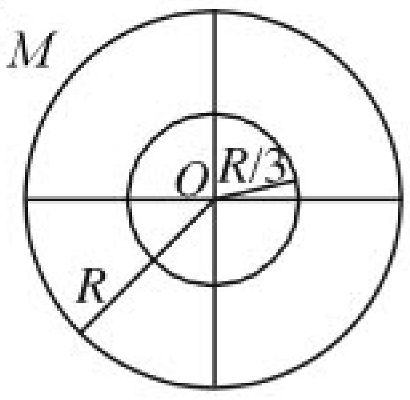
Force of friction ≥ Centrifugal force

$$\mu mg \geq mr\omega^2$$

or $\quad r \leq \dfrac{\mu g}{\omega^2}$

36. (a) : Mass of the disc = $9M$

Mass of removed portion of disc = M



The moment of inertia of the complete disc about an axis passing through its centre O and perpendicular to its plane is $I_1 = \frac{9}{2}MR^2$

Now, the moment of inertia of the disc with removed portion

$$I_2 = \frac{1}{2}M\left(\frac{R}{3}\right)^2 = \frac{1}{18}MR^2$$

Therefore, moment of inertia of the remaining portion of disc about O is

$$I = I_1 - I_2 = 9\frac{MR^2}{2} - \frac{MR^2}{18} = \frac{40MR^2}{9}$$

37. (d) : Time taken to reach the bottom of inclined plane.

$$t = \sqrt{\frac{2l\left(1 + \frac{K^2}{R^2}\right)}{g\sin\theta}}$$

Here, l is length of incline plane

For solid cylinder $K^2 = \dfrac{R^2}{2}$

For hollow cylinder $K^2 = R^2$

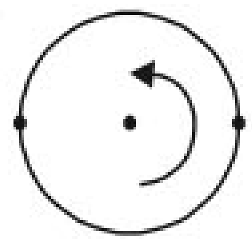
Hence, solid cylinder will reach the bottom first.

38. (d) : As no external torque is acting about the axis, angular momentum of system remains conserved.

$$I_1\omega_1 = I_2\omega_2$$

$$\Rightarrow \omega_2 = \frac{I_1\omega_1}{I_2} = \frac{Mr^2\omega}{(M+2m)r^2} = \frac{M\omega}{(M+2m)}$$

39. (a) : As the masses are added to the ring gently, there is no torque and angular momentum is conserved.



$$I\omega = I'\omega'$$

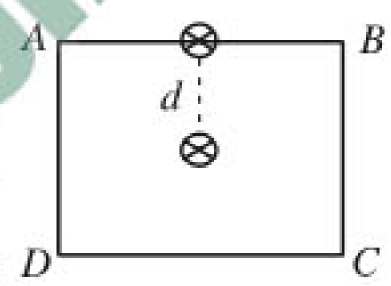
$$\Rightarrow MR^2\omega = (MR^2 + 2mR^2)\omega'$$

$$\Rightarrow \omega' = \frac{MR^2\omega}{(M+2m)R^2} \Rightarrow \omega' = \frac{M\omega}{M+2m}.$$

40. (b) : Torque is always perpendicular to $\vec{F}$ as well as $\vec{r}$.

$\therefore \quad \vec{r}\cdot\vec{\tau} = 0$ as well as $\vec{F}\cdot\vec{\tau} = 0$.

41. (d) : Moment of inertia for the rod AB rotating about an axis through the mid-point of AB perpendicular to the plane of the paper is $\dfrac{Ml^2}{12}$.



$\therefore$ Moment of inertia about the axis through the centre of the square and parallel to this axis,

$$I = I_0 + Md^2 = M\left(\frac{l^2}{12} + \frac{l^2}{4}\right) = \frac{Ml^2}{3}.$$

For all the four rods, $I = \dfrac{4}{3}Ml^2$.

42. (a) : $\vec{r}_1 = \hat{i} + 2\hat{j} + \hat{k}$ for $M_1 = 1$ kg

$\vec{r}_2 = -3\hat{i} - 2\hat{j} + \hat{k}$ for $M_2 = 3$ kg

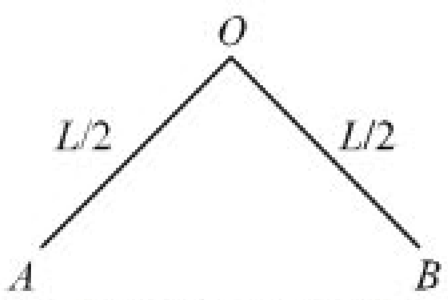
$$r_{C.M.} = \frac{\sum m_i r_i}{\sum m_i}$$

$$\Rightarrow r_{C.M.} = \frac{(1\hat{i} + 2\hat{j} + 1\hat{k})\times 1 + (-3\hat{i} - 2\hat{j} + \hat{k})\times 3}{4}$$

$$\Rightarrow r_{C.M.} = \frac{(1\hat{i} + 2\hat{j} + 1\hat{k})\times 1 + (-9\hat{i} - 6\hat{j} + 3\hat{k})}{4}$$

$$\Rightarrow r_{C.M.} = \frac{-8\hat{i} - 4\hat{j} + 4\hat{k}}{4} = -2\hat{i} - \hat{j} + \hat{k}.$$

43. (d) :



Total mass = M, total length = L

Moment of inertia of OA about O = Moment of inertia of OB about O.

$$\Rightarrow \text{M.I. total} = 2\times\left(\frac{M}{2}\right)\left(\frac{L}{2}\right)^2\cdot\frac{1}{3} = \frac{ML^2}{12}$$

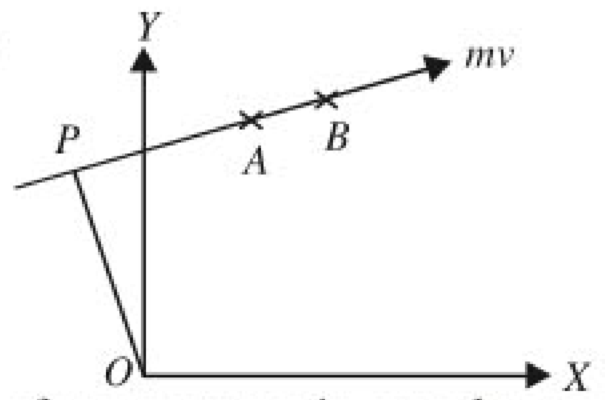
44. (d) : M.I. of a circular disc, $Mk^2 = \dfrac{M\cdot R^2}{2}$

M.I. of a circular ring = MR^2.

$\therefore$ Ratio of their radius of gyration $= \frac{1}{\sqrt{2}} : 1$

or $1 : \sqrt{2}$

45. (a) :



Moment of momentum is angular momentum. OP is the same whether the mass is at A or B.

$\therefore$ $L_A = L_B$.

46. (c) : Torque about A,

$\tau = mg \times \frac{l}{2} = \frac{mgl}{2}$

Also $\tau = I\alpha$

$\therefore$ Angular acceleration,

$$\alpha = \frac{\tau}{I} = \frac{mgl/2}{ml^2/3} = \frac{3}{2}\frac{g}{l}.$$

47. (a) : Given: Angular acceleration, $\alpha = 3$ rad/sec^2

Initial angular velocity $\omega_i = 2$ rad/sec

Time $t = 2$ sec

Using, $\theta = \omega_i t + \frac{1}{2}\alpha t^2$

$\therefore$ $\theta = 2\times 2 + \frac{1}{2}\times 3\times 4 = 4 + 6 = 10$ radian.

48. (d) : Moment of inertia of a uniform circular disc about an axis through its centre and perpendicular to its plane is $I_C = \frac{1}{2}MR^2$.

By the theorem of parallel axes,

$\therefore$ Moment of inertia of a uniform circular disc about an axis touching the disc at its diameter and normal to the disc is I.

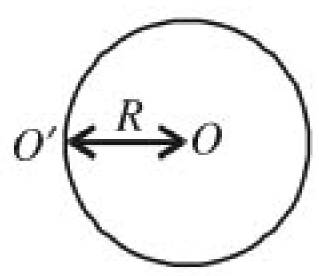
$$I = I_C + Mh^2 = \frac{1}{2}MR^2 + MR^2 = \frac{3}{2}MR^2.$$

49. (b) : The centre of the tube will be at length $L/2$. So radius $r = L/2$.

The force exerted by the liquid at the other end = centrifugal force

Centrifugal force $= Mr\omega^2 = M\left(\frac{L}{2}\right)\omega^2 = \frac{ML\omega^2}{2}$

50. (c) : M.I. of disc about its normal $= \frac{1}{2}MR^2$

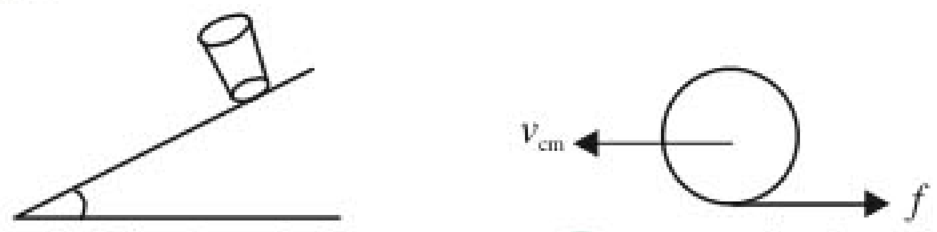


M.I. about its one edge $= MR^2 + \frac{MR^2}{2}$

(Perpendicular to the plane)

Moment of inertia $= \frac{3}{2}MR^2$.

51. (d) :



Required frictional force converts translational energy into rotational energy.

52. (c) : K.E. $= \frac{1}{2}I\omega^2$

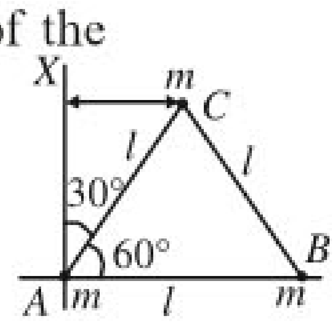
$\therefore$ $\frac{1}{2}I_1\omega_1^2 = \frac{1}{2}\cdot 2I_1\omega_2^2$

$$\frac{\omega_1^2}{\omega_2^2} = \frac{2}{1} \Rightarrow \frac{\omega_1}{\omega_2} = \frac{\sqrt{2}}{1}.$$

53. (c) : The moment of inertia of the system $= m_A r_A^2 + m_B r_B^2 + m_C r_C^2$

$= m_A(0)^2 + m(l)^2 + m(l\sin 30°)^2$

$= ml^2 + ml^2\times(1/4) = (5/4)\,ml^2$



54. (b) : C.M. $= \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$ ...(i)

After changing position of m_1 and to keep the position of C.M. same

$$\text{C.M.} = \frac{m_1(x_1 - d) + m_2(x_2 + d_2)}{m_1 + m_2}$$

$$0 = \frac{m_1 d + m_2 d_2}{m_1 + m_2}$$

[Substituting value of C.M. from (i)]

$$\Rightarrow d_2 = \frac{m_1}{m_2}d$$

55. (c) : $\omega_f = \omega_i - \alpha t \Rightarrow 0 = \omega_i - \alpha t$

$\therefore$ $\alpha = \omega_i/t$, where α is retardation.

The torque on the wheel is given by

$$\tau = I\alpha = \frac{I\omega}{t} = \frac{I\cdot 2\pi\upsilon}{t} = \frac{2\times 2\times\pi\times 60}{60\times 60}$$

$$\tau = \frac{\pi}{15}\text{ N m}$$

This is the torque required to stop the wheel in 1 min. (or 60 sec.).

56. (c) : Applying conservation of angular momentum.

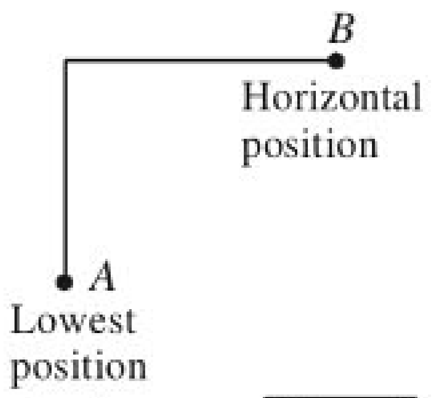
$$I_1\omega = (I_1 + I_2)\omega_1$$

$$\omega_1 = \frac{I_1}{(I_1 + I_2)}\omega$$

57. (c) : Radius of gyration of disc about a tangential axis in the plane of disc is $\frac{\sqrt{5}}{2}R = K_1$, radius of gyration of circular ring of same radius about a tangential axis in the plane of circular ring is

$$K_2 = \sqrt{\frac{3}{2}}R \quad \therefore \quad \frac{K_1}{K_2} = \frac{\sqrt{5}}{\sqrt{6}}.$$

58. (a) : The total energy at A = the total energy at B



$$\Rightarrow \frac{1}{2}mu^2 = \frac{1}{2}mv^2 + mgl$$

$$\Rightarrow v = \sqrt{u^2 - 2gl}$$

The change in magnitude of velocity $= \sqrt{u^2 + v^2}$

$$= \sqrt{2(u^2 - gl)}$$

59. (c) : Total energy

$$= \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2 = \frac{1}{2}mv^2(1 + K^2/R^2)$$

Required fraction $= \frac{K^2/R^2}{1+K^2/R^2} = \frac{K^2}{R^2+K^2}$.

60. (c) : Potential energy of the solid cylinder at height $h = Mgh$

K.E. of centre of mass when reached at bottom

$$= \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2 \quad = \frac{1}{2}Mv^2 + \frac{1}{2}Mk^2v^2/R^2$$

$$= \frac{1}{2}Mv^2\left(1 + \frac{k^2}{R^2}\right)$$

For a solid cylinder $\frac{k^2}{R^2} = \frac{1}{2} \quad \therefore \quad$ K.E. $= \frac{3}{4}Mv^2$

$$\therefore \quad Mgh = \frac{3}{4}Mv^2 \qquad v = \sqrt{\frac{4}{3}gh}.$$

61. (b) : According to conservation of angular momentum, $L = I\omega$ = constant.

Therefore, $I_2\omega_2 = I_1\omega_1$

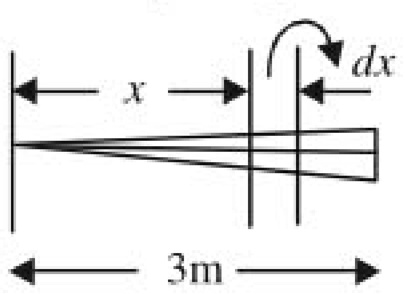
or $\quad \omega_2 = \frac{I_1\omega_1}{I_2} = \frac{Mk^2\omega}{(M+4m)k^2} = \frac{M\omega}{M+4m}$.

62. (b) : Let us consider an elementary length dx at a distance x from one end.

It's mass $= k \cdot x \cdot dx$

[k = proportionality constant]

Then centre of gravity of the rod x_c is given by

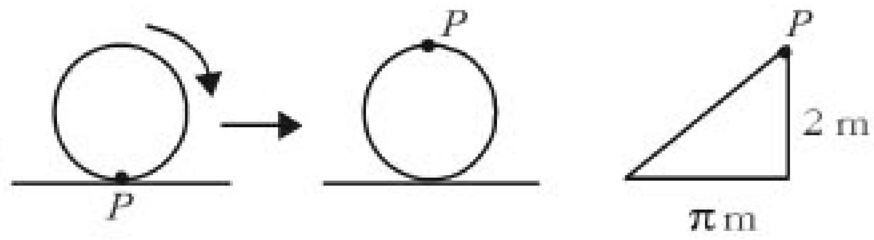


$$x_c = \frac{\int_0^3 kxdx \cdot x}{\int_0^3 kxdx} = \frac{\int_0^3 x^2dx}{\int_0^3 xdx} = \frac{\left.\frac{x^3}{3}\right|_0^3}{\left.\frac{x^2}{2}\right|_0^3}$$

or, $\quad x_c = \frac{27/3}{9/2} = 2.$

$\therefore$ Centre of gravity of the rod will be at distance of 2 m from one end.

63. (b) :



In half rotation point P has moved horizontally.

$\frac{\pi d}{2} = \pi r = \pi \times 1$ m $= \pi$ m . [$\because$ radius = 1 m]

In the same time, it has moved vertically a distance which is equal to its diameter = 2 m.

$\therefore$ Displacement of $P = \sqrt{\pi^2 + 2^2} = \sqrt{\pi^2 + 4}$ m .

64. (d) : Since there is no friction at the contact surface (smooth horizontal surface) there will be no rolling. Hence, the acceleration of the centre of mass of the sphere will be independent of the position of the applied force F. Therefore, there is no relation between h and R.

65. (b) : When a child sits on a rotating disc, no external torque is introduced. Hence the angular momentum of the system is conserved. But the moment of inertia of the system will increase and as a result, the angular speed of the disc will decrease to maintain constant angular momentum.

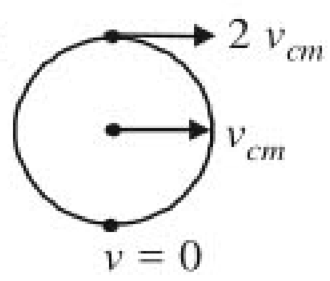
[$\because$ angular momentum = moment of inertia × angular velocity]

66. (a) : A circular disc may be divided into a large number of circular rings. Moment of inertia of the disc will be the summation of the moments of inertia of these rings about the geometrical axis.

Now, moment of inertia of a circular ring about its geometrical axis is MR^2, where M is the mass and R is the radius of the ring.

Since the density (mass per unit volume) for iron is more than that of aluminium, the proposed rings made of iron should be placed at a higher radius to get more value of MR^2. Hence to get maximum moment of inertia for the circular disc, aluminium should be placed at interior and iron at the outside.

67. (a) :



68. (b) : As effective distance of mass from BC is greater than the effective distance of mass from AB, therefore $I_2 > I_1$.

69. (a) : Solid sphere reaches the bottom first because for solid cylinder $\frac{K^2}{R^2}=\frac{1}{2}$, and for hollow cylinder $\frac{K^2}{R^2}=1$.

Acceleration down the inclined plane $\propto \frac{1}{K^2/R^2}$.

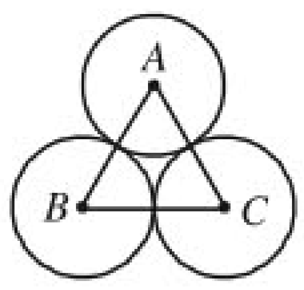
Solid cylinder has greater acceleration, so it reaches the bottom first.

70. (b) : When a sphere is rotating in a vertical circle, it exerts the maximum outward pull when it is at the lowest point B.

Therefore, tension at B is maximum = Weight$+\frac{mv^2}{R}$

So, the string breaks at point B.

71. (d) :



Centre of mass of each ball lies on the centre.

$\Rightarrow$ Centre of mass of combined body will be at the centroid of equilateral triangle.

72. (a) : Moment of inertia of a disc about its diameter

$$=\frac{1}{4}MR^2$$

Using theorem of parallel axes,

$$I=\frac{1}{4}MR^2+MR^2=\frac{5}{4}MR^2.$$

73. (c) : Force $(\vec{F})=-3\hat{i}+\hat{j}+5\hat{k}$ and distance of the point $(\vec{r})=7\hat{i}+3\hat{j}+\hat{k}$.

$$\text{Torque}\quad \vec{\tau}=\vec{r}\times\vec{F}=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 7 & 3 & 1\\ -3 & 1 & 5\end{vmatrix}=14\hat{i}-38\hat{j}+16\hat{k}$$

74. (d) : The resultant of all forces, on any system of particles, is zero. Therefore their centre of mass does not depend upon the forces acting on the particles.

75. (d)

76. (d) : The intersection of medians is the centre of mass of the triangle. Since the distances of centre of mass from the sides is related as $x_{BC}<x_{AB}<x_{AC}$.

Therefore $I_{BC}>I_{AB}>I_{AC}$ or $I_{BC}>I_{AB}$.

77. (d) : Force $(\vec{F})=2\hat{i}-3\hat{j}+4\hat{k}$ N and distance of the point from origin $(r)=3\hat{i}+2\hat{j}+3\hat{k}$ m.

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

$$(3\hat{i}+2\hat{j}+3\hat{k})\times(2\hat{i}-3\hat{j}+4\hat{k})=\begin{vmatrix}\hat{i} & \hat{j} & \hat{k}\\ 3 & 2 & 3\\ 2 & -3 & 4\end{vmatrix}$$

$$=17\hat{i}-6\hat{j}-13\hat{k}.$$

78. (d) : Linear K.E. of ball $=\frac{1}{2}mv^2$ and rotational K.E. of ball $=\frac{1}{2}I\omega^2=\frac{1}{2}\left(\frac{2}{5}mr^2\right)\omega^2=\frac{1}{5}mv^2$.

Therefore total K.E. $=\frac{1}{2}mv^2+\frac{1}{5}mv^2=\frac{7}{10}mv^2$.

And ratio of rotational K.E. and total K.E.

$$=\frac{(1/5)mv^2}{(7/10)mv^2}=\frac{2}{7}.$$

79. (d) : The moment of inertia is minimum about EG because mass distribution is at minimum distance from EG.

80. (a) : For solid sphere, $\frac{K^2}{R^2}=\frac{2}{5}$

For disc and solid cylinder, $\frac{K^2}{R^2}=\frac{1}{2}$

As $\frac{K^2}{R^2}$ for solid sphere is smallest, it takes minimum time to reach the bottom of the incline, disc and cylinder reach together later.

81. (a) : P.E. = total K.E

$$mgh=\frac{7}{10}mv^2,\ v=\sqrt{\frac{10gh}{7}}$$

82. (d) : Total kinetic energy =

$$E_{\text{trans}}+E_{\text{rot}}=\frac{1}{2}mv^2+\frac{1}{2}I\omega^2$$

$$=\frac{1}{2}mv^2+\frac{1}{2}\times\left(\frac{2}{5}mr^2\right)\omega^2$$

$$=\frac{1}{2}mv^2+\frac{1}{5}mv^2=\frac{7}{10}mv^2$$

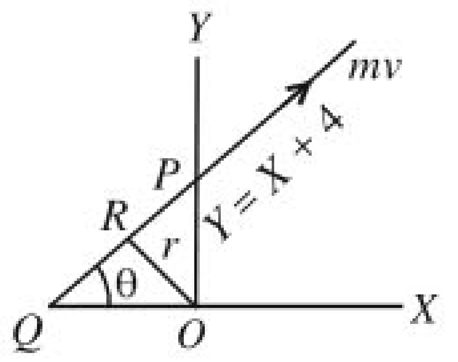
$$\therefore\ \frac{E_{trans}}{E_{total}}=\frac{\frac{1}{2}mv^2}{\frac{7}{10}mv^2}=\frac{5}{7}$$

83. (a) : $\vec{L}=\vec{r}\times\vec{p}$

$Y=X+4$ line has been shown in the figure.

When $X=0$,

$Y=4$, So $OP=4$.



The slope of the line can be obtained by comparing with the equation of line

$y = mx + c$

$m = \tan\theta = 1 \quad \Rightarrow \theta = 45°$

$\angle OQP = \angle OPQ = 45°$

If we draw a line perpendicular to this line.

Length of the perpendicular = OR

$\Rightarrow \quad OR = OP\sin 45°$

$= 4\ \dfrac{1}{\sqrt{2}} = \dfrac{4}{\sqrt{2}} = 2\sqrt{2}$

Angular momentum of particle going along this line

$= r \times mv = 2\sqrt{2} \times 5 \times 3\sqrt{2} = 60$ units

84. (c) : K.E. $= \dfrac{1}{2}I\omega^2$

$I = \dfrac{2\text{K.E.}}{\omega^2} = \dfrac{2 \times 360}{30 \times 30} = 0.8\ \text{kgm}^2$

85. (b) : $I = 1.2$ kgm^2, $E_r = 1500$ J,

$\alpha = 25$ rad/s^2, $\omega_1 = 0$, $t = ?$

As $E_r = \dfrac{1}{2}I\omega^2$, $\omega = \sqrt{\dfrac{2E_r}{I}}$

$\omega \quad = \sqrt{\dfrac{2 \times 1500}{1.2}} = 50$ rad/sec

From $\omega_2 = \omega_1 + \alpha t$.

$50 = 0 + 25t, \qquad$ or $t = 2$ s.

86. (c) : Moment of inertia of uniform circular disc about diameter = I

According to theorem of perpendicular axes.

Moment of inertia of disc about axis = $2I = \dfrac{1}{2}mr^2$

Applying theorem of parallel axes

Moment of inertia of disc about the given axis

$= 2I + mr^2 = 2I + 4I = 6I$.

87. (b) : Angular momentum about the point of contact with the surface includes the angular momentum about the centre. Because of friction, linear momentum will not be conserved.

88. (a) : Kinetic energy $= \dfrac{1}{2}I\omega^2$, and for ring $I = mr^2$

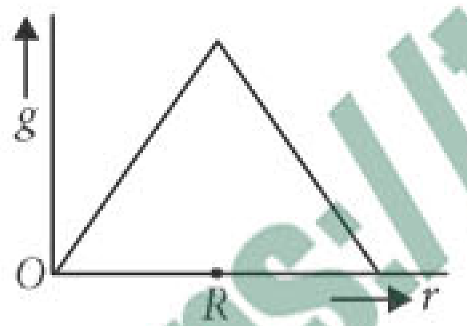
Hence KE $= \dfrac{1}{2}mr^2\omega^2$

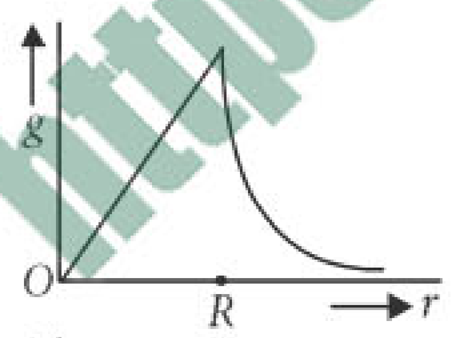
Chapter 7 Gravitation

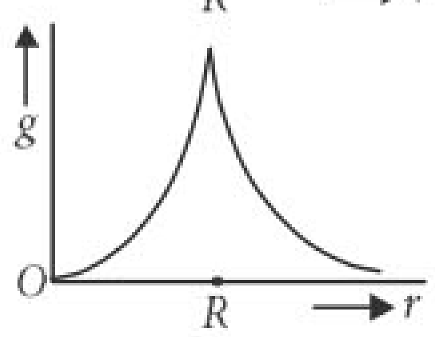
1. The acceleration due to gravity at a height 1 km above the earth is the same as at a depth d below the surface of earth. Then
(a) $d = 1$ km (b) $d = \frac{3}{2}$ km
(c) $d = 2$ km (d) $d = \frac{1}{2}$ km
(NEET 2017)

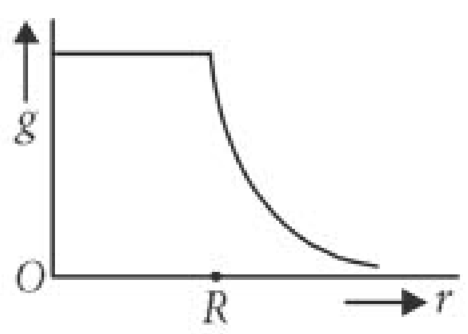
2. Two astronauts are floating in gravitational free space after having lost contact with their spaceship. The two will
(a) move towards each other.
(b) move away from each other.
(c) will become stationary.
(d) keep floating at the same distance between them.
(NEET 2017)

3. Starting from the centre of the earth having radius R, the variation of g(acceleration due to gravity) is shown by

(a)


(b)


(c)


(d)


(NEET-II 2016)

4. A satellite of mass m is orbiting the earth (of radius R) at a height h from its surface. The total energy of the satellite in terms of g_0, the value of acceleration due to gravity at the earth's surface, is
(a) $\frac{mg_0R^2}{2(R+h)}$ (b) $-\frac{mg_0R^2}{2(R+h)}$
(c) $\frac{2mg_0R^2}{R+h}$ (d) $-\frac{2mg_0R^2}{R+h}$
(NEET-II 2016)

5. At what height from the surface of earth the gravitation potential and the value of g are -5.4×10^7 J kg^{-1} and 6.0 m s^{-2} respectively? Take the radius of earth as 6400 km.
(a) 1400 km (b) 2000 km
(c) 2600 km (d) 1600 km
(NEET-I 2016)

6. The ratio of escape velocity at earth (v_e) to the escape velocity at a planet (v_p) whose radius and mean density are twice as that of earth is
(a) $1:4$ (b) $1:\sqrt{2}$
(c) $1:2$ (d) $1:2\sqrt{2}$
(NEET-I 2016)

7. A remote-sensing satellite of earth revolves in a circular orbit at a height of 0.25×10^6 m above the surface of earth. If earth's radius is 6.38×10^6 m and $g = 9.8$ ms^{-2}, then the orbital speed of the satellite is
(a) 9.13 km s^{-1} (b) 6.67 km s^{-1}
(c) 7.76 km s^{-1} (d) 8.56 km s^{-1}
(2015)

8. A satellite S is moving in an elliptical orbit around the earth. The mass of the satellite is very small compared to the mass of the earth. Then,
(a) the linear momentum of S remains constant in magnitude.
(b) the acceleration of S is always directed towards the centre of the earth.

(c) the angular momentum of S about the centre of the earth changes in direction, but its magnitude remains constant.
(d) the total mechanical energy of S varies periodically with time.

(2015)

9. Kepler's third law states that square of period of revolution (T) of a planet around the sun, is proportional to third power of average distance r between sun and planet *i.e.* $T^2 = Kr^3$ here K is constant. If the masses of sun and planet are M and m respectively then as per Newton's law of gravitation force of attraction between them is $F = \dfrac{GMm}{r^2}$, here G is gravitational constant. The relation between G and K is described as

(a) $K = G$ (b) $K = \dfrac{1}{G}$
(c) $GK = 4\pi^2$ (d) $GMK = 4\pi^2$

(2015 Cancelled)

10. Two spherical bodies of mass M and $5M$ and radii R and $2R$ are released 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 before collision is

(a) $7.5R$ (b) $1.5R$
(c) $2.5R$ (d) $4.5R$

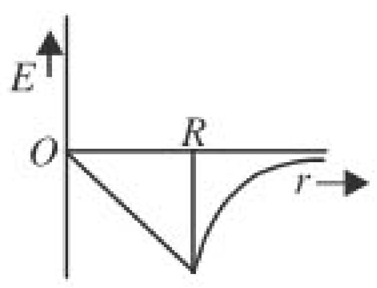
(2015 Cancelled)

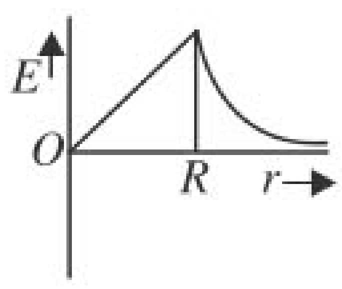
11. A black hole is an object whose gravitational field is so strong that even light cannot escape from it. To what approximate radius would earth (mass = 5.98×10^{24} kg) have to be compressed to be a black hole?

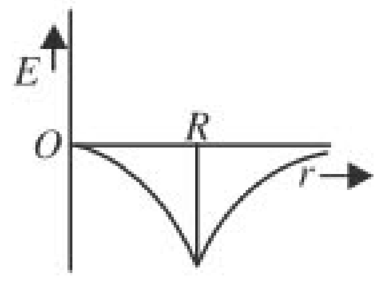
(a) 10^{-9} m (b) 10^{-6} m
(c) 10^{-2} m (d) 100 m

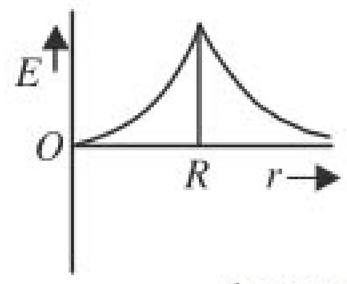
(2014)

12. Dependence of intensity of gravitational field (E) of earth with distance (r) from centre of earth is correctly represented by

(a) 

(b) 

(c) 

(d) 

(2014)

13. Infinite number of bodies, each of mass 2 kg are situated on x-axis at distances 1 m, 2 m, 4 m, 8 m, ..., respectively, from the origin. The resulting gravitational potential due to this system at the origin will be

(a) $-\dfrac{4}{3}G$ (b) $-4G$
(c) $-G$ (d) $-\dfrac{8}{3}G$

(NEET 2013)

14. A body of mass 'm' is taken from the earth's surface to the height equal to twice the radius (R) of the earth. The change in potential energy of body will be

(a) $3mgR$ (b) $\dfrac{1}{3}mgR$
(c) $mg2R$ (d) $\dfrac{2}{3}mgR$

(NEET 2013)

15. The radius of a planet is twice the radius of earth. Both have almost equal average mass-densities. V_P and V_E are escape velocities of the planet and the earth, respectively, then

(a) $V_P = 1.5\, V_E$ (b) $V_P = 2\, V_E$
(c) $V_E = 3\, V_P$ (d) $V_E = 1.5\, V_P$

(Karnataka NEET 2013)

16. A particle of mass 'm' is kept at rest at a height $3R$ from the surface of earth, where 'R' is radius of earth and 'M' is mass of earth. The minimum speed with which it should be projected, so that it does not return back, is
(g is acceleration due to gravity on the surface of earth)

(a) $\left(\dfrac{GM}{2R}\right)^{1/2}$ (b) $\left(\dfrac{gR}{4}\right)^{1/2}$
(c) $\left(\dfrac{2g}{R}\right)^{1/2}$ (d) $\left(\dfrac{GM}{R}\right)^{1/2}$

(Karnataka NEET 2013)

17. The height at which the weight of a body becomes $\left(\dfrac{1}{16}\right)$th, its weight on the surface of earth (radius R), is

(a) $5R$ (b) $15R$
(c) $3R$ (d) $4R$ *(2012)*

18. A spherical planet has a mass M_p and diameter D_p. A particle of mass m falling freely near the surface of this planet will experience an acceleration due to gravity, equal to

(a) $\frac{4GM_p}{D_p^2}$ (b) $\frac{GM_pm}{D_p^2}$

(c) $\frac{GM_p}{D_p^2}$ (d) $\frac{4GM_pm}{D_p^2}$ *(2012)*

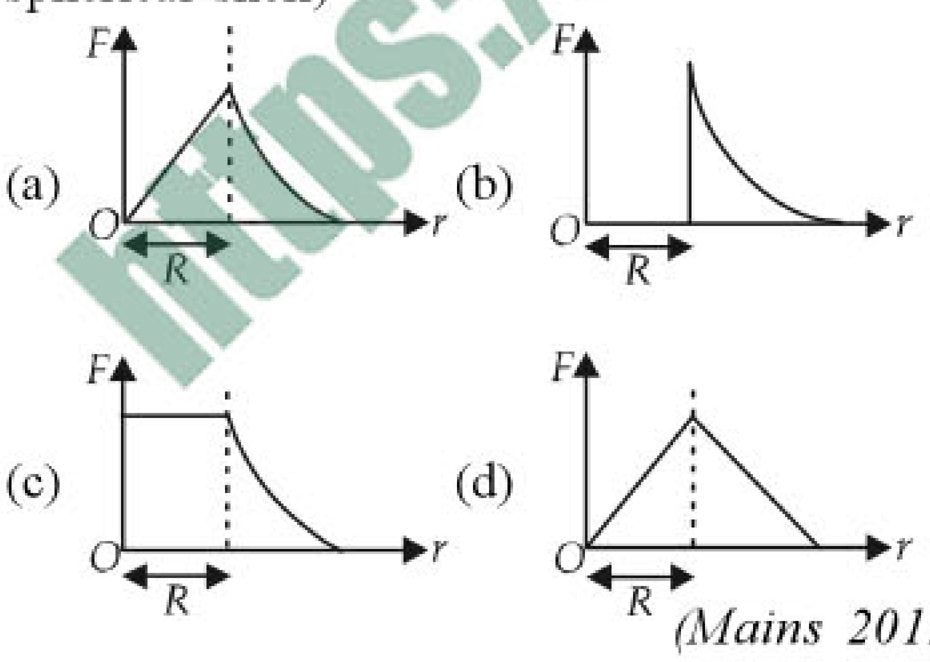
19. A geostationary satellite is orbiting the earth at a height of $5R$ above the surface of the earth, R being the radius of the earth. The time period of another satellite in hours at a height of $2R$ from the surface of the earth is

(a) 5 (b) 10
(c) $6\sqrt{2}$ (d) $\frac{6}{\sqrt{2}}$ *(2012)*

20. If v_e is escape velocity and v_o is orbital velocity of a satellite for orbit close to the earth's suface, then these are related by

(a) $v_o = \sqrt{2}v_e$ (b) $v_o = v_e$
(c) $v_e = \sqrt{2v_o}$ (d) $v_e = \sqrt{2}v_o$ *(Mains 2012)*

21. Which one of the following plots represents the variation of gravitational field on a particle with distance r due to a thin spherical shell of radius R? (r is measured from the centre of the spherical shell)



(Mains 2012)

22. A planet moving along an elliptical orbit is closest to the sun at a distance r_1 and farthest away at a distance of r_2. If v_1 and v_2 are the linear velocities at these points respectively, then the ratio $\frac{v_1}{v_2}$ is

(a) $(r_1/r_2)^2$ (b) r_2/r_1
(c) $(r_2/r_1)^2$ (d) r_1/r_2 *(2011)*

23. A particle of mass m is thrown upwards from the surface of the earth, with a velocity u. The mass and the radius of the earth are, respectively, M and R. G is gravitational constant and g is acceleration due to gravity on the surface of the earth. The minimum value of u so that the particle does not return back to earth, is

(a) $\sqrt{\frac{2GM}{R^2}}$ (b) $\sqrt{\frac{2GM}{R}}$

(c) $\sqrt{\frac{2gM}{R^2}}$ (d) $\sqrt{2gR^2}$

(Mains 2011)

24. A particle of mass M is situated at the centre of a spherical shell of same mass and radius a. The magnitude of the gravitational potential at a point situated at $a/2$ distance from the centre, will be

(a) $\frac{GM}{a}$ (b) $\frac{2GM}{a}$

(c) $\frac{3GM}{a}$ (d) $\frac{4GM}{a}$

(Mains 2011, 2010)

25. The radii of circular orbits of two satellites A and B of the earth, are $4R$ and R, respectively. If the speed of satellite A is $3V$, then the speed of satellite B will be

(a) $\frac{3V}{4}$ (b) $6V$

(c) $12V$ (d) $\frac{3V}{2}$

(2010)

26. A man of 50 kg mass is standing in a gravity free space at a height of 10 m above the floor. He throws a stone of 0.5 kg mass downwards with a speed 2 m/s. When the stone reaches the floor, the distance of the man above the floor will be

(a) 9.9 m (b) 10.1 m
(c) 10 m (d) 20 m *(2010)*

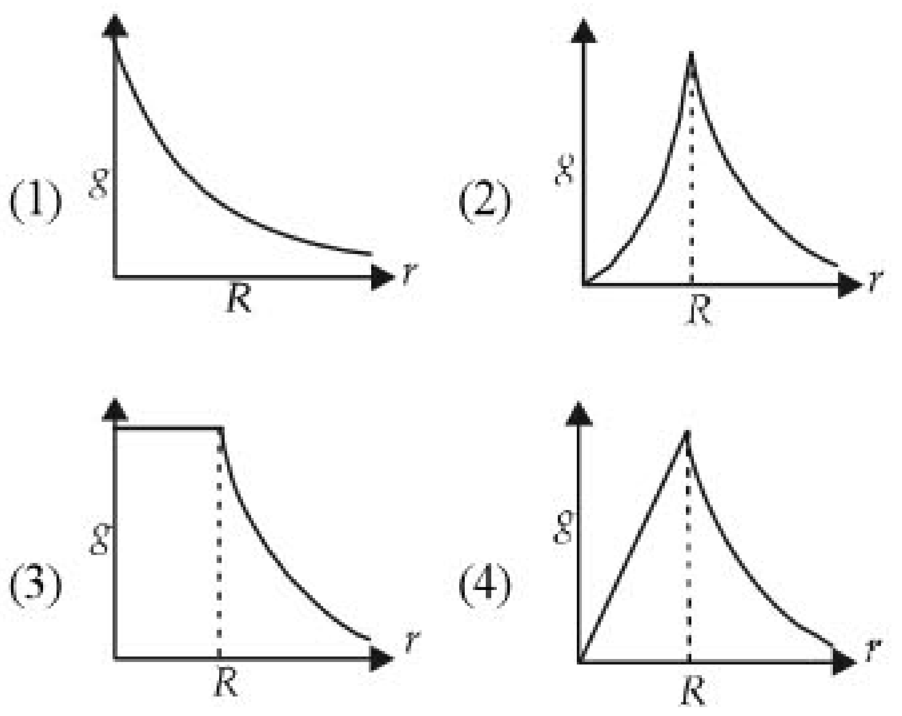
27. The additional kinetic energy to be provided to a satellite of mass m revolving around a planet of mass M, to transfer it from a circular orbit of radius R_1 to another of radius $R_2 (R_2 > R_1)$ is

(a) $GmM\left(\frac{1}{R_1^2} - \frac{1}{R_2^2}\right)$ (b) $GmM\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

(c) $2GmM\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$ (d) $\frac{1}{2}GmM\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$

(Mains 2010)

28. The dependence of acceleration due to gravity g on the distance r from the centre of the earth, assumed to be a sphere of radius R of uniform density is as shown in figures below



The correct figure is

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

(Mains 2010)

29. (1) Centre of gravity (C.G.) of a body is the point at which the weight of the body acts

(2) Centre of mass coincides with the centre of gravity if the earth is assumed to have infinitely large radius.

(3) To evaluate the gravitational field intensity due to any body at an external point, the entire mass of the body can be considered to be concentrated at its C.G.

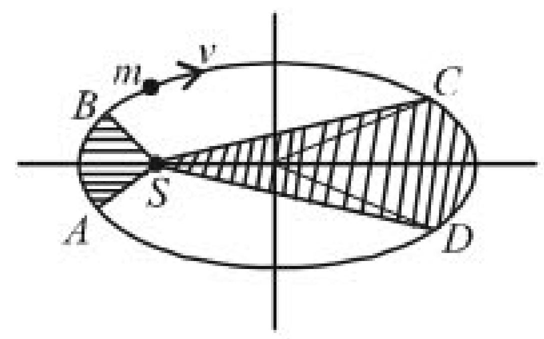
(4) The radius of gyration of any body rotating about an axis is the length of the perpendicular dropped from the C.G. of the body to the axis.

Which one of the following pairs of statements is correct?

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

(Mains 2010)

30. The figure shows elliptical orbit of a planet m about the sun S. The shaded area SCD is twice the shaded area SAB. If t_1 is the time for the planet to move from C to D and t_2 is the time to move from A to B then



(a) $t_1 = 4t_2$ (b) $t_1 = 2t_2$
(c) $t_1 = t_2$ (d) $t_1 > t_2$

(2009)

31. Two satellites of earth, S_1 and S_2 are moving in the same orbit. The mass of S_1 is four times the mass of S_2. Which one of the following statements is true?

(a) The potential energies of earth and satellite in the two cases are equal.
(b) S_1 and S_2 are moving with the same speed.
(c) The kinetic energies of the two satellites are equal.
(d) The time period of S_1 is four times that of S_2.

(2007)

32. The earth is assumed to be a sphere of radius R. A platform is arranged at a height R from the surface of the earth. The escape velocity of a body from this platform is fv, where v is its escape velocity from the surface of the Earth. The value of f is

(a) 1/2 (b) $\sqrt{2}$
(c) $1/\sqrt{2}$ (d) 1/3. *(2006)*

33. Imagine a new planet having the same density as that of earth but it is 3 times bigger than the earth in size. If the acceleration due to gravity on the surface of earth is g and that on the surface of the new planet is g', then

(a) $g' = g/9$ (b) $g' = 27g$
(c) $g' = 9g$ (d) $g' = 3g$.

(2005)

34. For a satellite moving in an orbit around the earth, the ratio of kinetic energy to potential energy is

(a) 1/2 (b) $1/\sqrt{2}$
(c) 2 (d) $\sqrt{2}$ *(2005)*

35. The density of a newly discovered planet is twice that of earth. The acceleration due to gravity at the surface of the planet is equal

to that at the surface of the earth. If the radius of the earth is R, the radius of the planet would be
(a) $2R$ (b) $4R$
(c) $\frac{1}{4}R$ (d) $\frac{1}{2}R$ *(2004)*

36. Two spheres of masses 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) $3F$ (b) F
(c) $F/3$ (d) $F/9$
(2003)

37. The acceleration due to gravity on the planet A is 9 times the acceleration due to gravity on planet B. A man jumps to a height of 2 m on the surface of A. What is the height of jump by the same person on the planet B?
(a) (2/9) m (b) 18 m
(c) 6 m (d) (2/3) m
(2003)

38. A body of mass m is placed on earth's surface which is taken from earth surface to a height of $h = 3R$, then change in gravitational potential energy is
(a) $\frac{mgR}{4}$ (b) $\frac{2}{3}mgR$
(c) $\frac{3}{4}mgR$ (d) $\frac{mgR}{2}$
(2003)

39. With what velocity should a particle be projected so that its height becomes equal to radius of earth?
(a) $\left(\frac{GM}{R}\right)^{1/2}$ (b) $\left(\frac{8GM}{R}\right)^{1/2}$
(c) $\left(\frac{2GM}{R}\right)^{1/2}$ (d) $\left(\frac{4GM}{R}\right)^{1/2}$
(2001)

40. For a planet having mass equal to mass of the earth but radius is one fourth of radius of the earth. Then escape velocity for this planet will be
(a) 11.2 km/sec (b) 22.4 km/sec
(c) 5.6 km/sec (d) 44.8 km/sec.
(2000)

41. Gravitational force is required for
(a) stirring of liquid
(b) convection
(c) conduction
(d) radiation. *(2000)*

42. A body of weight 72 N moves from the surface of earth at a height half of the radius of earth, then gravitational force exerted on it will be
(a) 36 N (b) 32 N
(c) 144 N (d) 50 N. *(2000)*

43. The escape velocity of a sphere of mass m is given by (G = Universal gravitational constant; M_e = Mass of the earth and R_e = Radius of the earth)
(a) $\sqrt{\frac{2GM_e m}{R_e}}$ (b)
(c) $\sqrt{\frac{GM_e}{R_e}}$ (d) $\sqrt{\frac{2GM_e + R_e}{R_e}}$
(1999)

44. 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 radius of the earth becomes half, the escape velocity becomes
(a) 22.4 km/s (b) 44.8 km/s
(c) 5.6 km/s (d) 11.2 km/s. *(1997)*

45. The period of revolution of planet A around the sun is 8 times that of B. The distance of A from the sun is how many times greater than that of B from the sun?
(a) 4 (b) 5
(c) 2 (d) 3 *(1997)*

46. What will be the formula of mass of the earth in terms of g, R and G?
(a) $G\frac{R}{g}$ (b) $g\frac{R^2}{G}$
(c) $g^2\frac{R}{G}$ (d) $G\frac{g}{R}$. *(1996)*

47. A ball is dropped from a spacecraft revolving around the earth at a height of 120 km. What will happen to the ball?
(a) it will fall down to the earth gradually
(b) it will go very far in the space
(c) it will continue to move with the same speed along the original orbit of spacecraft

(d) it will move with the same speed, tangentially to the spacecraft.

(1996)

48. The acceleration due to gravity g and mean density of the earth ρ are related by which of the following relations? (where G is the gravitational constant and R is the radius of the earth.)

(a) $\rho = \dfrac{3g}{4\pi GR}$ (b) $\rho = \dfrac{3g}{4\pi GR^3}$

(c) $\rho = \dfrac{4\pi gR^2}{3G}$ (d) $\rho = \dfrac{4\pi gR^3}{3G}$.

(1995)

49. Two particles of equal mass go around a circle of radius R under the action of their mutual gravitational attraction. The speed v of each particle is

(a) $\dfrac{1}{2}\sqrt{\dfrac{Gm}{R}}$ (b) $\sqrt{\dfrac{4Gm}{R}}$

(c) $\dfrac{1}{2R}\sqrt{\dfrac{1}{Gm}}$ (d) $\sqrt{\dfrac{Gm}{R}}$.

(1995)

50. The earth (mass = 6×10^{24} kg) revolves around the sun with an angular velocity of 2×10^{-7} rad/s in a circular orbit of radius 1.5×10^8 km. The force exerted by the sun on the earth, in newton, is

(a) 36×10^{21} (b) 27×10^{39}

(c) zero (d) 18×10^{25}.

(1995)

51. The radius of earth is about 6400 km and that of mars is 3200 km. The mass of the earth is about 10 times mass of mars. An object weighs 200 N on the surface of earth. Its weight on the surface of mars will be

(a) 20 N (b) 8 N

(c) 80 N (d) 40 N.

(1994)

52. The distance of two planets from the sun are 10^{13} m and 10^{12} m respectively. The ratio of time periods of the planets is

(a) $\sqrt{10}$ (b) $10\sqrt{10}$

(c) 10 (d) $1/\sqrt{10}$.

(1994, 1988)

53. If the gravitational force between two objects were proportional to $1/R$ (and not as $1/R^2$), where R is the distance between them, then a particle in a circular path (under such a force) would have its orbital speed v, proportional to

(a) R

(b) R^0 (independent of R)

(c) $1/R^2$ (d) $1/R$.

(1994, 1989)

54. A satellite in force free space sweeps stationary interplanetary dust at a rate of $dM/dt = \alpha v$, where M is mass and v is the speed of satellite and α is a constant. The acceleration of satellite is

(a) $\dfrac{-\alpha v^2}{2M}$ (b) $-\alpha v^2$

(c) $\dfrac{-2\alpha v^2}{M}$ (d) $\dfrac{-\alpha v^2}{M}$ *(1994)*

55. The escape velocity from earth is 11.2 km/s. If a body is to be projected in a direction making an angle 45° to the vertical, then the escape velocity is

(a) 11.2×2 km/s (b) 11.2 km/s

(c) $11.2/\sqrt{2}$ km/s (d) $11.2\sqrt{2}$ km/s

(1993)

56. A satellite A of mass m is at a distance of r from the surface of the earth. Another satellite B of mass $2m$ is at a distance of $2r$ from the earth's centre. Their time periods are in the ratio of

(a) 1 : 2 (b) 1 : 16

(c) 1 : 32 (d) $1:2\sqrt{2}$

(1993)

57. The mean radius of earth is R, its angular speed on its own axis is ω and the acceleration due to gravity at earth's surface is g. What will be the radius of the orbit of a geostationary satellite ?

(a) $(R^2g/\omega^2)^{1/3}$ (b) $(Rg/\omega^2)^{1/3}$

(c) $(R^2\omega^2/g)^{1/3}$ (d) $(R^2g/\omega)^{1/3}$

(1992)

58. The satellite of mass m is orbiting around the earth in a circular orbit with a velocity v. What will be its total energy ?

(a) $(3/4)mv^2$ (b) $(1/2)mv^2$

(c) mv^2 (d) $-(1/2)mv^2$

(1991)

59. A planet is moving in an elliptical orbit around the sun. If T, V, E and L stand respectively for its kinetic energy, gravitational potential energy, total energy and magnitude of angular momentum about the centre of force, which of the following is correct ?
(a) T is conserved (b) V is always positive
(c) E is always negative
(d) L is conserved but direction of vector L changes continously.
(1990)

60. For a satellite escape velocity is 11 km/s. If the satellite is launched at an angle of 60° with the vertical, then escape velocity will be
(a) 11 km/s (b) $11\sqrt{3}$ km/s
(c) $\frac{11}{\sqrt{3}}$ km/s (d) 33 km/s
(1989)

61. The largest and the shortest distance of the earth from the sun are r_1 and r_2. Its distance from the sun when it is at perpendicular to the major-axis of the orbit drawn from the sun is
(a) $\frac{r_1+r_2}{4}$ (b) $\frac{r_1+r_2}{r_1-r_2}$
(c) $\frac{2r_1r_2}{r_1+r_2}$ (d) $\frac{r_1+r_2}{3}$ *(1988)*

Answer Key

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

EXPLANATIONS

1. **(c) :** The acceleration due to gravity at a height h is given as

$$g_h = g\left(1 - \frac{2h}{R_e}\right)$$

where R_e is radius of earth.

The acceleration due to gravity at a depth d is given as $g_d = g\left(1 - \frac{d}{R_e}\right)$

Given, $g_h = g_d$

$$\therefore \quad g\left(1 - \frac{2h}{R_e}\right) = g\left(1 - \frac{d}{R_e}\right)$$

$\therefore \quad d = 2h = 2 \times 1 = 2$ km ($\because h = 1$ km)

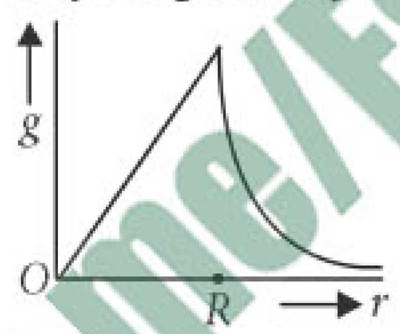
2. **(a) :** Since two astronauts are floating in gravitational free space. The only force acting on the two astronauts is the gravitational pull of their masses, $F = \frac{Gm_1m_2}{r^2}$,

which is attractive in nature.

Hence they move towards each other.

3. **(b) :** Acceleration due to gravity is given by

$$g = \begin{cases} \frac{4}{3}\pi\rho G r & ; \; r \le R \\ \frac{4}{3}\frac{\pi\rho R^3 G}{r^2} & ; \; r > R \end{cases}$$



4. **(b) :** Total energy of satellite at height h from the earth surface,

$$E = PE + KE$$

$$= -\frac{GMm}{(R+h)} + \frac{1}{2}mv^2 \quad \text{...(i)}$$

Also, $\frac{mv^2}{(R+h)} = \frac{GMm}{(R+h)^2}$

or, $v^2 = \frac{GM}{R+h}$ ...(ii)

From eqns. (i) and (ii),

$$E = -\frac{GMm}{(R+h)} + \frac{1}{2}\frac{GMm}{(R+h)} = -\frac{1}{2}\frac{GMm}{(R+h)}$$

$$= -\frac{1}{2}\frac{GM}{R^2} \times \frac{mR^2}{(R+h)}$$

$$= -\frac{mg_0R^2}{2(R+h)} \qquad \left(\because g_0 = \frac{GM}{R^2}\right)$$

5. **(c) :** Gravitation potential at a height h from the surface of earth, $V_h = -5.4 \times 10^7$ J kg^{-1}

At the same point acceleration due to gravity,

$g_h = 6$ m s^{-2}

$R = 6400$ km $= 6.4 \times 10^6$ m

We know, $V_h = -\frac{GM}{(R+h)}$,

$$g_h = \frac{GM}{(R+h)^2} = -\frac{V_h}{R+h} \Rightarrow R + h = -\frac{V_h}{g_h}$$

$$\therefore \quad h = -\frac{V_h}{g_h} - R = -\frac{(-5.4 \times 10^7)}{6} - 6.4 \times 10^6$$

$= 9 \times 10^6 - 6.4 \times 10^6 = 2600$ km

6. **(d) :** As escape velocity, $v = \sqrt{\frac{2GM}{R}}$

$$= \sqrt{\frac{2G}{R} \cdot \frac{4\pi R^3}{3}\rho} = R\sqrt{\frac{8\pi G}{3}\rho}$$

$$\therefore \quad \frac{v_e}{v_p} = \frac{R_e}{R_p} \times \sqrt{\frac{\rho_e}{\rho_p}} = \frac{1}{2} \times \sqrt{\frac{1}{2}} = \frac{1}{2\sqrt{2}}$$

($\because R_p = 2R_e$ and $\rho_p = 2\rho_e$)

7. **(c) :** The orbital speed of the satellite is

$$v_o = R\sqrt{\frac{g}{(R+h)}}$$

where R is the earth's radius, g is the acceleration due to gravity on earth's surface and h is the height above the surface of earth.

Here, $R = 6.38 \times 10^6$ m, $g = 9.8$ m s^{-2} and $h = 0.25 \times 10^6$ m

$$\therefore v_o = (6.38 \times 10^6 \text{ m})\sqrt{\frac{(9.8 \text{ m s}^{-2})}{(6.38 \times 10^6 \text{ m} + 0.25 \times 10^6 \text{ m})}}$$

$= 7.76 \times 10^3$ m s^{-1} $= 7.76$ km s^{-1}

8. **(b) :** The gravitational force on the satellite S acts towards the centre of the earth, so the acceleration of the satellite S is always directed towards the centre of the earth.

9. **(d) :** Gravitational force of attraction between sun and planet provides centripetal force for the orbit of planet.

$\therefore \quad \dfrac{GMm}{r^2} = \dfrac{mv^2}{r}; \; v^2 = \dfrac{GM}{r}$ ...(i)

Time period of the planet is given by

$T = \dfrac{2\pi r}{v}, \quad T^2 = \dfrac{4\pi^2 r^2}{v^2} = \dfrac{4\pi^2 r^2}{\left(\dfrac{GM}{r}\right)}$ (Using (i))

$T^2 = \dfrac{4\pi^2 r^3}{GM}$ ...(ii)

According to question,

$T^2 = Kr^3$ ...(iii)

Comparing equations (ii) and (iii), we get

$K = \dfrac{4\pi^2}{GM} \quad \therefore \; GMK = 4\pi^2$

10. (a)

11. (c) : Light cannot escape from a black hole,

$v_{esc} = c$

$\sqrt{\dfrac{2GM}{R}} = c \quad \text{or} \quad R = \dfrac{2GM}{c^2}$

$$R = \frac{2 \times 6.67 \times 10^{-11}\ \text{N m}^2\text{kg}^{-2} \times 5.98 \times 10^{24}\text{kg}}{(3 \times 10^8\ \text{m s}^{-1})^2}$$

$= 8.86 \times 10^{-3}\ \text{m} \approx 10^{-2}\ \text{m}$

12. (a) : For a point inside the earth *i.e.* $r < R$

$E = -\dfrac{GM}{R^3} r$

where M and R be mass and radius of the earth respectively.

At the centre, $r = 0$

$\therefore \quad E = 0$

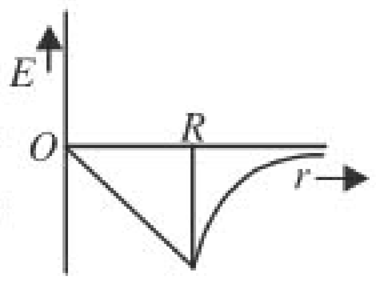
For a point outside the earth *i.e.* $r > R$,

$E = -\dfrac{GM}{r^2}$

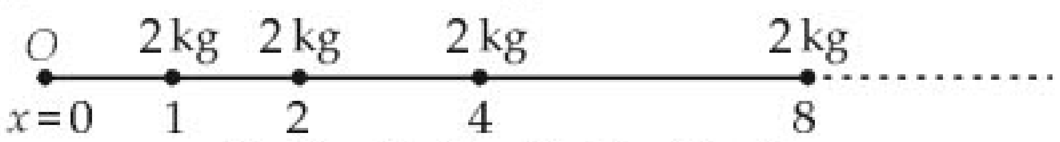
On the surface of the earth *i.e.* $r = R$,

$E = -\dfrac{GM}{R^2}$

The variation of E with distance r from the centre is as shown in the figure.



13. (b) : The resulting gravitational potential at the origin O due to each of mass 2 kg located at positions as shown in figure is



$V = -\dfrac{G \times 2}{1} - \dfrac{G \times 2}{2} - \dfrac{G \times 2}{4} - \dfrac{G \times 2}{8} - ...$

$= -2G\left[1 + \dfrac{1}{2} + \dfrac{1}{4} + \dfrac{1}{8} + ...\right] = -2G\left[\dfrac{1}{1 - \dfrac{1}{2}}\right]$

$= -2G\left[\dfrac{2}{1}\right] = -4G$

14. (d) : Gravitational potential energy at any point at a distance r from the centre of the earth is

$U = -\dfrac{GMm}{r}$

where M and m be masses of the earth and the body respectively.

At the surface of the earth, $r = R$

$\therefore \quad U_i = -\dfrac{GMm}{R}$

At a height h from the surface,

$r = R + h = R + 2R$ $\quad (h = 2R \text{ (Given)})$

$= 3R$

$\therefore \quad U_f = -\dfrac{GMm}{3R}$

Change in potential energy,

$\Delta U = U_f - U_i$

$= -\dfrac{GMm}{3R} - \left(-\dfrac{GMm}{R}\right) = \dfrac{GMm}{R}\left(1 - \dfrac{1}{3}\right)$

$= \dfrac{2}{3}\dfrac{GMm}{R} = \dfrac{2}{3} mgR \qquad \left(\because g = \dfrac{GM}{R^2}\right)$

15. (b) : Here, $R_P = 2R_E$, $\rho_E = \rho_P$

Escape velocity of the earth,

$V_E = \sqrt{\dfrac{2GM_E}{R_E}} = \sqrt{\dfrac{2G}{R_E}\left(\dfrac{4}{3}\pi R_E^3 \rho_E\right)} = R_E\sqrt{\dfrac{8}{3}\pi G \rho_E}$ ...(i)

Escape velocity of the planet

$V_P = \sqrt{\dfrac{2GM_P}{R_P}} = \sqrt{\dfrac{2G}{R_P}\left(\dfrac{4}{3}\pi R_P^3 \rho_P\right)} = R_P\sqrt{\dfrac{8}{3}\pi G \rho_P}$ ...(ii)

Divide (i) by (ii), we get

$\dfrac{V_E}{V_P} = \dfrac{R_E}{R_P}\sqrt{\dfrac{\rho_E}{\rho_P}} = \dfrac{R_E}{2R_E}\sqrt{\dfrac{\rho_E}{\rho_E}} = \dfrac{1}{2}$

or $\quad V_P = 2V_E$

16. (a) : The minimum speed with which the particle should be projected from the surface of the earth so that it does not return back is known as escape speed and it is given by

$v_e = \sqrt{\dfrac{2GM}{(R + h)}}$

Here, $h = 3R$

$$\therefore \quad v_e = \sqrt{\frac{2GM}{(R+3R)}} = \sqrt{\frac{2GM}{4R}} = \sqrt{\frac{GM}{2R}}$$

$$= \sqrt{\frac{gR}{2}} \qquad \left(\because g = \frac{GM}{R^2}\right)$$

17. (c) : Acceleration due to gravity at a height h from the surface of earth is

$$g' = \frac{g}{\left(1+\frac{h}{R}\right)^2} \qquad \text{....(i)}$$

where g is the acceleration due to gravity at the surface of earth and R is the radius of earth.
Multiplying by m (mass of the body) on both sides in (i), we get

$$mg' = \frac{mg}{\left(1+\frac{h}{R}\right)^2}$$

$\therefore$ Weight of body at height h, $W' = mg'$
Weight of body at surface of earth, $W = mg$
According to question, $W' = \frac{1}{16}W$

$$\therefore \quad \frac{1}{16} = \frac{1}{\left(1+\frac{h}{R}\right)^2}$$

$$\left(1+\frac{h}{R}\right)^2 = 16 \quad \text{or} \quad 1+\frac{h}{R} = 4$$

or $\quad \frac{h}{R} = 3 \quad$ or $\quad h = 3R$

18. (a) : Gravitational force acting on particle of mass m is

$$F = \frac{GM_p m}{(D_p/2)^2}$$

Acceleration due to gravity experience by the particle is

$$g = \frac{F}{m} = \frac{GM_p}{(D_p/2)^2} = \frac{4GM_p}{D_p^2}$$

19. (c) : According to Kepler's third law $T \propto r^{3/2}$

$$\therefore \quad \frac{T_2}{T_1} = \left(\frac{r_2}{r_1}\right)^{3/2} = \left(\frac{R+2R}{R+5R}\right)^{3/2} = \frac{1}{2^{3/2}}$$

Since $T_1 = 24$ hours

So, $\frac{T_2}{24} = \frac{1}{2^{3/2}}$ or $T_2 = \frac{24}{2^{3/2}} = \frac{24}{2\sqrt{2}} = 6\sqrt{2}$ hours

20. (d) : Escape velocity, $v_e = \sqrt{\frac{2GM}{R}}$ ...(i)

where M and R be the mass and radius of the earth respectively.
The orbital velocity of a satellite close to the earth's surface is

$$v_o = \sqrt{\frac{GM}{R}} \qquad \text{...(ii)}$$

From (i) and (ii), we get

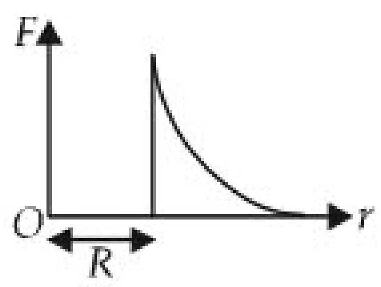
$$v_e = \sqrt{2}v_o$$

21. (b) : Gravitational field due to the thin spherical shell
Inside the shell, *i.e.* (For $r < R$)
$F = 0$
On the surface of the shell, *i.e.* (For $r = R$)

$$F = \frac{GM}{R^2}$$

Outside the shell, *i.e.* (For $r > R$)

$$F = \frac{GM}{r^2}$$



The variation of F with distance r from the centre is as shown in the adjacent figure.

22. (b) : According to the law of conservation of angular momentum

$$L_1 = L_2$$

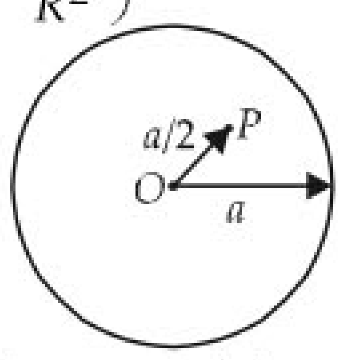
$$mv_1r_1 = mv_2r_2 \Rightarrow v_1r_1 = v_2r_2 \quad \text{or} \quad \frac{v_1}{v_2} = \frac{r_2}{r_1}$$

23. (b) : According to law of conservation of mechanical energy

$$\frac{1}{2}mu^2 - \frac{GMm}{R} = 0 \quad \text{or} \quad u^2 = \frac{2GM}{R}$$

$$u = \sqrt{\frac{2GM}{R}} = \sqrt{2gR} \qquad \left(\because g = \frac{GM}{R^2}\right)$$

24. (c) : Here,
Mass of a particle $= M$
Mass of a spherical shell $= M$
Radius of a spherical shell $= a$
Let O be centre of a spherical shell.



Gravitational potential at point P due to particle at O is

$$V_1 = -\frac{GM}{a/2}$$

Gravitational potential at point P due to spherical shell is

$$V_2 = -\frac{GM}{a}$$

Hence, total gravitational potential at point P is

$$V = V_1 + V_2$$

$$= -\frac{GM}{a/2} + \left(\frac{-GM}{a}\right) = -\frac{2GM}{a} - \frac{GM}{a} = -\frac{3GM}{a}$$

$$|V| = \frac{3GM}{a}$$

25. (b) : Orbital speed of the satellite around the earth is

$$v = \sqrt{\frac{GM}{r}}$$

For satellite A

$$r_A = 4R,\ v_A = 3V$$

$$v_A = \sqrt{\frac{GM}{r_A}} \quad \text{...(i)}$$

For satellite B

$$r_B = R,\ v_B = ?$$

$$v_B = \sqrt{\frac{GM}{r_B}} \quad \text{...(ii)}$$

Dividing equation (ii) by equation (i), we get

$$\therefore \frac{v_B}{v_A} = \sqrt{\frac{r_A}{r_B}} \text{ or } v_B = v_A\sqrt{\frac{r_A}{r_B}}$$

Substituting the given values, we get

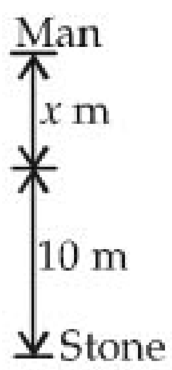
$$v_B = 3V\sqrt{\frac{4R}{R}} \text{ or } v_B = 6V$$

26. (b) : Since the man is in gravity free space, force on man + stone system is zero.
Therefore centre of mass of the system remains at rest. Let the man goes x m above when the stone reaches the floor, then

$$M_{\text{man}} \times x = M_{\text{stone}} \times 10$$

$$x = \frac{0.5}{50} \times 10$$

$$x = 0.1 \text{ m}$$



Therefore final height of man above floor $= 10 + x = 10 + 0.1 = 10.1$ m

27 (d)

28. (a) : The acceleration due to gravity at a depth d below surface of earth is

$$g' = \frac{GM}{R^2}\left(1 - \frac{d}{R}\right) = g\left(1 - \frac{d}{R}\right)$$

$$g' = 0 \text{ at } d = R.$$

i.e., acceleration due to gravity is zero at the centre of earth.
Thus, the variation in value g with r is

For, $r > R$,

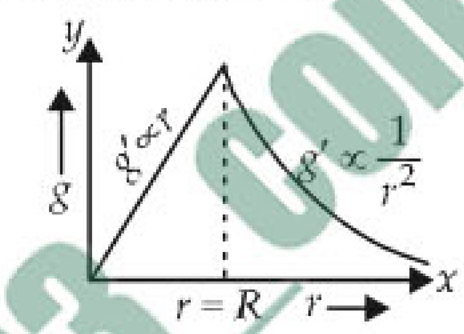
$$g' = \frac{g}{\left(1 + \frac{h}{R}\right)^2} = \frac{gR^2}{r^2} \Rightarrow g' \propto \frac{1}{r^2}$$

Here, $R + h = r$

$$\text{For } r < R,\ g' = g\left(1 - \frac{d}{R}\right) = \frac{gr}{R}$$

Here, $R - d = r \Rightarrow g' \propto r$

Therefore, the variation of g with distance from centre of the earth will be as shown in the figure.



29. (a)

30. (b) : Equal areas are swept in equal time.
t_1, the time taken to go from C to $D = 2t_2$
where t_2 is the time taken to go from A to B.
As it is given that area $SCD = 2SAB$.

31. (b) : The satellite of mass m is moving in a circular orbit of radius r.

$$\therefore \text{ Kinetic energy of the satellite, } K = \frac{GMm}{2r} \quad \text{... (i)}$$

$$\text{Potential energy of the satellite, } U = \frac{-GMm}{r} \quad \text{... (ii)}$$

$$\text{Orbital speed of satellite, } v = \sqrt{\frac{GM}{r}} \quad \text{... (iii)}$$

$$\text{Time-period of satellite, } T = \left[\left(\frac{4\pi^2}{GM}\right)r^3\right]^{1/2} \quad \text{... (iv)}$$

Given $m_{S_1} = 4m_{S_2}$
Since M, r is same for both the satellites S_1 and S_2
$\therefore$ From equation (ii), we get $U \propto m$

$$\therefore \frac{U_{S_1}}{U_{S_2}} = \frac{m_{S_1}}{m_{S_2}} = 4 \text{ or, } U_{S_1} = 4U_{S_2}.$$

Option (a) is wrong.
From (iii), since v is independent of the mass of a satellite, the orbital speed is same for both satellites S_1 and S_2.
Hence option (b) is correct.
From (i), we get $K \propto m$

$$\therefore \frac{K_{S_1}}{K_{S_2}} = \frac{m_{S_1}}{m_{S_2}} = 4 \text{ or, } K_{S_1} = 4K_{S_2}.$$

Hence option (c) is wrong.
From (iv), since T is independent of the mass of a satellite, time period is same for both the satellites S_1 and S_2. Hence option (d) is wrong.

32. (c) : Escape velocity of the body from the surface of earth is $v = \sqrt{2gR}$

For escape velocity of the body from the platform potential energy + kinetic energy = 0

$$-\frac{GMm}{2R} + \frac{1}{2}mv^2 = 0$$

$$\Rightarrow \quad fv_{escape} = \sqrt{\frac{GM}{R^2} \cdot R} = \sqrt{gR} = fv$$

From the surface of the earth, $v_{\text{escape}} = \sqrt{2gR}$

$$\therefore \quad fv_{\text{escape}} = \frac{v_{\text{escape}}}{\sqrt{2}} \quad \therefore \quad f = \frac{1}{\sqrt{2}}.$$

33. (d) : $g = \frac{GM}{r^2} = \frac{G}{r^2}\left(\frac{4}{3} \times r^3 \rho\right) = \frac{4}{3} \times \rho G r$

$$\frac{g'}{g} = \frac{3R}{R} \Rightarrow g' = 3g.$$

34. (a) : $-\frac{GMm}{R^2} + m\omega^2 R = 0$

$$\therefore \quad \frac{GMm}{R^2} = m\omega^2 R$$

$$K.E. = \frac{1}{2}I\omega^2 = \frac{1}{2}mR^2\omega^2 = \frac{GMm}{2R}$$

$$P.E. = -\frac{GMm}{R}.$$

$$\therefore \quad K.E. = \frac{|P.E.|}{2} \quad \text{or,} \quad \frac{K.E.}{|P.E.|} = \frac{1}{2}$$

35. (d) : From equation of acceleration due to gravity.

$$g_e = \frac{GM_e}{R_e^2} = \frac{G(4/3)\pi R_e^3}{R_e^2}\rho_e$$

$$g_e \propto R_e \rho_e$$

Acceleration due to gravity of planet $g_p \propto R_p \rho_p$

$R_e\rho_e = R_p\rho_p \Rightarrow R_e\rho_e = R_p 2\rho_e \Rightarrow R_p = \frac{1}{2}R$
$(\because R_e = R)$

36. (b) : The gravitational force does not depend upon the medium in which objects are placed.

37. (b) : The velocity of the mass while reaching the surface of both the planets will be same.

i.e., $\sqrt{2g'h'} = \sqrt{2gh}$

$$\sqrt{2 \times g \times h'} = \sqrt{2 \times 9g \times 2} \qquad 2h' = 36 \Rightarrow h' = 18 \text{ m.}$$

38. (c) : Gravitational potential energy on earth's surface $= -\frac{GMm}{R}$, where M and R are the mass and radius of the earth respectively, m is the mass of the body and G is the universal gravitational constant.

Gravitational potential energy at a height $h = 3R$

$$= -\frac{GMm}{R+h} = -\frac{GMm}{R+3R} = -\frac{GMm}{4R}$$

$\therefore$ Change in potential energy

$$= -\frac{GMm}{4R} - \left(-\frac{GMm}{R}\right)$$

$$= -\frac{GMm}{4R} + \frac{GMm}{R} = \frac{3}{4}\frac{GMm}{R} = \frac{3}{4}mgR$$

39. (a) : Use $v^2 = \frac{2gh}{1+\frac{h}{R}}$ given $h = R$.

$$\therefore \quad v = \sqrt{gR} = \sqrt{\frac{GM}{R}}.$$

40. (b) : $v_e = \sqrt{2gR} = \sqrt{\frac{2GM}{R}}$

If R is 1/4th then $v_e = 2\, v_{e\text{-earth}}$
$= 2 \times 11.2 = 22.4$ km/sec.

41. (b)

42. (b) : $F_{\text{surface}} = G\frac{Mm}{R_e^2}$

$$F_{R_e/2} = G\frac{Mm}{(R_e + R_e/2)^2} = \frac{4}{9} \times F_{\text{surface}} = \frac{4}{9} \times 72 = 32 \text{ N.}$$

43. (b)

44. (a) : Escape velocity of a body $(v_e) = 11.2$ km/s; New mass of the earth $M'_e = 2M_e$ and new radius of the earth $R'_e = 0.5\,R_e$.

Escape velocity $(v_e) = \sqrt{\frac{2GM_e}{R_e}} \propto \sqrt{\frac{M_e}{R_e}}$.

Therefore $\frac{v_e}{v'_e} = \sqrt{\frac{M_e}{R_e} \times \frac{0.5R_e}{2M_e}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$

or, $v'_e = 2v_e = 22.4$ km/sec.

45. (a) : Period of revolution of planet A $(T_A) = 8T_B$.
According to Kepler's III law of planetary motion $T^2 \propto R^3$.

Therefore $\left(\frac{r_A}{r_B}\right)^3 = \left(\frac{T_A}{T_B}\right)^2 = \left(\frac{8T_B}{T_B}\right)^2 = 64$

or $\frac{r_A}{r_B} = 4$ or $r_A = 4r_B$.

46. (b)

47. (c) : Since no external torque is applied therefore, according to law of conservation of angular momentum, the ball will continue to move with the same angular velocity along the original orbit of the spacecraft.

48. (a) : Acceleration due to gravity $(g) = G \times \frac{M}{R^2}$

$= G\frac{(4/3)\pi R^3 \times \rho}{R^2} = G \times \frac{4}{3}\pi R \times \rho$ or $\rho = \frac{3g}{4\pi GR}$

49. (d) : The two masses, separated by a distance $2R$ are going round their common centre of mass, the centre of the circle.

Attractive force $= -G\frac{mm}{4R^2}$. But the two masses are going round the centre of mass or the reduced mass $\mu = \frac{mm}{m+m}$ is going round a circle of radius = distance of separation

$\therefore$ Centrifugal force $= \frac{m}{2}\omega^2 . 2R = \frac{m}{2}v^2 . \frac{1}{2R}$

Now, $\frac{m}{2} \times \frac{v^2}{2R} = \frac{Gm^2}{4R^2} \Rightarrow v = \sqrt{\frac{Gm}{R}}$

50. (a) : Mass $(m) = 6 \times 10^{24}$ kg;
Angular velocity $(\omega) = 2 \times 10^{-7}$ rad/s and radius $(r) = 1.5 \times 10^8$ km $= 1.5 \times 10^{11}$ m.
Force exerted on the earth $= mR\omega^2$

$= (6 \times 10^{24}) \times (1.5 \times 10^{11}) \times (2 \times 10^{-7})^2$
$= 36 \times 10^{21}$ N.

51. (c) : Radius of earth $(R_e) = 6400$ km; Radius of mars $(R_m) = 3200$ km; Mass of earth $(M_e) = 10$ Mm and weight of the object on earth $(W_e) = 200$ N.

$$\frac{W_m}{W_e} = \frac{mg_m}{mg_e} = \frac{M_m}{M_e} \times \left(\frac{R_e}{R_m}\right)^2 = \frac{1}{10} \times (2)^2 = \frac{2}{5}$$

or $W_m = W_e \times \frac{2}{5} = 200 \times 0.4 = 80$ N.

52. (b) : Distance of two planets from sun, $r_1 = 10^{13}$ m and $r_2 = 10^{12}$ m.
Relation between time period (T) and distance of the planet from the sun is $T^2 \propto r^3$ or $T \propto r^{3/2}$.

Therefore $\frac{T_1}{T_2} = \left(\frac{r_1}{r_2}\right)^{3/2} = \left(\frac{10^{13}}{10^{12}}\right)^{3/2} = 10^{3/2} = 10\sqrt{10}$.

53. (b) : Centripetal force $(F) = \frac{mv^2}{R}$ and the gravitational force $(F) = \frac{GMm}{R^2} = \frac{GMm}{R}$ (where $R^2 \to R$). Since $\frac{mv^2}{R} = \frac{GMm}{R}$, therefore $v = \sqrt{GM}$.
Thus velocity v is independent of R.

54. (d) : Rate of change of mass $\frac{dM}{dt} = \alpha v$.
Retarding force = Rate of change of momentum
= Velocity $\times$ Rate of change in mass $= -v \times \frac{dM}{dt}$
$= -v \times \alpha v = -\alpha v^2$. (Minus sign of v due to deceleration)
Therefore, acceleration $= -\frac{\alpha v^2}{M}$.

55. (b) : Escape velocity does not depend on the angle of projection.

56. (d) : Time period does not depend on the mass.
As $T^2 \propto r^3$.

$\frac{T_A}{T_B} = \frac{r^{3/2}}{2^{3/2} r^{3/2}} = 1 : 2\sqrt{2}$

57. (a) : $\frac{GMm}{r^2} = m\omega^2 r \Rightarrow r^3 = \frac{GM}{\omega^2} = \frac{gR^2}{\omega^2}$
$\therefore r = (gR^2/\omega^2)^{1/3}$.

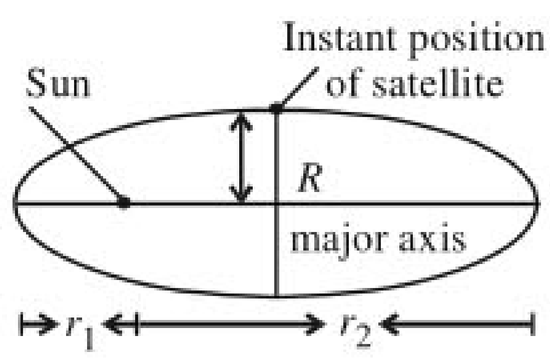
58. (d) : Total energy = –K.E. $= -\frac{1}{2}mv^2$

59. (c) : In a circular or elliptical orbital motion torque is always acting parallel to displacement or velocity. So, angular momentum is conserved. In attractive field, potential energy is negative. Kinetic energy changes as velocity increase when distance is less. But if the motion is in a plane, the direction of L does not change.

60. (a) : Since escape velocity $\left(v_e = \sqrt{2gR_e}\right)$ is independent of angle of projection, so it will not change.

61. (c) : Applying the properties of ellipse, we have

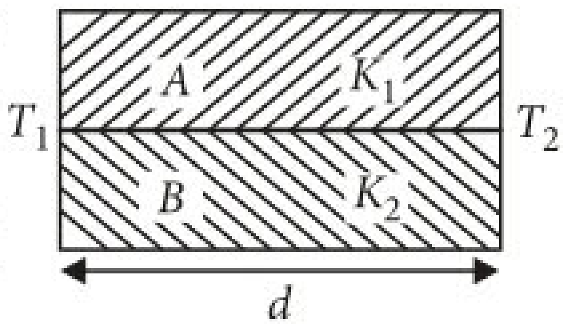
$$\frac{2}{R} = \frac{1}{r_1} + \frac{1}{r_2} = \frac{r_1 + r_2}{r_1 r_2} \quad 1$$



$$R = \frac{2r_1 r_2}{r_1 + r_2}$$

Chapter 8 Properties of Matter

1. Two rods A and B of different materials are welded together as shown in figure. Their thermal conductivities are K_1 and K_2. The thermal conductivity of the composite rod will be



(a) $\frac{3(K_1+K_2)}{2}$ (b) K_1+K_2

(c) $2(K_1+K_2)$ (d) $\frac{K_1+K_2}{2}$

(NEET 2017)

2. A spherical black body with a radius of 12 cm radiates 450 watt power at 500 K. If the radius were halved and the temperature doubled, the power radiated in watt would be

(a) 450 (b) 1000 (c) 1800 (d) 225

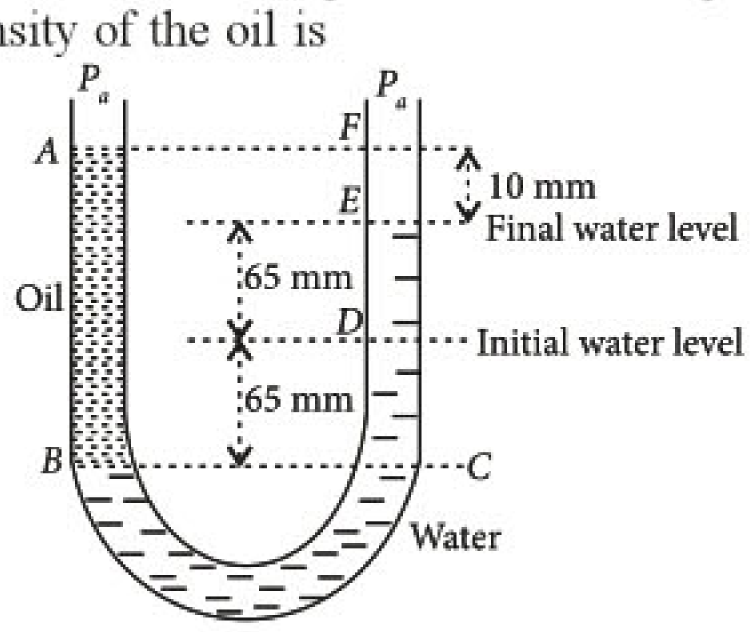
(NEET 2017)

3. The bulk modulus of a spherical object is 'B'. If it is subjected to uniform pressure 'p', the fractional decrease in radius is

(a) $\frac{B}{3p}$ (b) $\frac{3p}{B}$ (c) $\frac{p}{3B}$ (d) $\frac{p}{B}$

(NEET 2017)

4. A U tube with both ends open to the atmosphere, is partially filled with water. Oil, which is immiscible with water, is poured into one side until it stands at a distance of 10 mm above the water level on the other side. Meanwhile the water rises by 65 mm from its original level (see diagram). The density of the oil is



(a) $425\ kg\ m^{-3}$ (b) $800\ kg\ m^{-3}$

(c) $928\ kg\ m^{-3}$ (d) $650\ kg\ m^{-3}$

(NEET 2017)

5. A rectangular film of liquid is extended from (4 cm × 2 cm) to (5 cm × 4 cm). If the work done is 3×10^{-4} J, the value of the surface tension of the liquid is

(a) $0.250\ N\ m^{-1}$ (b) $0.125\ N\ m^{-1}$

(c) $0.2\ N\ m^{-1}$ (d) $8.0\ N\ m^{-1}$

(NEET-II 2016)

6. Three liquids of densities ρ_1, ρ_2 and ρ_3 (with $\rho_1 > \rho_2 > \rho_3$), having the same value of surface tension T, rise to the same height in three identical capillaries. The angles of contact θ_1, θ_2 and θ_3 obey

(a) $\frac{\pi}{2} > \theta_1 > \theta_2 > \theta_3 \geq 0$

(b) $0 \leq \theta_1 < \theta_2 < \theta_3 < \frac{\pi}{2}$

(c) $\frac{\pi}{2} < \theta_1 < \theta_2 < \theta_3 < \pi$

(d) $\pi > \theta_1 > \theta_2 > \theta_3 > \frac{\pi}{2}$ *(NEET-II 2016)*

7. Two identical bodies are made of a material for which the heat capacity increases with temperature. One of these is at 100 °C, while the other one is at 0 °C. If the two bodies are brought into contact, then, assuming no heat loss, the final common temperature is

(a) 50 °C

(b) more than 50 °C

(c) less than 50 °C but greater than 0 °C

(d) 0 °C *(NEET-II 2016)*

8. A body cools from a temperature $3T$ to $2T$ in 10 minutes. The room temperature is T. Assume that Newton's law of cooling is applicable. The temperature of the body at the end of next 10 minutes will be

(a) $\frac{7}{4}T$ (b) $\frac{3}{2}T$ (c) $\frac{4}{3}T$ (d) T

(NEET-II 2016)

9. Coefficient of linear expansion of brass and steel rods are α_1 and α_2. Lengths of brass and steel rods are l_1 and l_2 respectively. If $(l_2 - l_1)$ is maintained same at all temperatures, which one of the following relations holds good?

(a) $\alpha_1^2 l_2 = \alpha_2^2 l_1$ (b) $\alpha_1 l_1 = \alpha_2 l_2$
(c) $\alpha_1 l_2 = \alpha_2 l_1$ (d) $\alpha_1 l_2^2 = \alpha_2 l_1^2$

(NEET-I 2016, 1999)

10. A piece of ice falls from a height h so that it melts completely. Only one-quarter of the heat produced is absorbed by the ice and all energy of ice gets converted into heat during its fall. The value of h is [Latent heat of ice is 3.4×10^5 J/ kg and $g = 10$ N/kg]

(a) 136 km (b) 68 km
(c) 34 k m (d) 544 km

(NEET-I 2016)

11. A black body is at a temperature of 5760 K. The energy of radiation emitted by the body at wavelength 250 nm is U_1, at wavelength 500 nm is U_2 and that at 1000 nm is U_3. Wien's constant, $b = 2.88 \times 10^6$ nm K. Which of the following is correct?

(a) $U_1 > U_2$ (b) $U_2 > U_1$
(c) $U_1 = 0$ (d) $U_3 = 0$

(NEET-I 2016)

12. Two non-mixing liquids of densities ρ and $n\rho$ $(n > 1)$ are put in a container. The height of each liquid is h. A solid cylinder of length L and density d is put in this container. The cylinder floats with its axis vertical and length pL $(p < 1)$ in the denser liquid. The density d is equal to

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

(NEET-I 2016)

13. The cylindrical tube of a spray pump has radius R, one end of which has n fine holes, each of radius r. If the speed of the liquid in the tube is V, the speed of the ejection of the liquid through the holes is

(a) $\dfrac{VR^2}{n^3r^2}$ (b) $\dfrac{V^2R}{nr}$ (c) $\dfrac{VR^2}{n^2r^2}$ (d) $\dfrac{VR^2}{nr^2}$

(2015)

14. Water rises to a height h in capillary tube. If the length of capillary tube above the surface of water is made less than h, then

(a) water rises upto a point a little below the top and stays there.
(b) water does not rise at all.
(c) water rises upto the tip of capillary tube and then starts overflowing like a fountain.
(d) water rises upto the top of capillary tube and stays there without overflowing.

(2015)

15. The value of coefficient of volume expansion of glycerin is 5×10^{-4} K^{-1}. The fractional change in the density of glycerin for a rise of 40°C in its temperature, is

(a) 0.025 (b) 0.010 (c) 0.015 (d) 0.020

(2015)

16. The Young's modulus of steel is twice that of brass. Two wires of same length and of same area of cross section, one of steel and another of brass are suspended from the same roof. If we want the lower ends of the wires to be at the same level, then the weights added to the steel and brass wires must be in the ratio of

(a) 4 : 1 (b) 1 : 1 (c) 1 : 2 (d) 2 : 1

(2015)

17. The two ends of a metal rod are maintained at temperatures 100°C and 110°C. The rate of heat flow in the rod is found to be 4.0 J/s. If the ends are maintained at temperatures 200°C and 210°C, the rate of heat flow will be

(a) 8.0 J/s (b) 4.0 J/s
(c) 44.0 J/s (d) 16.8 J/s

(2015 Cancelled)

18. A wind with speed 40 m/s blows parallel to the roof of a house. The area of the roof is 250 m^2. Assuming that the pressure inside the house is atmospheric pressure, the force exerted by the wind on the roof and the direction of the force will be $(\rho_{air} = 1.2$ kg/m$^3)$

(a) 2.4×10^5 N, upwards
(b) 2.4×10^5 N, downwards
(c) 4.8×10^5 N, downwards
(d) 4.8×10^5 N, upwards *(2015 Cancelled)*

19. On observing light from three different stars P, Q and R, it was found that intensity of violet colour is maximum in the spectrum of P, the intensity of green colour is maximum in the spectrum of R and the intensity of red colour is maximum in the spectrum of Q. If T_P, T_Q and T_R are the respective absolute temperatures of P, Q and R, then it can be concluded from the above observations that

(a) $T_P < T_R < T_Q$ (b) $T_P < T_Q < T_R$
(c) $T_P > T_Q > T_R$ (d) $T_P > T_R > T_Q$

(2015 Cancelled)

20. The approximate depth of an ocean is 2700 m. The compressibility of water is 45.4×10^{-11} Pa^{-1} and density of water is 10^3 kg/m^3. What fractional compression of water will be obtained at the bottom of the ocean?
(a) 1.2×10^{-2} (b) 1.4×10^{-2}
(c) 0.8×10^{-2} (d) 1.0×10^{-2}
(2015 Cancelled)

21. Copper of fixed volume V is drawn into wire of length l. When this wire is subjected to a constant force F, the extension produced in the wire is Δl. Which of the following graphs is a straight line?
(a) Δl versus $1/l$ (b) Δl versus l^2
(c) Δl versus $1/l^2$ (d) Δl versus l *(2014)*

22. A certain number of spherical drops of a liquid of radius r coalesce to form a single drop of radius R and volume V. If T is the surface tension of the liquid, then
(a) energy $= 4VT\left(\frac{1}{r} - \frac{1}{R}\right)$ is released.
(b) energy $= 3VT\left(\frac{1}{r} + \frac{1}{R}\right)$ is absorbed.
(c) energy $= 3VT\left(\frac{1}{r} - \frac{1}{R}\right)$ is released.
(d) energy is neither released nor absorbed.
(2014)

23. Steam at 100°C is passed into 20 g of water at 10°C. When water acquires a temperature of 80°C, the mass of water present will be
[Take specific heat of water = 1 cal g^{-1} °C^{-1} and latent heat of steam = 540 cal g^{-1}]
(a) 24 g (b) 31.5 g (c) 42.5 g (d) 22.5 g
(2014)

24. Certain quantity of water cools from 70°C to 60°C in the first 5 minutes and to 54°C in the next 5 minutes. The temperature of the surroundings is
(a) 45°C (b) 20°C (c) 42°C (d) 10°C
(2014)

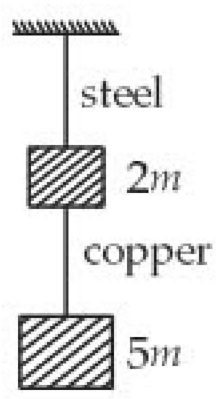
25. A piece of iron is heated in a flame. It first becomes dull red then becomes reddish yellow and finally turns to white hot. The correct explanation for the above observation is possible by using
(a) Kirchhoff's Law
(b) Newton's Law of cooling
(c) Stefan's Law
(d) Wien's displacement Law *(NEET 2013)*

26. The wettability of a surface by a liquid depends primarily on
(a) density
(b) angle of contact between the surface and the liquid
(c) viscosity
(d) surface tension *(NEET 2013)*

27. The following four wires are made of the same material. Which of these will have the largest extension when the same tension is applied?
(a) length = 200 cm, diameter = 2 mm
(b) length = 300 cm, diameter = 3 mm
(c) length = 50 cm, diameter = 0.5 mm
(d) length = 100 cm, diameter = 1 mm
(NEET 2013)

28. The molar specific heats of an ideal gas at constant pressure and volume are denoted by C_p and C_v respectively. If $\gamma = \frac{C_p}{C_v}$ and R is the universal gas constant, then C_v is equal to
(a) $\frac{(\gamma - 1)}{R}$ (b) γR
(c) $\frac{1+\gamma}{1-\gamma}$ (d) $\frac{R}{(\gamma - 1)}$ *(NEET 2013)*

29. If the ratio of diameters, lengths and Young's modulus of steel and copper wires shown in the figure are p, q and s respectively, then the corresponding ratio of increase in their lengths would be



(a) $\frac{5q}{(7sp^2)}$ (b) $\frac{7q}{(5sp^2)}$
(c) $\frac{2q}{(5sp)}$ (d) $\frac{7q}{(5sp)}$
(Karnataka NEET 2013)

30. Two metal rods 1 and 2 of same lengths have same temperature difference between their ends. Their thermal conductivities are K_1 and K_2 and cross sectional areas A_1 and A_2, respectively. If the rate of heat conduction in 1 is four times that in 2, then
(a) $K_1A_1 = 4K_2A_2$ (b) $K_1A_1 = 2K_2A_2$
(c) $4K_1A_1 = K_2A_2$ (d) $K_1A_1 = K_2A_2$
(Karnataka NEET 2013)

31. A fluid is in streamline flow across a horizontal pipe of variable area of cross section. For this which of the following statements is correct?

(a) The velocity is maximum at the narrowest part of the pipe and pressure is maximum at the widest part of the pipe.
(b) Velocity and pressure both are maximum at the narrowest part of the pipe.
(c) Velocity and pressure both are maximum at the widest part of the pipe.
(d) The velocity is minimum at the narrowest part of the pipe and the pressure is minimum at the widest part of the pipe.
(Karnataka NEET 2013)

32. The density of water at 20°C is 998 kg/m^3 and at 40°C is 992 kg/m^3. The coefficient of volume expansion of water is
(a) 3×10^{-4}/°C (b) 2×10^{-4}/°C
(c) 6×10^{-4}/°C (d) 10^{-4}/°C
(Karnataka NEET 2013)

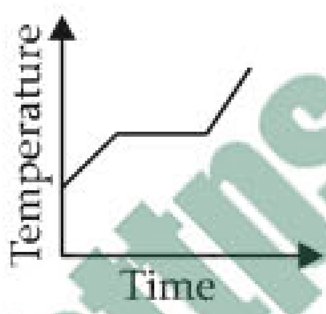
33. If the radius of a star is R and it acts as a black body, what would be the temperature of the star, in which the rate of energy production is Q?

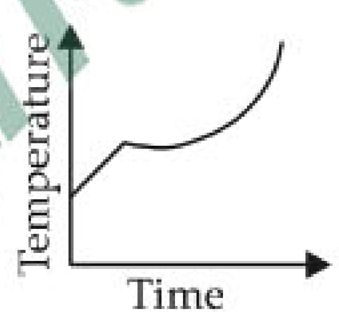
(a) $\dfrac{Q}{4\pi R^2\sigma}$ (b) $\left(\dfrac{Q}{4\pi R^2\sigma}\right)^{-1/2}$

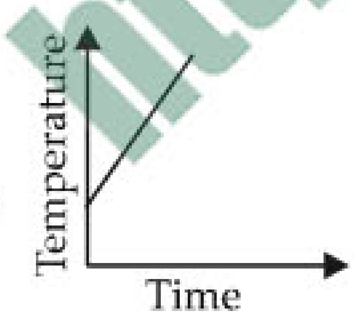
(c) $\left(\dfrac{4\pi R^2 Q}{\sigma}\right)^{1/4}$ (d) $\left(\dfrac{Q}{4\pi R^2\sigma}\right)^{1/4}$

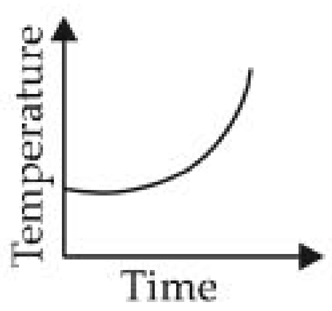
(σ stands for Stefan's constant) *(2012)*

34. Liquid oxygen at 50 K is heated to 300 K at constant pressure of 1 atm. The rate of heating is constant. Which one of the following graphs represents the variation of temperature with time?

(a) 

(b) 

(c) 

(d) 

(2012)

35. A slab of stone of area 0.36 m^2 and thickness 0.1 m is exposed on the lower surface to steam at 100°C. A block of ice at 0°C rests on the upper surface of the slab. In one hour 4.8 kg of ice is melted. The thermal conductivity of slab is
(Given latent heat of fusion of ice $= 3.36 \times 10^5$ J kg^{-1})
(a) 1.24 J/m/s/°C (b) 1.29 J/m/s/°C
(c) 2.05 J/m/s/°C (d) 1.02 J/m/s/°C
(Mains 2012)

36. A cylindrical metallic rod in thermal contact with two reservoirs of heat at its two ends conducts an amount of heat Q in time t. The metallic rod is melted and the material is formed into a rod of half the radius of the original rod. What is the amount of heat conducted by the new rod, when placed in thermal contact with the two reservoirs in time t?
(a) $\dfrac{Q}{4}$ (b) $\dfrac{Q}{16}$ (c) $2Q$ (d) $\dfrac{Q}{2}$
(2010)

37. The total radiant energy per unit area, normal to the direction of incidence, received at a distance R from the centre of a star of radius r, whose outer surface radiates as a black body at a temperature T K is given by

(a) $\dfrac{\sigma r^2 T^4}{R^2}$ (b) $\dfrac{\sigma r^2 T^4}{4\pi R^2}$

(c) $\dfrac{\sigma r^4 T^4}{R^4}$ (d) $\dfrac{4\pi\sigma r^2 T^4}{R^2}$

(where σ is Stefan's constant) *(2010)*

38. Assuming the sun to have a spherical outer surface of radius r, radiating like a black body at temperature t°C, the power received by a unit surface, (normal to the incident rays) at a distance R from the centre of the sun is

(a) $\dfrac{r^2\sigma(t+273)^4}{4\pi R^2}$ (b) $\dfrac{16\pi^2 r^2 \sigma t^4}{R^2}$

(c) $\dfrac{r^2\sigma(t+273)^4}{R^2}$ (d) $\dfrac{4\pi r^2 \sigma t^4}{R^2}$

where σ is the Stefan's constant.
(2010, 2007)

39. A black body at 227°C radiates heat at the rate of 7 cals/cm^{2}s. At a temperature of 727°C, the rate of heat radiated in the same units will be
(a) 50 (b) 112 (c) 80 (d) 60
(2009)

40. The two ends of a rod of length L and a uniform cross-sectional area A are kept at two temperatures T_1 and T_2 ($T_1 > T_2$). The rate of heat transfer, $\dfrac{dQ}{dt}$, through the rod in a steady state is given by

(a) $\dfrac{dQ}{dt} = \dfrac{k(T_1 - T_2)}{LA}$

(b) $\frac{dQ}{dt} = kLA(T_1 - T_2)$

(c) $\frac{dQ}{dt} = \frac{kA(T_1 - T_2)}{L}$

(d) $\frac{dQ}{dt} = \frac{kL(T_1 - T_2)}{A}$ *(2009)*

41. On a new scale of temperature (which is linear) and called the W scale, the freezing and boiling points of water are 39°W and 239°W respectively. What will be the temperature on the new scale, corresponding to a temperature of 39°C on the Celsius scale ?
(a) 200°W (b) 139°W
(c) 78°W (d) 117°W *(2008)*

42. A black body is at 727°C. It emits energy at a rate which is proportional to
(a) $(1000)^4$ (b) $(1000)^2$
(c) $(727)^4$ (d) $(727)^2$. *(2007)*

43. A black body at 1227°C emits radiations with maximum intensity at a wavelength of 5000 Å. If the temperature of the body is increased by 1000°C, the maximum intensity will be observed at
(a) 3000 Å (b) 4000 Å
(c) 5000 Å (d) 6000 Å. *(2006)*

44. Which of the following rods, (given radius r and length l) each made of the same material and whose ends are maintained at the same temperature will conduct most heat?
(a) $r = r_0$, $l = l_0$ (b) $r = 2r_0$, $l = l_0$
(c) $r = r_0$, $l = 2l_0$ (d) $r = 2r_0$, $l = 2l_0$. *(2005)*

45. If λ_m denotes the wavelength at which the radiative emission from a black body at a temperature T K is maximum, then
(a) $\lambda_m \propto T^4$ (b) λ_m is independent of T
(c) $\lambda_m \propto T$ (d) $\lambda_m \propto T^{-1}$ *(2004)*

46. Consider a compound slab consisting of two different materials having equal thicknesses and thermal conductivities K and $2K$, respectively. The equivalent thermal conductivity of the slab is
(a) $\frac{2}{3}K$ (b) $\sqrt{2}\,K$ (c) $3K$ (d) $\frac{4}{3}K$ *(2003)*

47. Unit of Stefan's constant is
(a) watt m^2 K^4 (b) watt m^2/K^4
(c) watt/m^2 K (d) watt/m^{2}K^4. *(2002)*

48. Consider two rods of same length and different specific heats (S_1, S_2), conductivities (K_1, K_2) and area of cross-sections (A_1, A_2) and both having temperatures T_1 and T_2 at their ends. If rate of loss of heat due to conduction is equal, then
(a) $K_1A_1 = K_2A_2$ (b) $\frac{K_1A_1}{S_1} = \frac{K_2A_2}{S_2}$
(c) $K_2A_1 = K_1A_2$ (d) $\frac{K_2A_1}{S_2} = \frac{K_1A_2}{S_1}$.
(2002)

49. For a black body at temperature 727°C, its radiating power is 60 watt and temperature of surrounding is 227°C. If temperature of black body is changed to 1227°C then its radiating power will be
(a) 304 W (b) 320 W
(c) 240 W (d) 120 W. *(2002)*

50. Which of the following is best close to an ideal black body?
(a) black lamp
(b) cavity maintained at constant temperature
(c) platinum black
(d) a lump of charcoal heated to high temperature. *(2002)*

51. The Wien's displacement law express relation between
(a) wavelength corresponding to maximum energy and temperature
(b) radiation energy and wavelength
(c) temperature and wavelength
(d) colour of light and temperature.
(2002)

52. A cylindrical rod having temperature T_1 and T_2 at its end. The rate of flow of heat Q_1 cal/sec. If all the linear dimension are doubled keeping temperature constant, then rate of flow of heat Q_2 will be
(a) $4Q_1$ (b) $2Q_1$ (c) $\frac{Q_1}{4}$ (d) $\frac{Q_1}{2}$.
(2001)

53. A black body has maximum wavelength λ_m at 2000 K. Its corresponding wavelength at 3000 K will be
(a) $\frac{3}{2}\lambda_m$ (b) $\frac{2}{3}\lambda_m$
(c) $\frac{16}{81}\lambda_m$ (d) $\frac{81}{16}\lambda_m$. *(2000)*

54. If 1 g of steam is mixed with 1 g of ice, then resultant temperature of the mixture is
(a) 100°C (b) 230°C
(c) 270°C (d) 50°C *(1999)*

55. The radiant energy from the sun, incident normally at the surface of earth is 20 kcal/m^2 min. What would have been the radiant energy, incident normally on the earth, if the sun had a temperature, twice of the present one?
(a) 320 kcal/m^2 min (b) 40 kcal/m^2 min
(c) 160 kcal/m^2 min (d) 80 kcal/m^2 min *(1998)*

56. A black body is at a temperature of 500 K. It emits energy at a rate which is proportional to
(a) $(500)^3$ (b) $(500)^4$ (c) 500 (d) $(500)^2$. *(1997)*

57. A beaker full of hot water is kept in a room. If it cools from 80°C to 75°C in t_1 minutes, from 75°C to 70°C in t_2 minutes and from 70°C to 65°C in t_3 minutes, then
(a) $t_1 < t_2 < t_3$ (b) $t_1 > t_2 > t_3$
(c) $t_1 = t_2 = t_3$ (d) $t_1 < t_2 = t_3$. *(1995)*

58. Heat is flowing through two cylindrical rods of the same material. The diameters of the rods are in the ratio 1 : 2 and the lengths in the ratio 2 : 1. If the temperature difference between the ends is same, then ratio of the rate of flow of heat through them will be
(a) 2 : 1 (b) 8 : 1 (c) 1 : 1 (d) 1 : 8. *(1995)*

59. If the temperature of the sun is doubled, the rate of energy recieved on earth will be increased by a factor of
(a) 2 (b) 4
(c) 8 (d) 16 *(1993)*

60. Mercury thermometer can be used to measure temperature upto
(a) 260°C (b) 100°C
(c) 360°C (d) 500°C *(1992)*

61. A Centigrade and a Fahrenheit thermometer are dipped in boiling water. The water temperature is lowered until the Fahrenheit thermometer registers 140°F. What is the fall in temperature as registered by the centigrade thermometer ?
(a) 80°C (b) 60°C
(c) 40°C (d) 30°C *(1990)*

62. Thermal capacity of 40 g of aluminum (s = 0.2 cal/g K) is
(a) 168 J/K (b) 672 J/K
(c) 840 J/K (d) 33.6 J/K *(1990)*

63. 10 gm of ice cubes at 0° C are released in a tumbler (water equivalent 55 g) at 40° C. Assuming that negligible heat is taken from the surroundings, the temperature of water in the tumbler becomes nearely (L = 80 cal/g)
(a) 31 °C
(b) 22 °C
(c) 19 °C
(d) 15 °C *(1988)*

Answer Key

1.	(d)	**2.**	(c)	**3.**	(c)	**4.**	(c)	**5.**	(b)	**6.**	(b)	**7.**	(b)	**8.**	(b)	**9.**	(b)	**10.**	(a)
11.	(b)	**12.**	(b)	**13.**	(d)	**14.**	(d)	**15.**	(d)	**16.**	(d)	**17.**	(b)	**18.**	(a)	**19.**	(d)	**20.**	(a)
21.	(b)	**22.**	(c)	**23.**	(d)	**24.**	(a)	**25.**	(d)	**26.**	(b)	**27.**	(c)	**28.**	(d)	**29.**	(b)	**30.**	(a)
31.	(a)	**32.**	(a)	**33.**	(d)	**34.**	(a)	**35.**	(a)	**36.**	(b)	**37.**	(a)	**38.**	(c)	**39.**	(b)	**40.**	(c)
41.	(d)	**42.**	(a)	**43.**	(a)	**44.**	(b)	**45.**	(d)	**46.**	(a)	**47.**	(d)	**48.**	(a)	**49.**	(b)	**50.**	(b)
51.	(a)	**52.**	(b)	**53.**	(b)	**54.**	(a)	**55.**	(a)	**56.**	(b)	**57.**	(a)	**58.**	(d)	**59.**	(d)	**60.**	(c)
61.	(c)	**62.**	(d)	**63.**	(b)														

EXPLANATIONS

1. (d) : Equivalent thermal conductivity of the composite rod in parallel combination will be,

$$K = \frac{K_1A_1 + K_2A_2}{A_1 + A_2} = \frac{K_1 + K_2}{2}$$

2. (c) : According to Stefan-Boltzman law, rate of energy radiated by a black body is given as

$E = \sigma AT^4 = \sigma 4\pi R^2T^4$

Given $E_1 = 450$ W, $T_1 = 500$ K, $R_1 = 12$ cm

$$R_2 = \frac{R_1}{2}, T_2 = 2T_1, E_2 = ?$$

$$\frac{E_2}{E_1} = \frac{\sigma 4\pi R_2^2 T_2^4}{\sigma 4\pi R_1^2 T_1^4} = \left(\frac{R_2}{R_1}\right)^2\left(\frac{T_2}{T_1}\right)^4$$

$$\frac{E_2}{E_1} = \frac{1}{4}\times 16 = 4$$

$E_2 = E_1 \times 4 = 450 \times 4 = 1800$ W

3. (c) : Bulk modulus B is given as

$$B = \frac{-pV}{\Delta V} \quad \text{...(i)}$$

The volume of a spherical object of radius r is given as

$$V = \frac{-pV}{\Delta V}, \Delta V = \frac{4}{3}\pi(3r^2)\Delta r$$

$$\therefore \quad -\frac{V}{\Delta V} = \frac{\frac{4}{3}\pi r^3}{\frac{4}{3}\pi 3r^2\Delta r} \quad \text{or} \quad -\frac{V}{\Delta V} = -\frac{r}{3\Delta r}$$

Put this value in eqn. (i), we get

$$B = -\frac{pr}{3\Delta r}$$

Fractional decrease in radius is

$$-\frac{\Delta r}{r} = \frac{p}{3B}$$

4. (c) : Pressure at point C,

$P_C = P_a + \rho_{water}gh_{water}$,

where $h_{water} = CE = (65 + 65)$ mm $= 130$ mm

Pressure at point B, $P_B = P_a + \rho_{oil}gh_{oil}$

where $h_{oil} = AB = (65 + 65 + 10)$ mm $= 140$ mm

In liquid, pressure is same at same liquid level,

$P_B = P_C \Rightarrow \rho_{oil}gh_{oil} = \rho_{water}g\,h_{water}$

$$\rho_{oil} = \frac{130\times 10^3}{140} = \frac{13}{14}\times 10^3 = 928.57 \text{ kg m}^{-3}$$

5. (b) : Work done = Surface tension of film × Change in area of the film

or, $W = T \times \Delta A$

Here, $A_1 = 4$ cm × 2 cm = 8 cm²

$A_2 = 5$ cm × 4 cm = 20 cm²

$\Delta A = 2(A_2 - A_1) = 24$ cm² $= 24 \times 10^{-4}$ m²

$W = 3 \times 10^{-4}$ J, $T = ?$

$$\therefore \quad T = \frac{W}{\Delta A} = \frac{3\times 10^{-4}}{24\times 10^{-4}} = \frac{1}{8} = 0.125 \text{ N m}^{-1}$$

6. (b) : Capillary rise, $h = \dfrac{2T\cos\theta}{r\rho g}$

For given value of T and r, $h \propto \dfrac{\cos\theta}{\rho}$

Also, $h_1 = h_2 = h_3$ or $\dfrac{\cos\theta_1}{\rho_1} = \dfrac{\cos\theta_2}{\rho_2} = \dfrac{\cos\theta_3}{\rho_3}$

Since, $\rho_1 > \rho_2 > \rho_3$, so $\cos\theta_1 > \cos\theta_2 > \cos\theta_3$

For $0 \le \theta < \dfrac{\pi}{2}$, $\theta_1 < \theta_2 < \theta_3$

Hence, $0 \le \theta_1 < \theta_2 < \theta_3 < \dfrac{\pi}{2}$

7. (b) : Since, heat capacity of material increases with increase in temperature so, body at 100 °C has more heat capacity than body at 0 °C. Hence, final common temperature of the system will be closer to 100 °C.

$\therefore \quad T_c > 50$ °C

8. (b) : According to Newton's law of cooling,

$$\frac{dT}{dt} = K(T - T_s)$$

For two cases,

$$\frac{dT_1}{dt} = K(T_1 - T_s) \text{ and } \frac{dT_2}{dt} = K(T_2 - T_s)$$

Here, $T_s = T$, $T_1 = \dfrac{3T + 2T}{2} = 2.5\,T$

and $\dfrac{dT_1}{dt} = \dfrac{3T - 2T}{10} = \dfrac{T}{10}$

$$T_2 = \frac{2T + T'}{2} \text{ and } \frac{dT_2}{dt} = \frac{2T - T'}{10}$$

So, $\dfrac{T}{10} = K(2.5T - T)$ ...(i)

$$\frac{2T - T'}{10} = K\left(\frac{2T + T'}{2} - T\right) \quad \text{...(ii)}$$

Dividing eqn. (i) by eqn. (ii), we get

$$\frac{T}{2T - T'} = \frac{(2.5T - T)}{\left(\frac{2T + T'}{2} - T\right)}$$

$$\frac{2T+T'}{2}-T=(2T-T')\times\frac{3}{2}$$

$$T'=3(2T-T') \text{ or, } 4T'=6T \quad \therefore \quad T'=\frac{3}{2}T$$

9. (b) : Linear expansion of brass = α_1
Linear expansion of steel = α_2
Length of brass rod = l_1
Length of steel rod = l_2
On increasing the temperature of the rods by ΔT, new lengths would be

$$l_1'=l_1(1+\alpha_1\Delta T) \quad ...(i) \qquad l_2'=l_2(1+\alpha_2\Delta T) \quad ...(ii)$$

Subtracting eqn. (i) from eqn. (ii), we get

$$l_2'-l_1'=(l_2-l_1)+(l_2\alpha_2-l_1\alpha_1)\Delta T$$

According to question,

$$l_2'-l_1'=l_2-l_1 \qquad \text{(for all temperatures)}$$

$\therefore \quad l_2\alpha_2-l_1\alpha_1=0$ or $l_1\alpha_1=l_2\alpha_2$

10. (a) : Gravitational potential energy of a piece of ice at a height $(h)=mgh$
Heat absorbed by the ice to melt completely

$$\Delta Q=\frac{1}{4}mgh \qquad ...(i)$$

Also, $\Delta Q=mL$ ...(ii)

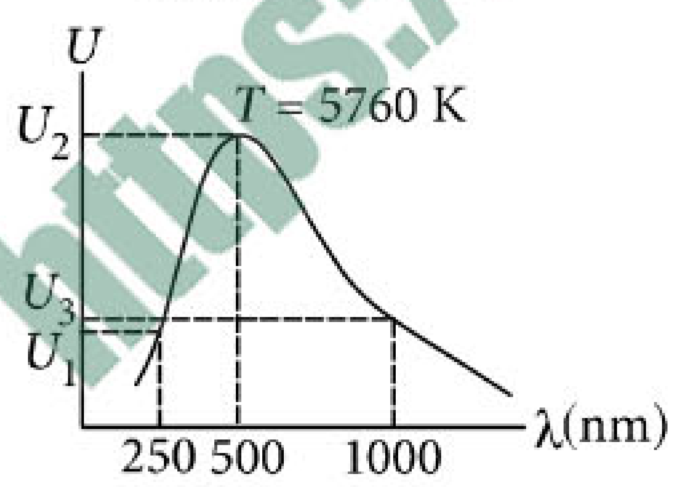
From eqns. (i) and (ii), $mL=\frac{1}{4}mgh$ or, $h=\frac{4L}{g}$

Here $L=3.4\times10^5$ J kg^{-1}, $g=10$ N kg^{-1}

$$\therefore \quad h=\frac{4\times3.4\times10^5}{10}=4\times34\times10^3=136\text{ km}$$

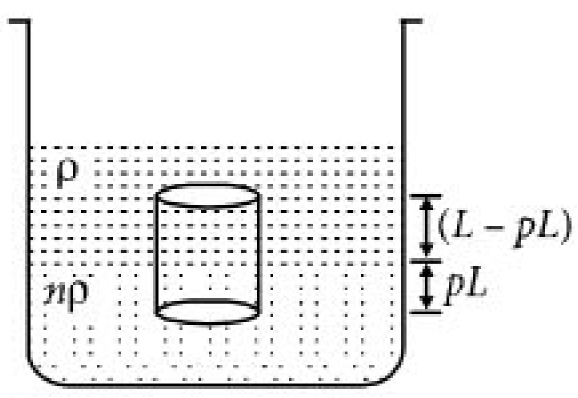
11. (b) : According to Wein's displacement law

$$\lambda_m=\frac{b}{T}=\frac{2.88\times10^6\text{ nm K}}{5760\text{ K}}=500\text{ nm}$$



Clearly from graph, $U_1<U_2>U_3$

12. (b) :



d = density of cylinder
A = area of cross-section of cylinder

Using law of floatation,
Weight of cylinder = Upthrust by two liquids

$$L\times A\times d\times g=n\rho\times(pL\times A)g+\rho(L-pL)Ag$$
$$d=np\rho+\rho(1-p)=(np+1-p)\rho$$
$$d=\{1+(n-1)p\}\ \rho$$

13. (d) : Let the speed of the ejection of the liquid through the holes be v. Then according to the equation of continuity,

$$\pi R^2V=n\pi r^2v \text{ or } v=\frac{\pi R^2V}{n\pi r^2}=\frac{VR^2}{nr^2}$$

14. (d) : Water will not overflow but will change its radius of curvature.

15. (d) : Let ρ_0 and ρ_T be densities of glycerin at 0°C and T°C respectively. Then,

$$\rho_T=\rho_0(1-\gamma\Delta T)$$

where γ is the coefficient of volume expansion of glycerine and ΔT is rise in temperature.

$$\frac{\rho_T}{\rho_0}=1-\gamma\Delta T \text{ or } \gamma\Delta T=1-\frac{\rho_T}{\rho_0}$$

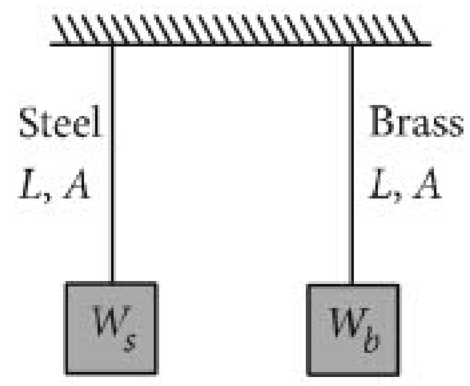
Thus, $\frac{\rho_0-\rho_T}{\rho_0}=\gamma\Delta T$

Here, $\gamma=5\times10^{-4}$ K^{-1} and $\Delta T=40$°C $=40$ K

$\therefore$ The fractional change in the density of glycerin

$$=\frac{\rho_0-\rho_T}{\rho_0}=\gamma\Delta T=(5\times10^{-4}\text{K}^{-1})(40\text{ K})=0.020$$

16. (d) : Let L and A be length and area of cross section of each wire. In order to have the lower ends of the wires to be at the same level (*i.e.* same elongation is produced in both wires), let weights W_s and W_b are added to steel and brass wires respectively. Then



By definition of Young's modulus, the elongation produced in the steel wire is

$$\Delta L_s=\frac{W_sL}{Y_sA} \qquad \left(\text{as } Y=\frac{W/A}{\Delta L/L}\right)$$

and that in the brass wire is $\Delta L_b=\frac{W_bL}{Y_bA}$

But $\Delta L_s=\Delta L_b$ (given)

$$\therefore \quad \frac{W_sL}{Y_sA}=\frac{W_bL}{Y_bA} \text{ or } \frac{W_s}{W_b}=\frac{Y_s}{Y_b}$$

As $\frac{Y_s}{Y_b}=2$ (given)

$$\therefore \quad \frac{W_s}{W_b}=\frac{2}{1}$$

17. (b) **18. (a)**

19. (d) : According to Wein's displacement law

$\lambda_m T$ = constant ...(i)

For star P, intensity of violet colour is maximum

For star Q, intensity of red colour is maximum.

For star R, intensity of green colour is maximum.

Also, $\lambda_r > \lambda_g > \lambda_v$

Using equation (i), $T_r < T_g < T_v$

$T_Q < T_R < T_P$

20. (a) : Depth of ocean $d = 2700$ m

Density of water, $\rho = 10^3$ kg m^{-3}

Compressibility of water, $K = 45.4 \times 10^{-11}$ Pa^{-1}

$$\frac{\Delta V}{V} = ?$$

Excess pressure at the bottom, $\Delta P = \rho g d$

$= 10^3 \times 10 \times 2700 = 27 \times 10^6$ Pa

$$\text{We know, } B = \frac{\Delta P}{(\Delta V/V)}$$

$$\left(\frac{\Delta V}{V}\right) = \frac{\Delta P}{B} = K.\Delta P \qquad \left(\because K = \frac{1}{B}\right)$$

$= 45.4 \times 10^{-11} \times 27 \times 10^6 = 1.2 \times 10^{-2}$

21. (b) : As $V = Al$ ...(i)

where A is the area of cross-section of the wire.

$$\text{Young's modulus, } Y = \frac{(F/A)}{(\Delta l/l)} = \frac{Fl}{A\Delta l}$$

$$\Delta l = \frac{Fl}{YA} = \frac{Fl^2}{YV} \qquad \text{(Using (i))}$$

$\Delta l \propto l^2$

Hence, the graph between Δl and l^2 is a straight line.

22. (c) : Let n droplets each of radius r coalesce to form a big drop of radius R.

$\therefore$ Volume of n droplets = Volume of big drop

$$n \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3 \Rightarrow n = \frac{R^3}{r^3} \qquad \text{...(i)}$$

$$\text{Volume of big drop, } V = \frac{4}{3}\pi R^3 \qquad \text{...(ii)}$$

Initial surface area of n droplets,

$$A_i = n \times 4\pi r^2 = \frac{R^3}{r^3} \times 4\pi r^2 \qquad \text{(Using (i))}$$

$$= 4\pi\frac{R^3}{r} = \left(\frac{4}{3}\pi R^3\right)\frac{3}{r} = \frac{3V}{r} \qquad \text{(Using (ii))}$$

Final surface area of big drop

$$A_f = 4\pi R^2 = \left(\frac{4}{3}\pi R^3\right)\frac{3}{R} = \frac{3V}{R} \qquad \text{(Using (ii))}$$

Decrease in surface area

$$\Delta A = A_i - A_f = \frac{3V}{r} - \frac{3V}{R} = 3V\left(\frac{1}{r} - \frac{1}{R}\right)$$

$\therefore$ Energy released = Surface tension × Decrease in surface area

$$= T \times \Delta A = 3VT\left(\frac{1}{r} - \frac{1}{R}\right)$$

23. (d) : Here,

Specific heat of water, $s_w = 1$ cal g^{-1} °C^{-1}

Latent heat of steam, $L_s = 540$ cal g^{-1}

Heat lost by m g of steam at 100°C to change into water at 80°C is

$$Q_1 = mL_s + ms_w\Delta T_w = m \times 540 + m \times 1 \times (100 - 80)$$
$$= 540m + 20m = 560m$$

Heat gained by 20 g of water to change its temperature from 10°C to 80°C is

$$Q_2 = m_w s_w \Delta T_w = 20 \times 1 \times (80 - 10) = 1400$$

According to principle of calorimetry, $Q_1 = Q_2$

$\therefore$ $560m = 1400$ or $m = 2.5$ g

Total mass of water present

$= (20 + m)$ g $= (20 + 2.5)$ g $= 22.5$ g

24. (a) : Let T_s be the temperature of the surroundings.

According to Newton's law of cooling

$$\frac{T_1 - T_2}{t} = K\left(\frac{T_1 + T_2}{2} - T_s\right)$$

For first 5 minutes,

$T_1 = 70$°C, $T_2 = 60$°C, $t = 5$ minutes

$$\therefore \frac{70 - 60}{5} = K\left(\frac{70 + 60}{2} - T_s\right)$$

$$\frac{10}{5} = K(65 - T_s) \qquad \text{...(i)}$$

For next 5 minutes,

$T_1 = 60$°C, $T_2 = 54$°C, $t = 5$ minutes

$$\therefore \frac{60 - 54}{5} = K\left(\frac{60 + 54}{2} - T_s\right)$$

$$\frac{6}{5} = K(57 - T_s) \qquad \text{...(ii)}$$

Divide eqn. (i) by eqn. (ii), we get

$$\frac{5}{3} = \frac{65 - T_s}{57 - T_s}$$

$285 - 5T_s = 195 - 3T_s$

$2T_s = 90$ or $T_s = 45$°C

25. (d) : According to Wein's displacement law

$\lambda_m T$ = constant

$$\lambda_m = \frac{\text{constant}}{T}$$

So when a piece of iron is heated, λ_m decreases *i.e.* with rise in temperature the maximum intensity of radiation emitted gets shifted towards the shorter wavelengths. So the colour of the heated object will change that of longer wavelength (red) to that of shorter (reddish yellow) and when the temperature is sufficiently high and all wavelengths are emitted, the colour will become white.

26. (b) : The wettability of a surface by a liquid depends primarily on angle of contact between the surface and the liquid.

27. (c) : Young's modulus,

$$Y = \frac{FL}{A\Delta L} = \frac{4FL}{\pi D^2 \Delta L} \quad \text{or} \quad \Delta L = \frac{4FL}{\pi D^2 Y}$$

where F is the force applied, L is the length, D is the diameter and ΔL is the extension of the wire respectively.

As each wire is made up of same material therefore their Young's modulus is same for each wire.

For all the four wires, Y, F (= tension) are the same.

$$\therefore \quad \Delta L \propto \frac{L}{D^2}$$

In (a) $\frac{L}{D^2} = \frac{200 \text{ cm}}{(0.2 \text{ cm})^2} = 5 \times 10^3 \text{ cm}^{-1}$

In (b) $\frac{L}{D^2} = \frac{300 \text{ cm}}{(0.3 \text{ cm})^2} = 3.3 \times 10^3 \text{ cm}^{-1}$

In (c) $\frac{L}{D^2} = \frac{50 \text{ cm}}{(0.05 \text{ cm})^2} = 20 \times 10^3 \text{ cm}^{-1}$

In (d) $\frac{L}{D^2} = \frac{100 \text{ cm}}{(0.1 \text{ cm})^2} = 10 \times 10^3 \text{ cm}^{-1}$

Hence, ΔL is maximum in (c).

28. (d) : For an ideal gas

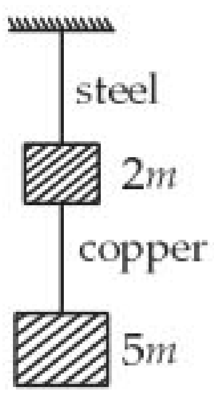
$$C_p - C_v = R \qquad \text{...(i)}$$

Divide C_v on both sides, we get

$$\frac{C_p}{C_v} - 1 = \frac{R}{C_v}$$

As $\gamma = \frac{C_p}{C_v}$ $\therefore$ $\gamma - 1 = \frac{R}{C_v}$ $\Rightarrow$ $C_v = \frac{R}{\gamma - 1}$

29. (b) : As $Y = \frac{FL}{A\Delta L} = \frac{4FL}{\pi D^2 \Delta L}$



$$\Delta L = \frac{4FL}{\pi D^2 Y}$$

$$\therefore \quad \frac{\Delta L_S}{\Delta L_C} = \frac{F_S}{F_C}\frac{L_S}{L_C}\frac{D_C^2}{D_S^2}\frac{Y_C}{Y_S}$$

where subscripts S and C refer to copper and steel respectively.

Here, $F_s = (5m + 2m)g = 7mg$

$F_C = 5mg$

$$\frac{L_S}{L_C} = q, \frac{D_S}{D_C} = p, \frac{Y_S}{Y_C} = s$$

$$\therefore \quad \frac{\Delta L_S}{\Delta L_C} = \left(\frac{7mg}{5mg}\right)(q)\left(\frac{1}{p}\right)^2\left(\frac{1}{s}\right) = \frac{7q}{5p^2 s}$$

30. (a) : Let L be length of each rod.

Rate of heat flow in rod 1 for the temperature difference ΔT is

$$H_1 = \frac{K_1 A_1 \Delta T}{L}$$

Rate of heat flow in rod 2 for the same difference ΔT is

$$H_2 = \frac{K_2 A_2 \Delta T}{L}$$

As per questionm, $H_1 = 4H_2$

$$\frac{K_1 A_1 \Delta T}{L} = 4\frac{K_2 A_2 \Delta T}{L} \therefore K_1 A_1 = 4K_2 A_2$$

31. (a) : According to equation of continuity,

Av = constant

Therefore, velocity is maximum at the narrowest part and minimum at the widest part of the pipe.

According to Bernoulli's theorem for a horizontal pipe,

$$P + \frac{1}{2}\rho v^2 = \text{constant}$$

Hence, when a fluid flow across a horizontal pipe of variable area of cross-section its velocity is maximum and pressure is minimum at the narrowest part and vice versa.

32. (a) : As $\rho_{T_2} = \frac{\rho_{T_1}}{(1 + \gamma\Delta T)} = \frac{\rho_{T_1}}{1 + \gamma(T_2 - T_1)}$

Here, $T_1 = 20°C$, $T_2 = 40°C$

$\rho_{20} = 998 \text{ kg/m}^3$, $\rho_{40} = 992 \text{ kg/m}^3$

$$\therefore \quad 992 = \frac{998}{1 + \gamma(40 - 20)}$$

$$992 = \frac{998}{1 + 20\gamma}$$

$$992(1 + 20\gamma) = 998$$

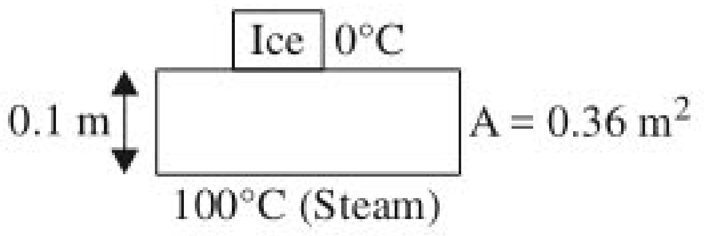
$$1 + 20\gamma = \frac{998}{992} \quad \text{or} \quad 20\gamma = \frac{998}{992} - 1 = \frac{6}{992}$$

$$\gamma = \frac{6}{992} \times \frac{1}{20} = 3 \times 10^{-4}/°C$$

33. (d) : According to Stefan's law, $Q = \sigma AT^4$

$$\text{or} \quad T = \left(\frac{Q}{\sigma A}\right)^{1/4} = \left(\frac{Q}{\sigma 4\pi R^2}\right)^{1/4}$$

34. (a) : Temperature of liquid oxygen will first increase in the same phase. Then, the liquid oxygen will change to gaseous phase during which temperature will remain constant. After that temperature of oxygen in gaseous state will increase. Hence option (a) represents corresponding temperature-time graph.

35. (a) : 

Heat flows through the slab in t s is

$$Q = \frac{KA(T_1 - T_2)t}{L} = \frac{K \times 0.36 \times (100-0) \times 3600}{0.1}$$

$$= \frac{K \times 0.36 \times 100 \times 3600}{0.1} \quad ...(i)$$

So ice melted by this heat is

$$m_{ice} = \frac{Q}{L_f} \quad ...(ii)$$

or $Q = m_{ice} L_f = 4.8 \times 3.36 \times 10^5$

From (i) and (ii), we get

$$\frac{K \times 0.36 \times (100-0) \times 3600}{0.1} = 4.8 \times 3.36 \times 10^5$$

$$K = \frac{4.8 \times 3.36 \times 10^5 \times 0.1}{0.36 \times 100 \times 3600} = 1.24 \text{ J/m/s/°C}$$

36. (b) : The amount of heat flows in time t through a cylindrical metallic rod of length L and uniform area of cross-section $A(= \pi R^2)$ with its ends maintained at temperatures T_1 and T_2 $(T_1 > T_2)$ is given by

$$Q = \frac{KA(T_1 - T_2)t}{L} \quad ...(i)$$

where K is the thermal conductivity of the material of the rod.

Area of cross-section of new rod

$$A' = \pi\left(\frac{R}{2}\right)^2 = \frac{\pi R^2}{4} = \frac{A}{4} \quad ...(ii)$$

As the volume of the rod remains unchanged

$\therefore \quad AL = A'L'$

where L' is the length the new rod

or $\quad L' = L\dfrac{A}{A'} \quad ...(iii)$

$= 4L$ (Using (ii))

Now, the amount of heat flows in same time t in the new rod with its ends maintained at the same temperatures T_1 and T_2 is given by

$$Q' = \frac{KA'(T_1 - T_2)t}{L'} \quad ...(iv)$$

Substituting the values of A' and L' from equations (ii) and (iii) in the above equation, we get

$$Q' = \frac{K(A/4)(T_1 - T_2)t}{4L} = \frac{1}{16}\frac{KA(T_1 - T_2)t}{L} = \frac{1}{16}Q$$

(Using (i))

37. (a) : According to the Stefan Boltzmann law, the power radiated by the star whose outer surface radiates as a black body at temperature T K is given by

$P = \sigma 4\pi r^2 T^4$

where, r = radius of the star

σ = Stefan's constant

The radiant power per unit area received at a distance R from the centre of a star is

$$S = \frac{P}{4\pi R^2} = \frac{\sigma 4\pi r^2 T^4}{4\pi R^2} = \frac{\sigma r^2 T^4}{R^2}$$

38. (c) : Power P radiated by the sun with its surface temperature $(t + 273)$ K is given by Stefan's Boltzmann law.

$P = \sigma e\, 4\pi r^2 (t + 273)^4$

where r is the radius of the sun and the sun is treated as a black body where $e = 1$.

The radiant power per unit area received by the surface at a distance R from the centre of the sun is given by

$$S = \frac{P}{4\pi R^2} = \frac{\sigma 4\pi r^2 (t+273)^4}{4\pi R^2} = \frac{r^2 \sigma (t+273)^4}{R^2}.$$

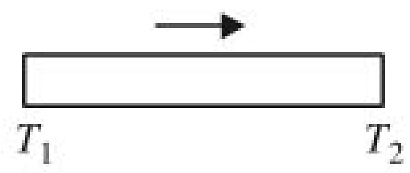
39. (b) : Rate of heat radiated at $(227 + 273)$ K $= 7$ cals/(cm²s)

Let rate of heat radiated at $(727 + 273)$ K $= x$ cals/(cm²s)

By Stefan's law, $7 \propto (500)^4$ and $x \propto (1000)^4$

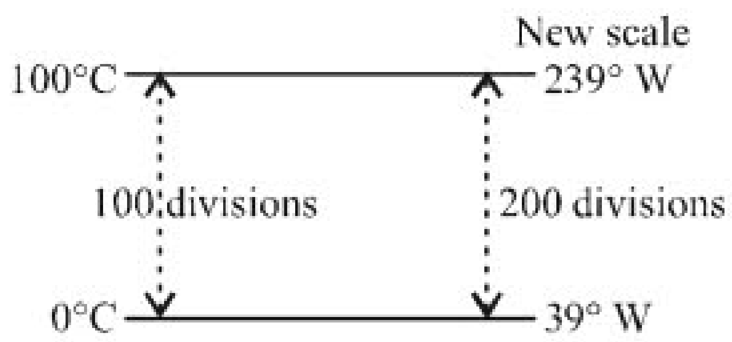
$$\therefore \frac{x}{7} = 2^4 \Rightarrow x = 7 \times 2^4 = 112 \text{ cals/(cm}^2\text{ s)}.$$

40. (c) : Similar to $I = V/R$



$$\frac{dQ}{dt} = \frac{kA}{L}(T_1 - T_2)$$

k = conductivity of the rod.

41. (d) : 

$\therefore \quad 39°\text{C} = 39 \times 2 + 39 = (78 + 39)°\text{ W} = 117°\text{ W}.$

42. (a) : According to Stefan's law, rate of energy radiated $E \propto T^4$

where T is the absolute temperature of a black body.

$\therefore \quad E \propto (727 + 273)^4 \quad$ or $\quad E \propto [1000]^4$.

43. (a) : According to Wein's displacement law,

$\lambda_{max} T$ = constant

$$\therefore \quad \frac{\lambda_{max_1}}{\lambda_{max_2}} = \frac{T_2}{T_1}$$

$$\text{or,} \quad \lambda_{max_2} = \frac{\lambda_{max_1} \times T_1}{T_2} = \frac{5000 \times 1500}{2500} = 3000 \text{ Å}.$$

44. (b) : Heat conducted

$$= \frac{KA(T_1 - T_2)t}{l} = \frac{K\pi r^2 (T_1 - T_2)t}{l}$$

The rod with the maximum ratio of A/l will conduct most. Here the rod with $r = 2r_0$ and $l = l_0$ will conduct most.

45. (d) : Wein's displacement law
$\lambda_m T$ = constant, $\lambda_m \propto T^{-1}$

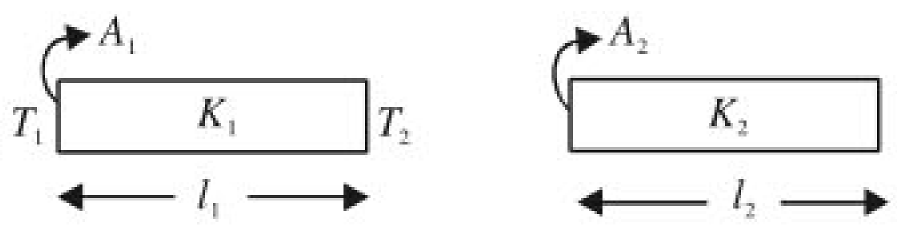
46. (a) : The slabs are in series.
Total resistance $R = R_1 + R_2$

$$\Rightarrow \frac{l}{AK_{\text{effective}}} = \frac{l}{A.K} + \frac{l}{A2K}$$

$$\Rightarrow \frac{1}{K_{\text{effective}}} = \frac{1}{K} + \frac{1}{2K} = \frac{3}{2K} \quad \therefore K_{\text{effective}} = \frac{2K}{3}$$

47. (d) : Unit of Stefan's constant is watt/m^{2}K^4.

48. (a) :



Rate of heat loss in rod 1 = $Q_1 = \dfrac{K_1 A_1 (T_1 - T_2)}{l_1}$

Rate of heat loss in rod 2 = $Q_2 = \dfrac{K_2 A_2 (T_1 - T_2)}{l_2}$

By problem, $Q_1 = Q_2$.

$$\therefore \frac{K_1 A_1 (T_1 - T_2)}{l_1} = \frac{K_2 A_2 (T_1 - T_2)}{l_2}.$$

$\therefore K_1 A_1 = K_2 A_2$. $\quad [\because l_1 = l_2]$

49. (b) : Radiating power of a black body

$$= E_0 = \sigma (T^4 - T_0^4) A$$

where σ is known as the Stefan-Boltzmann constant, A is the surface area of a black body, T is the temperature of the black body and T_0 is the temperature of the surrounding.

$\therefore$ $60 = \sigma(1000^4 - 500^4)$ ...(i)
$[T = 727°C = 727 + 273 = 1000$ K,
$T_0 = 227°C = 500$ K].

In the second case, T = 1227°C = 1500 K and let E' be the radiating power.

$\therefore$ $E' = \sigma(1500^4 - 500^4)$ ...(ii)

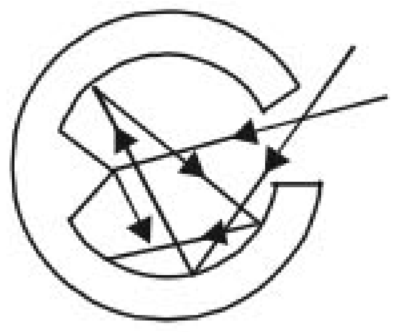
From (i) and (ii) we have

$$\frac{E'}{60} = \frac{1500^4 - 500^4}{1000^4 - 500^4} = \frac{15^4 - 5^4}{10^4 - 5^4} = \frac{50000}{9375}$$

$$\therefore E' = \frac{50000}{9375} \times 60 = 320 \text{ W}.$$

50. (b) : An ideal black body is one which absorbs all the incident radiation without reflecting or transmitting any part of it. Black lamp absorbs approximately 96% of incident radiation.

An ideal black body can be realized in practice by a small hole in the wall of a hollow body (as shown in figure) which is at uniform temperature.



Any radiation entering the hollow body through the holes suffers a number of reflections and ultimately gets completely absorbed. This can be facilitated by coating the interior surface with black so that about 96% of the radiation is absorbed at each reflection. The portion of the interior surface opposite to the hole is made conical to avoid the escape of the reflected ray after one reflection.

51. (a) : Wien's displacement law states that the product of absolute temperature and the wavelength at which the emissive power is maximum is constant *i.e.* $\lambda_{\max} T$ = constant. Therefore it expresses relation between wavelength corresponding to maximum energy and temperature.

52. (b) : Heat flow rate $\dfrac{dQ}{dt} = \dfrac{KA(T_1 - T_2)}{L} = Q$

When linear dimensions are double.

$A_1 \propto r_1^2,\ L_1 = L$

$A_2 \propto 4r_1^2,\ L_2 = 2L$ so $Q_2 = 2Q_1$.

53. (b) : According to Wein's law,

$\lambda_m T$ = constant. $\therefore \lambda' = (2/3)\lambda_m$

54. (a)

55. (a) : $E = \sigma T^4 = 20.\ T' = 2T$

$\therefore$ $E' = \sigma(2T)^4 = 16\ \sigma T^4$
$= 16 \times 20 = 320$ kcal/m^2 min

56. (b) : Temperature of black body (T) = 500 K. Therefore total energy emitted by the black body $(E) \propto T^4 \propto (500)^4$.

57. (a) : The rate of cooling is directly proportional to the temperature difference of the body and the surroundings. So, cooling will be fastest in the first case and slowest in the third case.

58. (d) : Ratio of diameters of rod = 1 : 2 and ratio of their lengths 2 : 1.

The rate of flow of heat, $(R) = \dfrac{KA\Delta T}{l} \propto \dfrac{A}{l}$.

Therefore $\dfrac{R_1}{R_2} = \dfrac{A_1}{A_2} \times \dfrac{l_2}{l_1} = \left(\dfrac{1}{2}\right)^2 \times \dfrac{1}{2} = \dfrac{1}{8}$

or $R_1 : R_2 = 1 : 8$

59. (d) : Amount of energy radiated $\propto T^4$.

60. (c) : Mercury thermometer is based on the principle of change of volume with rise of temperature and can measure temperatures ranging from –30°C to 357°C

61. (c) : Here, F = 140°

Using $\frac{F-32}{180} = \frac{C}{100}$,

$\therefore \quad \frac{140-32}{180} = \frac{C}{100} \Rightarrow C = 60°C$

we get, fall in temperature = 40°C

62. (d) : Thermal capacity = ms = 40 × 0.2 = 8 cal/K = 33.6 joule/K.

63. (b) : Let the final temperature be T

Heat required by ice $= mL + m \times s \times (T - 0)$
$= 10 \times 80 + 10 \times 1 \times T$

Heat lost by water = $55 \times (40 - T)$

By using law of calorimetry,

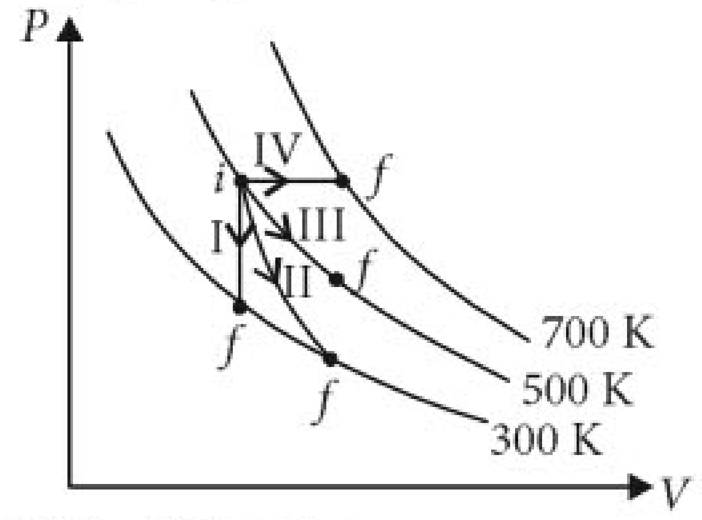
heat gained = heat lost

$800 + 10T = 55 \times (40 - T)$

$\Rightarrow \quad T = 21.54°C = 22°C$

Chapter 9 Thermodynamics and Kinetic Theory

1. Thermodynamic processes are indicated in the following diagram.



Match the following

	Column-1	Column-2
P.	Process I	A. Adiabatic
Q.	Process II	B. Isobaric
R.	Process III	C. Isochoric
S.	Process IV	D. Isothermal

(a) P $\rightarrow$ C, Q $\rightarrow$ A, R $\rightarrow$ D, S $\rightarrow$ B
(b) P $\rightarrow$ C, Q $\rightarrow$ D, R $\rightarrow$ B, S $\rightarrow$ A
(c) P $\rightarrow$ D, Q $\rightarrow$ B, R $\rightarrow$ A, S $\rightarrow$ C
(d) P $\rightarrow$ A, Q $\rightarrow$ C, R $\rightarrow$ D, S $\rightarrow$ B
(NEET 2017)

2. A carnot engine having an efficiency of $\frac{1}{10}$ as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is
(a) 90 J (b) 99 J (c) 100 J (d) 1 J
(NEET 2017)

3. A gas mixture consists of 2 moles of O_2 and 4 moles of Ar at temperature T. Neglecting all vibrational modes, the total internal energy of the system is
(a) 15 RT (b) 9 RT (c) 11 RT (d) 4 RT
(NEET 2017)

4. One mole of an ideal monatomic gas undergoes a process described by the equation PV^3 = constant. The heat capacity of the gas during this process is
(a) $\frac{3}{2}R$ (b) $\frac{5}{2}R$ (c) $2R$ (d) R
(NEET-II 2016)

5. The temperature inside a refrigerator is t_2 °C and the room temperature is t_1 °C. The amount of heat delivered to the room for each joule of electrical energy consumed ideally will be
(a) $\frac{t_1}{t_1 - t_2}$ (b) $\frac{t_1 + 273}{t_1 - t_2}$
(c) $\frac{t_2 + 273}{t_1 - t_2}$ (d) $\frac{t_1 + t_2}{t_1 + 273}$
(NEET-II 2016)

6. A given sample of an ideal gas occupies a volume V at a pressure P and absolute temperature T. The mass of each molecule of the gas is m. Which of the following gives the density of the gas ?
(a) $P/(kT)$ (b) $Pm/(kT)$
(c) $P/(kTV)$ (d) mkT
(NEET-II 2016)

7. A gas is compressed isothermally to half its initial volume. The same gas is compressed separately through an adiabatic process until its volume is again reduced to half. Then
(a) Compressing the gas isothermally or adiabatically will require the same amount of work.
(b) Which of the case (whether compression through isothermal or through adiabatic process) requires more work will depend upon the atomicity of the gas.
(c) Compressing the gas isothermally will require more work to be done.
(d) Compressing the gas through adiabatic process will require more work to be done.
(NEET-I 2016)

8. The molecules of a given mass of a gas have r.m.s. velocity of 200 m s^{-1} at 27°C and 1.0×10^5 N m^{-2} pressure. When the temperature and pressure of the gas are respectively, 127°C and 0.05×10^5 N m^{-2}, the r.m.s. velocity of its molecules in m s^{-1} is
(a) $\frac{100\sqrt{2}}{3}$ (b) $\frac{100}{3}$ (c) $100\sqrt{2}$ (d) $\frac{400}{\sqrt{3}}$
(NEET-I 2016)

9. A refrigerator works between 4°C and 30°C. It is required to remove 600 calories of heat every second in order to keep the temperature of the refrigerated space constant. The power required is (Take 1 cal = 4.2 Joules)

(a) 236.5 W (b) 2365 W
(c) 2.365 W (d) 23.65 W

(NEET-I 2016)

10. An ideal gas is compressed to half its initial volume by means of several processes. Which of the process results in the maximum work done on the gas?

(a) Isochoric (b) Isothermal
(c) Adiabatic (d) Isobaric *(2015)*

11. Two vessels separately contain two ideal gases *A* and *B* at the same temperature, the pressure of *A* being twice that of *B*. Under such conditions, the density of *A* is found to be 1.5 times the density of *B*. The ratio of molecular weight of *A* and *B* is

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

(2015)

12. The coefficient of performance of a refrigerator is 5. If the temperature inside freezer is –20°C, the temperature of the surroundings to which it rejects heat is

(a) 11°C (b) 21°C (c) 31°C (d) 41°C

(2015)

13. The ratio of the specific heats $\frac{C_p}{C_v} = \gamma$ in terms of degrees of freedom (n) is given by

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

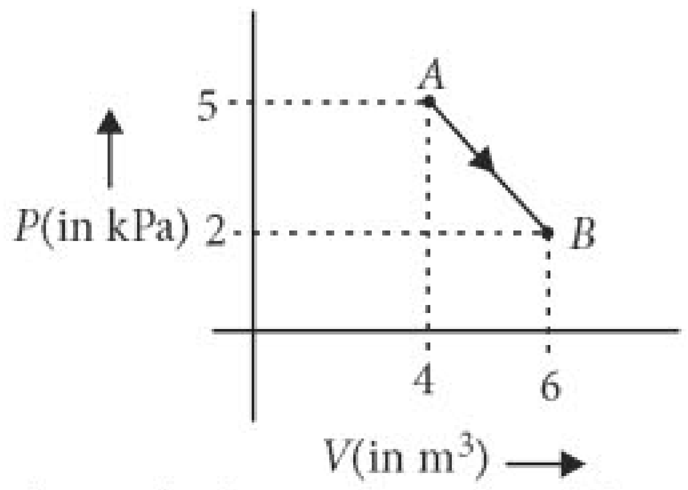
(2015 Cancelled)

14. A Carnot engine, having an efficiency of as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the amount of energy absorbed from the reservoir at lower temperature is

(a) 90 J (b) 1 J (c) 100 J (d) 99 J

(2015 Cancelled)

15. One mole of an ideal diatomic gas undergoes a transition from *A* to *B* along a path *AB* as shown in the figure.

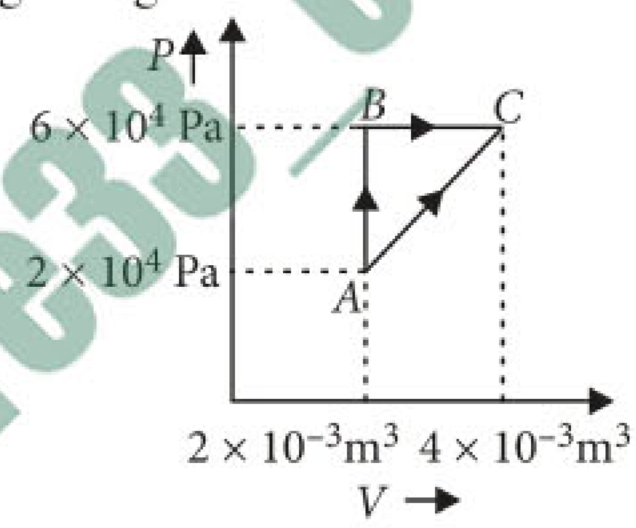


The change in internal energy of the gas during the transition is

(a) 20 J (b) –12 kJ
(c) 20 kJ (d) –20 kJ

(2015 Cancelled)

16. Figure below shows two paths that may be taken by a gas to go from a state *A* to a state *C*.



In process *AB*, 400 J of heat is added to the system and in process *BC*, 100 J of heat is added to the system. The heat absorbed by the system in the process *AC* will be

(a) 460 J (b) 300 J
(c) 380 J (d) 500 J

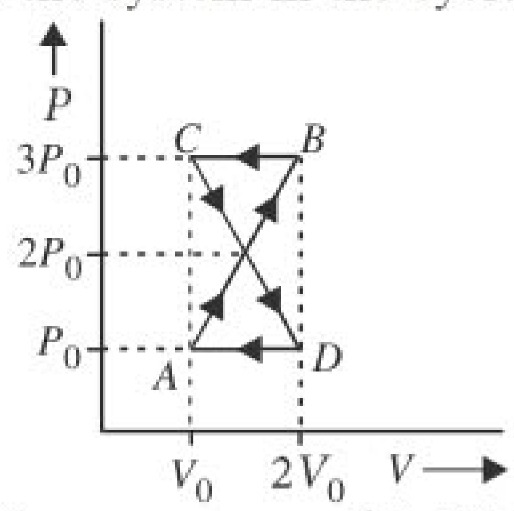
(2015 Cancelled)

17. A monatomic gas at a pressure *P*, having a volume *V* expands isothermally to a volume 2*V* and then adiabatically to a volume 16*V*. The final pressure of the gas is (Take γ = 5/3)

(a) 64*P* (b) 32*P* (c) *P*/64 (d) 16*P*

(2014)

18. A thermodynamic system undergoes cyclic process *ABCDA* as shown in figure. The work done by the system in the cycle is



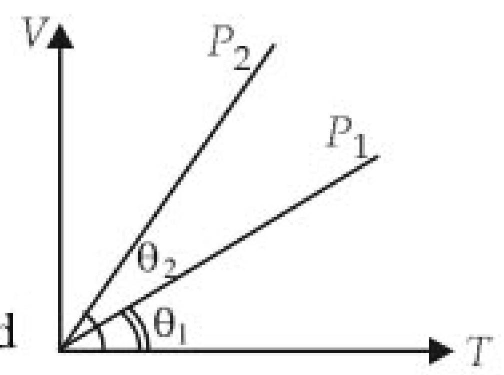
(a) P_0V_0 (b) $2P_0V_0$
(c) $\frac{P_0V_0}{2}$ (d) zero *(2014)*

19. The mean free path of molecules of a gas, (radius r) is inversely proportional to

(a) r^3 (b) r^2

(c) r (d) $\sqrt{r}$ *(2014)*

20. In the given $(V-T)$ diagram, what is the relation between pressures P_1 and P_2?



(a) $P_2 < P_1$

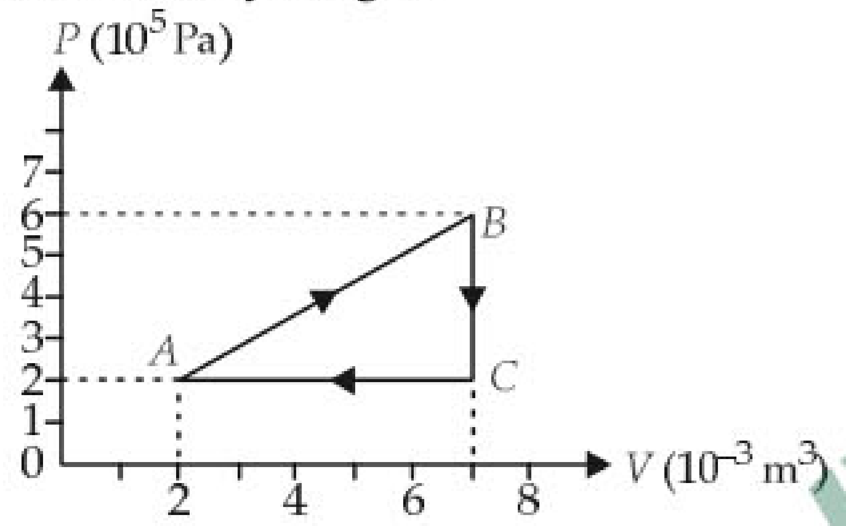
(b) Cannot be predicted

(c) $P_2 = P_1$

(d) $P_2 > P_1$

(NEET 2013)

21. A gas is taken through the cycle $A \to B \to C \to A$, as shown. What is the net work done by the gas?



(a) Zero (b) – 2000 J

(c) 2000 J (d) 1000 J

(NEET 2013)

22. During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its temperature. The ratio of $\frac{C_p}{C_v}$ for the gas is

(a) $\frac{5}{3}$ (b) $\frac{3}{2}$ (c) $\frac{4}{3}$ (d) 2

(NEET 2013)

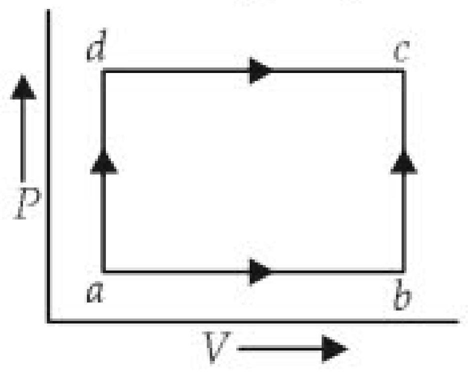
23. The amount of heat energy required to raise the temperature of 1 g of Helium at NTP, from T_1 K to T_2 K is

(a) $\frac{3}{4}N_a k_B(T_2-T_1)$ (b) $\frac{3}{4}N_a k_B\left(\frac{T_2}{T_1}\right)$

(c) $\frac{3}{8}N_a k_B(T_2-T_1)$ (d) $\frac{3}{2}N_a k_B(T_2-T_1)$

(NEET 2013)

24. A system is taken from state a to state c by two paths adc and abc as shown in the figure. The internal energy at a is $U_a = 10$ J. Along the path adc the amount of heat heat absorbed $dQ_1 = 50$ J and the work obtained $dW_1 = 20$ J whereas along the path abc the heat absorbed $dQ_2 = 36$ J. The amount of work along the path abc is



(a) 10 J (b) 12 J (c) 36 J (d) 6 J

(Karnataka NEET 2013)

25. Which of the following relations does not give the equation of an adiabatic process, where terms have their usual meaning?

(a) $P^{1-\gamma}T^{\gamma}$ = constant

(b) PV^{γ} = constant

(c) $TV^{\gamma-1}$ = constant

(d) $P^{\gamma}T^{1-\gamma}$ = constant

(Karnataka NEET 2013)

26. Two Carnot engines A and B are operated in series. The engine A receives heat from the source at temperature T_1 and rejects the heat to the sink at temperature T. The second engine B receives the heat at temperature T and rejects to its sink at temperature T_2. For what value of T the efficiencies of the two engines are equal

(a) $\frac{T_1-T_2}{2}$ (b) T_1T_2

(c) $\sqrt{T_1T_2}$ (d) $\frac{T_1+T_2}{2}$

(Karnataka NEET 2013)

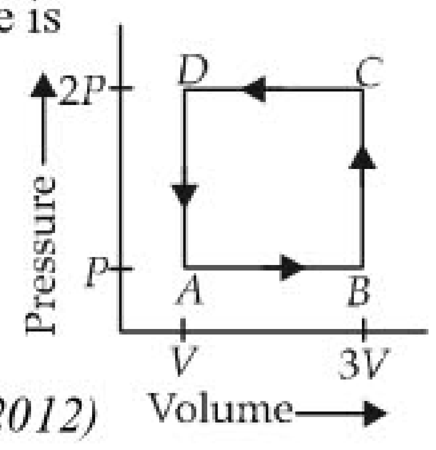
27. In a vessel, the gas is at pressure P. If the mass of all the molecules is halved and their speed is doubled, then the resultant pressure will be

(a) $2P$ (b) P

(c) $P/2$ (d) $4P$

(Karnataka NEET 2013)

28. A thermodynamic system is taken through the cycle $ABCD$ as shown in figure. Heat rejected by the gas during the cycle is



(a) $2PV$

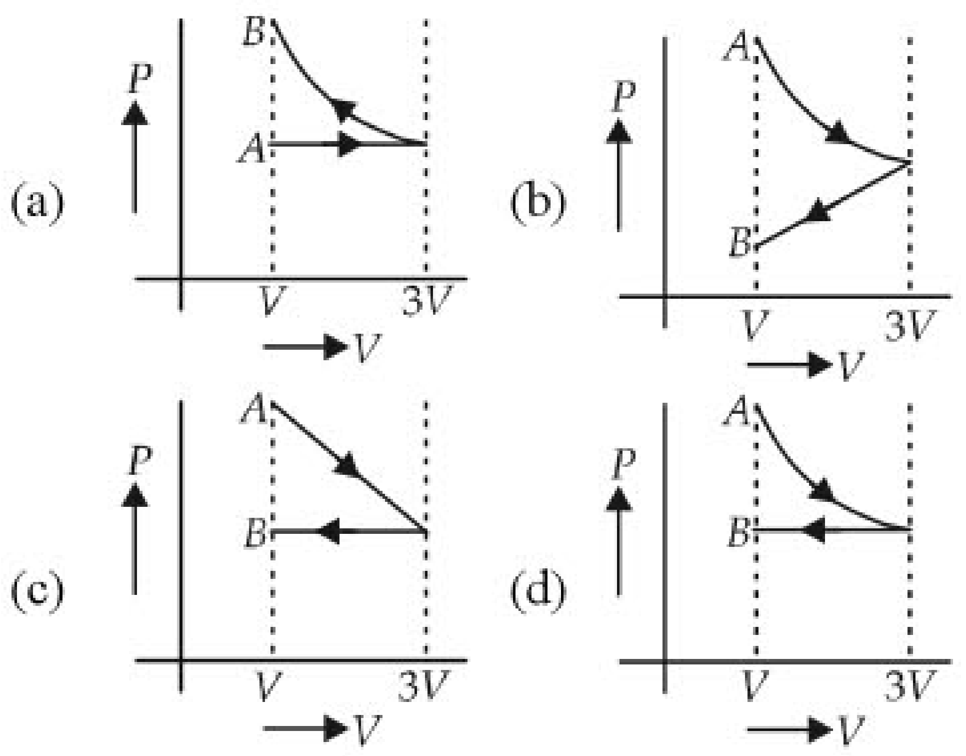
(b) $4PV$

(c) $\frac{1}{2}PV$

(d) PV *(2012)*

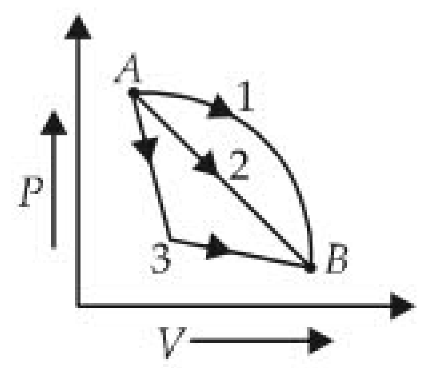
29. One mole of an ideal gas goes from an initial state A to final state B via two processes : It first undergoes isothermal expansion from volume V to $3V$ and then its volume is reduced from $3V$ to

V at constant pressure. The correct P-V diagram representing the two processes is



(2012)

30. An ideal gas goes from state A to state B via three different processes as indicated in the P-V diagram.



If Q_1, Q_2, Q_3 indicate the heat absorbed by the gas along the three processes and ΔU_1, ΔU_2, ΔU_3 indicate the change in internal energy along the three processes respectively, then

(a) $Q_1 > Q_2 > Q_3$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$
(b) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$
(c) $Q_1 = Q_2 = Q_3$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$
(d) $Q_3 > Q_2 > Q_1$ and $\Delta U_1 > \Delta U_2 > \Delta U_3$ *(Mains 2012)*

31. During an isothermal expansion, a confined ideal gas does –150 J of work against its surroundings. This implies that

(a) 150 J of heat has been removed from the gas
(b) 300 J of heat has been added to the gas
(c) no heat is transferred because the process is isothermal
(d) 150 J of heat has been added to the gas *(2011)*

32. When 1 kg of ice at 0°C melts to water at 0°C, the resulting change in its entropy, taking latent heat of ice to be 80 cal/°C, is

(a) 273 cal/K (b) 8×10^4 cal/K
(c) 80 cal/K (d) 293 cal/K *(2011)*

33. A mass of diatomic gas ($\gamma = 1.4$) at a pressure of 2 atmospheres is compressed adiabatically so that its temperature rises from 27°C to 927°C. The pressure of the gas in the final state is

(a) 8 atm (b) 28 atm
(c) 68.7 atm (d) 256 atm *(Mains 2011)*

34. If ΔU and ΔW represent the increase in internal energy and work done by the system respectively in a thermodynamical process, which of the following is true?

(a) $\Delta U = -\Delta W$, in an adiabatic process
(b) $\Delta U = \Delta W$, in an isothermal process
(c) $\Delta U = \Delta W$, in an adiabatic process
(d) $\Delta U = -\Delta W$, in an isothermal process *(2010)*

35. If c_p and c_v denote the specific heats (per unit mass of an ideal gas of molecular weight M, then

(a) $c_p - c_v = R/M^2$ (b) $c_p - c_v = R$
(c) $c_p - c_v = R/M$ (d) $c_p - c_v = MR$

where R is the molar gas constant. *(Mains 2010)*

36. A monatomic gas at pressure P_1 and volume V_1 is compressed adiabatically to $\frac{1}{8}$th of its original volume. What is the final pressure of the gas?

(a) $64P_1$ (b) P_1 (c) $16P_1$ (d) $32P_1$ *(Mains 2010)*

37. The internal energy change in a system that has absorbed 2 kcal of heat and done 500 J of work is

(a) 6400 J (b) 5400 J (c) 7900 J (d) 8900 J *(2009)*

38. In thermodynamic processes which of the following statements is not true?

(a) In an isochoric process pressure remains constant.
(b) In an isothermal process the temperature remains constant.
(c) In an adiabatic process PV^γ = constant.
(d) In an adiabatic process the system is insulated from the surroundings. *(2009)*

39. At 10°C the value of the density of a fixed mass of an ideal gas divided by it pressure is x. At 110°C this ratio is

(a) $\frac{10}{110}x$ (b) $\frac{283}{383}x$ (c) x (d) $\frac{383}{283}x$ *(2008)*

40. If Q, E and W denote respectively the heat added, change in internal energy and the work done in a closed cycle process, then

(a) $E = 0$ (b) $Q = 0$
(c) $W = 0$ (d) $Q = W = 0$ *(2008)*

41. An engine has an efficiency of 1/6. When the temperature of sink is reduced by 62°C, its efficiency is doubled. Temperatures of the source is
(a) 37°C (b) 62°C
(c) 99°C (d) 124°C. *(2007)*

42. A Carnot engine whose sink is at 300 K has an efficiency of 40%. By how much should the temperature of source be increased so as to increase its efficiency by 50% of original efficiency?
(a) 380 K (b) 275 K
(c) 325 K (d) 250 K *(2006)*

43. The molar specific heat at constant pressure of an ideal gas is (7/2)R. The ratio of specific heat at constant pressure to that at constant volume is
(a) 9/7 (b) 7/5
(c) 8/7 (d) 5/7. *(2006)*

44. An ideal gas heat engine operates in Carnot cycle between 227°C and 127°C. It absorbs 6×10^4 cal of heat at higher temperature. Amount of heat converted to work is
(a) 4.8×10^4 cal (b) 6×10^4 cal
(c) 2.4×10^4 cal (d) 1.2×10^4 cal. *(2005)*

45. Which of the following processes is reversible?
(a) Transfer of heat by conduction
(b) Transfer of heat by radiation
(c) Isothermal compression
(d) Electrical heating of a nichrome wire. *(2005)*

46. The equation of state for 5 g of oxygen at a pressure P and temperature T, when occupying a volume V, will be
(a) $PV = (5/32)RT$ (b) $PV = 5RT$
(c) $PV = (5/2)RT$ (d) $PV = (5/16)RT$
(where R is the gas constant) *(2004)*

47. One mole of an ideal gas at an initial temperature of T K does $6R$ joule of work adiabatically. If the ratio of specific heats of this gas at constant pressure and at constant volume is 5/3, the final temperature of gas will be
(a) $(T + 2.4)$ K (b) $(T - 2.4)$ K
(c) $(T + 4)$ K (d) $(T - 4)$ K *(2004)*

48. An ideal gas heat engine operates in a Carnot cycle between 227°C and 127°C. It absorbs 6 kcal at the higher temperature. The amount of heat (in kcal) converted into work is equal to
(a) 4.8 (b) 3.5
(c) 1.6 (d) 1.2 *(2003)*

49. The efficiency of Carnot engine is 50% and temperature of sink is 500 K. If temperature of source is kept constant and its efficiency raised to 60%, then the required temperature of sink will be
(a) 100 K (b) 600 K
(c) 400 K (d) 500 K *(2002)*

50. A scientist says that the efficiency of his heat engine which work at source temperature 127°C and sink temperature 27°C is 26%, then
(a) it is impossible
(b) it is possible but less probable
(c) it is quite probable
(d) data are incomplete. *(2001)*

51. The (W/Q) of a Carnot engine is 1/6, now the temperature of sink is reduced by 62°C, then this ratio becomes twice, therefore the initial temperature of the sink and source are respectively
(a) 33°C, 67°C (b) 37°C, 99°C
(c) 67°C, 33°C (d) 97 K, 37 K. *(2000)*

52. To find out degree of freedom, the expression is
(a) $f = \dfrac{2}{\gamma - 1}$ (b) $f = \dfrac{\gamma + 1}{2}$
(c) $f = \dfrac{2}{\gamma + 1}$ (d) $f = \dfrac{1}{\gamma + 1}$. *(2000)*

53. An ideal gas at 27°C is compressed adiabatically to 8/27 of its original volume. The rise in temperature is (Take $\gamma = 5/3$)
(a) 275 K (b) 375 K
(c) 475 K (d) 175 K *(1999)*

54. The degrees of freedom of a triatomic gas is
(a) 6 (b) 4
(c) 2 (d) 8 *(1999)*

55. If the ratio of specific heat of a gas at constant pressure to that at constant volume is γ, the change in internal energy of a mass of gas, when the volume changes from V to $2V$ at constant pressure P, is
(a) $\dfrac{PV}{(\gamma - 1)}$ (b) PV
(c) $\dfrac{R}{(\gamma - 1)}$ (d) $\dfrac{\gamma PV}{(\gamma - 1)}$ *(1998)*

56. 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 isothermal process
(b) $\Delta U = W$ in an isothermal process
(c) $\Delta U = -W$ in an adiabatic process
(d) $\Delta U = W$ in an adiabatic process *(1998)*

57. The efficiency of a Carnot engine operating with reservoir temperature of 100°C and – 23°C will be

(a) $\frac{373+250}{373}$ (b) $\frac{373-250}{373}$

(c) $\frac{100+23}{100}$ (d) $\frac{100-23}{100}$ *(1997)*

58. A sample of gas expands from volume V_1 to V_2. The amount of work done by the gas is greatest, when the expansion is

(a) adiabatic (b) equal in all cases

(c) isothermal (d) isobaric. *(1997)*

59. The value of critical temperature in terms of van der Waals' constant a and b is given by

(a) $T_C = \frac{8a}{27Rb}$ (b) $T_C = \frac{27a}{8Rb}$

(c) $T_C = \frac{a}{2Rb}$ (d) $T_C = \frac{a}{27Rb}$. *(1996)*

60. An ideal gas, undergoing adiabatic change, has which of the following pressure temperature relationship?

(a) $P^{\gamma}T^{1-\gamma}$ = constant (b) $P^{1-\gamma}T^{\gamma}$ = constant

(c) $P^{\gamma-1}T^{\gamma}$ = constant

(d) $P^{\gamma}T^{\gamma-1}$ = constant. *(1996)*

61. A diatomic gas initially at 18°C is compressed adiabatically to one eighth of its original volume. The temperature after compression will be

(a) 395.4°C (b) 144°C

(c) 18°C (d) 887.4°C. *(1996)*

62. At 0 K which of the following properties of a gas will be zero?

(a) vibrational energy (b) density

(c) kinetic energy (d) potential energy. *(1996)*

63. An ideal Carnot engine, whose efficiency is 40%, receives heat at 500 K. If its efficiency is 50%, then the intake temperature for the same exhaust temperature is

(a) 800 K (b) 900 K

(c) 600 K (d) 700 K. *(1995)*

64. In an adiabatic change, the pressure and temperature of a monatomic gas are related as $P \propto T^C$, where C equals

(a) $\frac{3}{5}$ (b) $\frac{5}{3}$ (c) $\frac{2}{5}$ (d) $\frac{5}{2}$. *(1994)*

65. Which of the following is not thermodynamical function ?

(a) Enthalpy (b) Work done

(c) Gibb's energy (d) Internal energy *(1993)*

66. 110 joule of heat is added to a gaseous system whose internal energy is 40 J, then the amount of external work done is

(a) 150 J (b) 70 J

(c) 110 J (d) 40 J *(1993)*

67. An ideal gas A and a real gas B have their volumes increased from V to $2V$ under isothermal conditions. The increase in internal energy

(a) will be same in both A and B

(b) will be zero in both the gases

(c) of B will be more than that of A

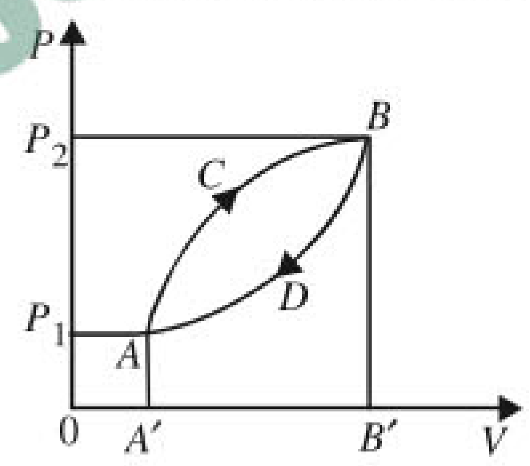
(d) of A will be more than that of B *(1993)*

68. The number of translational degrees of freedom for a diatomic gas is

(a) 2 (b) 3

(c) 5 (d) 6 *(1993)*

69. A thermodynamic system is taken from state A to B along ACB and is brought back to A along BDA as shown in the PV diagram. The net work done during the complete cycle is given by the area



(a) $P_1ACBP_2P_1$ (b) $ACBB'A'A$

(c) $ACBDA$ (d) $ADBB'A'A$ *(1992)*

70. If for a gas, $\frac{R}{C_V} = 0.67$, this gas is made up of molecules which are

(a) diatomic

(b) mixture of diatomic and polyatomic molecules

(c) monoatomic

(d) polyatomic *(1992)*

71. 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) $16b = a$

(c) $a = 4b$ (d) $a = b$ *(1991)*

72. Three containers of the same volume contain three different gases. The masses of the molecules are m_1, m_2 and m_3 and the number of molecules in their respective containers are N_1, N_2 and N_3. The gas pressure in the containers are P_1, P_2 and P_3 respectively. All the gases are now mixed and put in one of these containers. The pressure P of the mixture will be

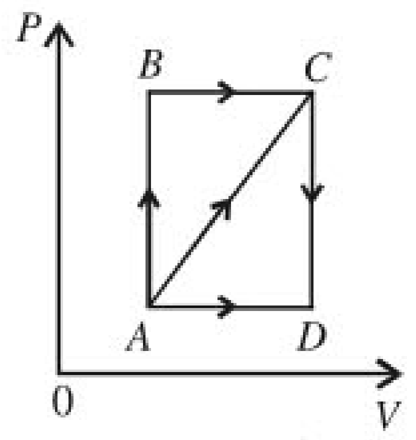
(a) $P < (P_1 + P_2 + P_3)$

(b) $P = \frac{P_1 + P_2 + P_3}{3}$

(c) $P = P_1 + P_2 + P_3$

(d) $P > (P_1 + P_2 + P_3)$ *(1991)*

73. A thermodynamic process is shown in the figure. The pressure and volumes corresponding to some points in the figure are $P_A = 3 \times 10^4$ Pa; $V_A = 2 \times 10^{-3}$ m^3; $P_B = 8 \times 10^4$ Pa; $V_D = 5 \times 10^{-3}$ m^3.
In the process AB, 600 J of heat is added to the system and in process BC, 200 J of heat is added to the system. The change in internal energy of the system is process AC would be



(a) 560 J (b) 800 J
(c) 600 J (d) 640 J *(1991)*

74. Relation between pressure (P) and energy (E) of a gas is

(a) $P = \frac{2}{3}E$ (b) $P = \frac{1}{3}E$
(c) $P = E$ (d) $P = 3E$ *(1991)*

75. One mole of an ideal gas requires 207 J heat to rise the temperature by 10 K when heated at constant pressure. If the same gas is heated at constant volume to raise the temperature by the same 10 K, the heat required is
(Given the gas constant R = 8.3 J/mole K)

(a) 198.7 J (b) 29 J
(c) 215.3 J (d) 124 J *(1990)*

76. According to kinetic theory of gases, at absolute zero of temperature

(a) water freezes
(b) liquid helium freezes
(c) molecular motion stops
(d) liquid hydrogen freezes *(1990)*

77. For a certain gas the ratio of specific heats is given to be $\gamma = 1.5$. For this gas

(a) $C_V = 3R/J$ (b) $C_P = 3R/J$
(c) $C_P = 5R/J$ (d) $C_V = 5R/J$ *(1990)*

78. A polyatomic gas with n degrees of freedom has a mean energy per molecule given by

(a) $\frac{nkT}{N}$ (b) $\frac{nkT}{2N}$
(c) $\frac{nkT}{2}$ (d) $\frac{3kT}{2}$ *(1989)*

79. At constant volume temperature is increased then

(a) collission on walls will be less
(b) number of collisions per unit time will increase
(c) collisions will be in straight lines
(d) collisions will not change *(1989)*

80. Two containers A and B are partly filled with water and closed. The volume of A is twice that of B and it contains half the amount of water in B. If both are at the same temperature, the water vapour in the containers will have pressure in the ratio of

(a) 1 : 2 (b) 1 : 1
(c) 2 : 1 (d) 4 : 1 *(1988)*

81. First law of thermodynamics is consequence of conservation of

(a) work (b) energy
(c) heat (d) all of these *(1988)*

Answer Key

1.	(a)	**2.**	(a)	**3.**	(c)	**4.**	(d)	**5.**	(b)	**6.**	(b)	**7.**	(d)	**8.**	(d)	**9.**	(a)	**10.**	(c)
11.	(d)	**12.**	(c)	**13.**	(a)	**14.**	(a)	**15.**	(d)	**16.**	(a)	**17.**	(c)	**18.**	(d)	**19.**	(b)	**20.**	(a)
21.	(d)	**22.**	(b)	**23.**	(c)	**24.**	(d)	**25.**	(d)	**26.**	(c)	**27.**	(a)	**28.**	(a)	**29.**	(d)	**30.**	(a)
31.	(d)	**32.**	(d)	**33.**	(d)	**34.**	(a)	**35.**	(c)	**36.**	(d)	**37.**	(c)	**38.**	(a)	**39.**	(b)	**40.**	(a)
41.	(c)	**42.**	(d)	**43.**	(b)	**44.**	(d)	**45.**	(c)	**46.**	(a)	**47.**	(d)	**48.**	(d)	**49.**	(c)	**50.**	(a)
51.	(b)	**52.**	(a)	**53.**	(b)	**54.**	(a)	**55.**	(a)	**56.**	(c)	**57.**	(b)	**58.**	(d)	**59.**	(a)	**60.**	(b)
61.	(a)	**62.**	(c)	**63.**	(c)	**64.**	(d)	**65.**	(b)	**66.**	(b)	**67.**	(b)	**68.**	(b)	**69.**	(c)	**70.**	(c)
71.	(d)	**72.**	(c)	**73.**	(a)	**74.**	(a)	**75.**	(d)	**76.**	(c)	**77.**	(b)	**78.**	(c)	**79.**	(b)	**80.**	(b)
81.	(b)																		

EXPLANATIONS

1. **(a) :** In process I, volume is constant

$\therefore$ Process I $\rightarrow$ Isochoric; P $\rightarrow$ C

As slope of curve II is more than the slope of curve III.

Process II $\rightarrow$ Adiabatic and Process III $\rightarrow$ Isothermal

$\therefore$ Q $\rightarrow$ A, R $\rightarrow$ D

In process IV, pressure is constant

Process IV $\rightarrow$ Isobaric; S $\rightarrow$ B

2. **(a) :** The relation between coefficient of performance and efficiency of carnot engine is given as

$$\beta = \frac{1-\eta}{\eta}$$

Given $\eta = \frac{1}{10}, W = 10\text{ J}$

$$\beta = \frac{1-\frac{1}{10}}{\frac{1}{10}} = \frac{9}{10}.10 = 9$$

Since, $\beta = \frac{Q_2}{W}$, where Q_2 is the amount of energy absorbed from the reservoir

$\therefore$ $Q_2 = \beta W = 9 \times 10 = 90$ J

3. **(c) :** The internal energy of 2 moles of O_2 atom is

$$U_{O_2} = \frac{n_1 f_1}{2} RT = 2 \times \frac{5}{2} \times RT$$

$$U_{O_2} = 5RT$$

The internal energy of 4 moles of Ar atom is

$$U_{Ar} = \frac{n_2 f_2 RT}{2} = 4 \times \frac{3}{2} \times RT = 6RT$$

$\therefore$ The total internal energy of the system is

$$U = U_{O_2} + U_{Ar} = 5RT + 6RT = 11RT$$

4. **(d) :** Process described by the equation,

PV^3 = constant

For a polytropic process, PV^{α} = constant

$$C = C_V + \frac{R}{1-\alpha} = \frac{3}{2}R + \frac{R}{1-3} = R$$

5. **(b) :** Temperature inside refrigerator = t_2 °C

Room temperature = t_1 °C

For refrigerator,

$$\frac{\text{Heat given to high temperature } (Q_1)}{\text{Heat taken from lower temperature } (Q_2)} = \frac{T_1}{T_2}$$

$$\frac{Q_1}{Q_2} = \frac{t_1+273}{t_2+273}$$

$$\Rightarrow \frac{Q_1}{Q_1 - W} = \frac{t_1+273}{t_2+273} \text{ or } 1 - \frac{W}{Q_1} = \frac{t_2+273}{t_1+273}$$

or $\frac{W}{Q_1} = \frac{t_1 - t_2}{t_1 + 273}$

The amount of heat delivered to the room for each joule of electrical energy (W = 1 J)

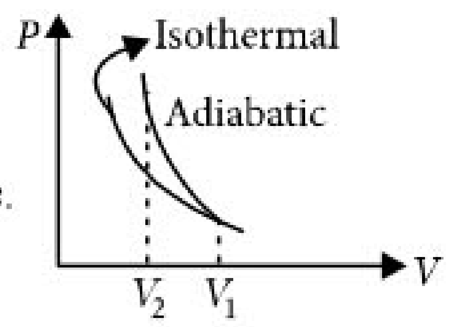
$$Q_1 = \frac{t_1+273}{t_1-t_2}$$

6. **(b) :** As $PV = nRT$ or $n = \frac{PV}{RT} = \frac{\text{mass}}{\text{molar mass}}$ ...(i)

Density, $\rho = \frac{\text{mass}}{\text{volume}} = \frac{(\text{molar mass})P}{RT} = \frac{(mN_A)P}{RT}$ [From eqn. (i)]

$$\rho = \frac{mP}{kT} \qquad (\because R = N_A k)$$

7. **(d) :** $V_1 = V$, $V_2 = V/2$



On P-V diagram,

Area under adiabatic curve

> Area under isothermal curve.

So compressing the gas through adiabatic process will require more work to be done.

8. **(d) :** As, $v_{\text{rms}} = \sqrt{\frac{3k_B T}{m}}$

$$\therefore \frac{v_{27}}{v_{127}} = \sqrt{\frac{27+273}{127+273}} = \sqrt{\frac{300}{400}} = \frac{\sqrt{3}}{2}$$

or $v_{127} = \frac{2}{\sqrt{3}} \times v_{27} = \frac{2}{\sqrt{3}} \times 200 \text{ m s}^{-1} = \frac{400}{\sqrt{3}} \text{ m s}^{-1}$

9. **(a) :** Given, $T_2 = 4°\text{C} = 277$ K, $T_1 = 30°\text{C} = 303$ K

Q_2 = 600 cal per second

Coefficient of performance, $\alpha = \frac{T_2}{T_1 - T_2}$

$$= \frac{277}{303-277} = \frac{277}{26}$$

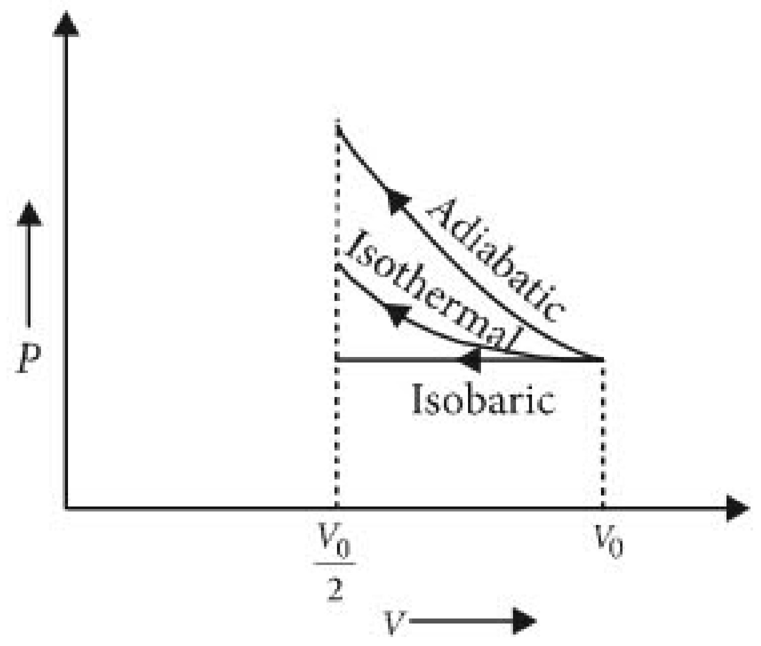
Also, $\alpha = \frac{Q_2}{W}$

$\therefore$ Work to be done per second = power required

$$= W = \frac{Q_2}{\alpha} = \frac{26}{277} \times 600 \text{ cal per second}$$

$$= \frac{26}{277} \times 600 \times 4.2 \text{ J per second} = 236.5 \text{ W}$$

10. (c) : The P-V diagram of an ideal gas compressed from its initial volume V_0 to $\frac{V_0}{2}$ by several processes is shown in the figure.



Work done on the gas = Area under P–V curve
As area under the P–V curve is maximum for adiabatic process, so work done on the gas is maximum for adiabatic process.

11. (d): According to an ideal gas equation, the molecular weight of an ideal gas is

$$M = \frac{\rho RT}{P} \qquad \left(\text{as } P = \frac{\rho RT}{M}\right)$$

where P, T and ρ are the pressure, temperature and density of the gas respectively and R is the universal gas constant.

$\therefore$ The molecular weight of A is

$M_A = \frac{\rho_A RT_A}{P_A}$ and that of B is $M_B = \frac{\rho_B RT_B}{P_B}$

Hence, their corresponding ratio is

$$\frac{M_A}{M_B} = \left(\frac{\rho_A}{\rho_B}\right)\left(\frac{T_A}{T_B}\right)\left(\frac{P_B}{P_A}\right)$$

Here, $\frac{\rho_A}{\rho_B} = 1.5 = \frac{3}{2}, \frac{T_A}{T_B} = 1$ and $\frac{P_A}{P_B} = 2$

$$\therefore \quad \frac{M_A}{M_B} = \left(\frac{3}{2}\right)(1)\left(\frac{1}{2}\right) = \frac{3}{4}$$

12. (c): The coefficient of performance of a refrigerator is

$$\alpha = \frac{T_2}{T_1 - T_2}$$

where T_1 and T_2 are the temperatures of hot and cold reservoirs (in kelvin) respectively.

Here, $\alpha = 5$, $T_2 = -20°\text{C} = -20 + 273\text{ K} = 253\text{ K}$

$T_1 = ?$

$$\therefore \quad 5 = \frac{253\text{ K}}{T_1 - 253\text{ K}}$$

$$5T_1 - 5(253\text{ K}) = 253\text{ K}$$

$$5T_1 = 253\text{ K} + 5(253\text{ K}) = 6(253\text{ K})$$

$$T_1 = \frac{6}{5}(253\text{K}) = 303.6\text{ K} = 303.6 - 273$$

$$= 30.6°\text{C} \approx 31°\text{C}$$

13. (a) For n degrees of freedom, $C_v = \frac{n}{2}R$

Also, $C_p - C_v = R$

$$C_p = C_v + R = \frac{n}{2}R + R = \left(\frac{n}{2} + 1\right)R$$

$$\gamma = \frac{C_p}{C_v} = \frac{\left(\frac{n}{2}+1\right)R}{(n/2)R} = \frac{n+2}{n} \quad \therefore \quad \gamma = 1 + \frac{2}{n}$$

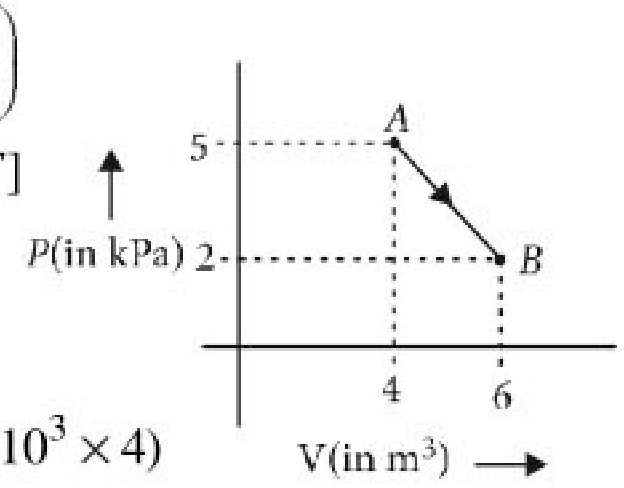
14. (a)

15. (d) : We know, $\Delta U = nC_v\Delta T$

$$= n\left(\frac{5R}{2}\right)(T_B - T_A) \qquad \left[\text{for diatomic gas}, C_v = \frac{5R}{2}\right]$$

$$= \frac{5nR}{2}\left(\frac{P_BV_B}{nR} - \frac{P_AV_A}{nR}\right)$$

$[\because PV = nRT]$

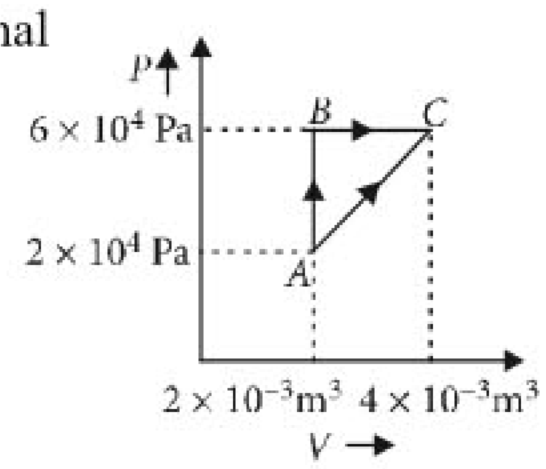


$$= \frac{5}{2}(P_BV_B - P_AV_A)$$

$$= \frac{5}{2}(2\times10^3 \times 6 - 5\times10^3 \times 4)$$

$$= \frac{5}{2}(-8\times10^3) = -20\text{ kJ}$$

16. (a) : As initial and final points are same so



$\Delta U_{ABC} = \Delta U_{AC}$

AB is isochoric process.

$\Delta W_{AB} = 0$

$\Delta Q_{AB} = \Delta U_{AB} = 400$ J

BC is isobaric process.

$\Delta Q_{BC} = \Delta U_{BC} + \Delta W_{BC}$

$100 = \Delta U_{BC} + 6\times10^4 (4\times10^{-3} - 2\times10^{-3})$

$100 = \Delta U_{BC} + 12\times10$

$\Delta U_{BC} = 100 - 120 = -20$ J

As, $\Delta U_{ABC} = \Delta U_{AC}$

$\Delta U_{AB} + \Delta U_{BC} = \Delta Q_{AC} - \Delta W_{AC}$

$$400 - 20 = \Delta Q_{AC} - \left(2\times10^4 \times 2\times10^{-3} + \frac{1}{2}\times2\times10^{-3} \times4\times10^4\right)$$

$\Delta Q_{AC} = 460$J

17. (c) : First, isothermal expansion

$PV = P'(2V)$; $P' = \frac{P}{2}$

Then, adiabatic expansion

$P'(2V)^{\gamma} = P_f(16V)^{\gamma}$

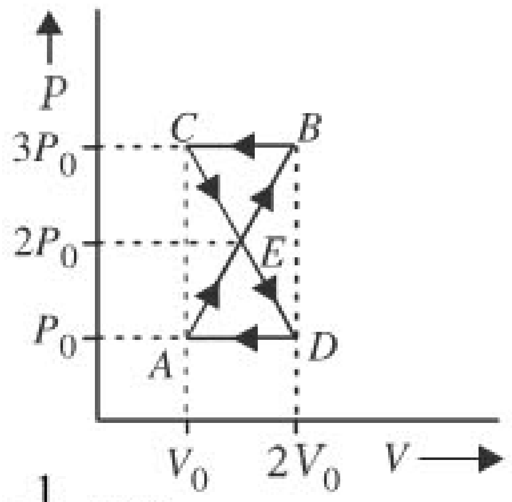
(For adiabatic process, PV^{γ} = constant)

$$\frac{P}{2}(2V)^{5/3} = P_f\,(16V)^{5/3}$$

$$P_f = \frac{P}{2}\left(\frac{2V}{16V}\right)^{5/3} = \frac{P}{2}\left(\frac{1}{8}\right)^{5/3} = \frac{P}{2}\left(\frac{1}{2^3}\right)^{5/3}$$

$$= \frac{P}{2}\left(\frac{1}{2^5}\right) = \frac{P}{64}$$

18. (d) : In a cyclic process work done is equal to the area under the cycle and is positive if the cycle is clockwise and negative if anticlockwise.



As is clear from figure,

$$W_{AEDA} = +\text{area of } \Delta AED = +\frac{1}{2}P_0V_0$$

$$W_{BCEB} = -\text{Area of } \Delta BCE = -\frac{1}{2}P_0V_0$$

The net work done by the system is

$$W_{\text{net}} = W_{AEDA} + W_{BCEB}$$

$$= +\frac{1}{2}P_0V_0 - \frac{1}{2}P_0V_0 = \text{zero}$$

19. (b) : Mean free path, $\lambda = \dfrac{1}{\sqrt{2}n\pi d^2}$

where n is the number density and d is the diameter of the molecule.

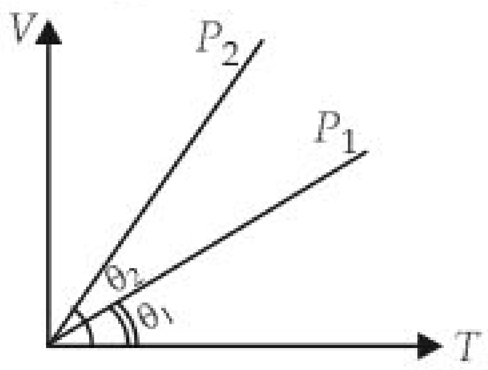
As $d = 2r$

$$\therefore\ \lambda = \frac{1}{4\sqrt{2}n\pi r^2} \quad \text{or} \quad \lambda \propto \frac{1}{r^2}$$

20. (a) : According to ideal gas equation

$PV = nRT$

or $V = \dfrac{nRT}{P}$



For an isobaric process,

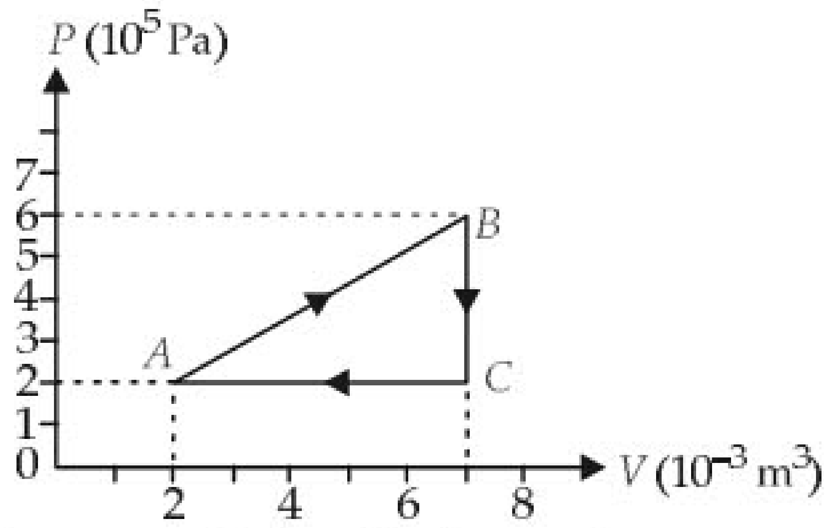
P = constant and $V \propto T$

Therefore, $V - T$ graph is a straight line passing through origin. Slope of this line is inversely proportional to P.

In the given figure,

$(\text{Slope})_2 > (\text{Slope})_1 \quad \therefore P_2 < P_1$

21. (d) : In a cyclic process, work done is equal to the area under the cycle and is positive if the cycle is clockwise and negative if the cycle is anticlockwise.



$\therefore$ The net work done by the gas is

W = Area of the cycle $ABCA$

$$= \frac{1}{2}\times(7-2)\times10^{-3}\times(6-2)\times10^{5}$$

$$= \frac{1}{2}\times5\times10^{-3}\times4\times10^{5} = 10 \times 10^2\text{ J} = 1000\text{ J}$$

22. (b) : $P \propto T^3$; $\quad PT^{-3}$ = constant ...(i)

For an adiabatic process, $PT^{\gamma/1-\gamma}$ = constant ...(ii)

Comparing (i) and (ii), we get

$$\frac{\gamma}{1-\gamma} = -3;\ \gamma = -3 + 3\gamma$$

$$-2\gamma = -3 \text{ or } \gamma = \frac{3}{2}$$

As $\gamma = \dfrac{C_p}{C_v} \quad \therefore \dfrac{C_p}{C_v} = \dfrac{3}{2}$

23. (c) : As here volume of the gas remains constant, therefore the amount of heat energy required to raise the temperature of the gas is

$\Delta Q = nC_V\,\Delta T$

Here,

Number of moles, $n = \dfrac{1}{4}$

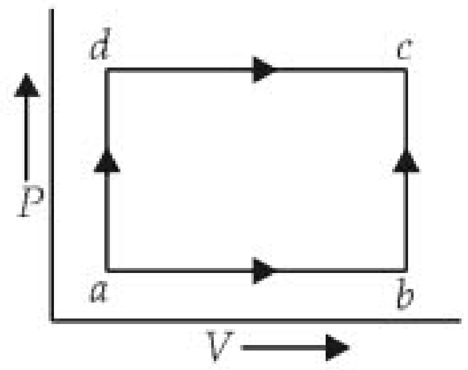
$C_V = \dfrac{3}{2}R$ $\quad$ ($\because$ He is a monatomic.)

$\Delta T = T_2 - T_1$

$$\therefore\ \Delta Q = \frac{1}{4}\frac{3}{2}R(T_2 - T_1)$$

$$= \frac{3}{8}N_a k_B(T_2 - T_1) \qquad \left(\because k_B = \frac{R}{N_a}\right)$$

24. (d) : According to first law of thermodynamics,



$\delta Q = \delta U + \delta W$

Along the path adc

Change in internal energy,

$\delta U_1 = \delta Q_1 - \delta W_1$

$= 50\text{ J} - 20\text{ J} = 30\text{ J}$

Along the path abc

Change in internal energy,

$\delta U_2 = \delta Q_2 - \delta W_2$; $\delta U_2 = 36\text{ J} - \delta W_2$

As change in internal energy is path independent.

$\therefore \quad \delta U_1 = \delta U_2 \Rightarrow 30\text{ J} = 36\text{ J} - \delta W_2$

$\delta W_2 = 36\text{ J} - 30\text{ J} = 6\text{ J}$

25. (d) : For an adiabatic process,

$PV^\gamma = \text{constant}$ ...(i)

According to ideal gas equation

$$PV = nRT \Rightarrow P = \frac{nRT}{V}$$

Putting (i), we get

$$\frac{nRT}{V}V^\gamma = \text{constant} \; ; \; \therefore \; TV^{\gamma-1} = \text{constant}$$

Again from the ideal gas equation

$$V = \frac{nRT}{P}$$

Putting in (i), we get

$$P\left(\frac{nRT}{P}\right)^\gamma = \text{constant} \; ; \; P^{1-\gamma}T^\gamma = \text{constant}$$

26. (c) : Efficiency of a Carnot engine

$$\eta = 1 - \frac{T_2}{T_1}$$

where T_1 is the temperature of source and T_2 is the temperature of sink respectively.

For engine A, $\eta_A = 1 - \frac{T}{T_1}$

For engine B, $\eta_B = 1 - \frac{T_2}{T}$

As per question, $\eta_A = \eta_B$

$$\therefore \quad 1 - \frac{T}{T_1} = 1 - \frac{T_2}{T} \Rightarrow \frac{T}{T_1} = \frac{T_2}{T} \text{ or } T = \sqrt{T_1 T_2}$$

27. (a) : As $P = \frac{1}{3}\frac{mN}{V}v_{\text{rms}}^2$ ...(i)

where m is the mass of each molecule, N is the total number of molecules, V is the volume of the gas.

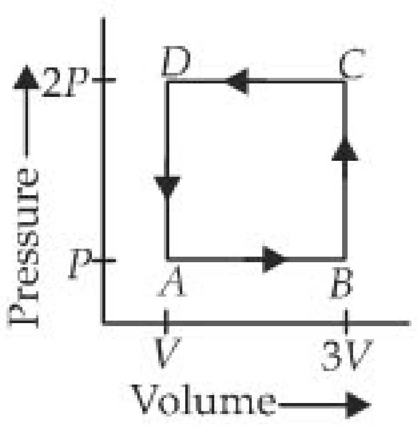
When mass of all the molecules is halved and their speed is doubled, then the pressure will be

$$P' = \frac{1}{3}\left(\frac{m}{2}\right) \times \frac{N}{V} \times (2v_{\text{rms}})^2 = \frac{2}{3}\frac{mN}{V}v_{\text{rms}}^2 = 2P$$

(Using (i))

28. (a) : In a cyclic process, $\Delta U = 0$.

In a cyclic process work done is equal to the area under the cycle and is positive if the cycle is clockwise and negative if anticlockwise.



$\therefore \quad \Delta W = -\text{Area of rectangle } ABCD = -P(2V)$

$= -2PV$

According to first law of thermodynamics

$\Delta Q = \Delta U + \Delta W$ or $\Delta Q = \Delta W$ (As $\Delta U = 0$)

i.e., heat supplied to the system is equal to the work done

So heat absorbed, $\Delta Q = \Delta W = -2PV$

$\therefore$ Heat rejected by the gas $= 2PV$

29. (d)

30. (a) : Change in internal energy is path independent and depends only on the initial and final states.

As the initial and final states in the three processes are same. Therefore,

$$\Delta U_1 = \Delta U_2 = \Delta U_3$$

Workdone, W = Area under P-V graph

As area under curve 1 > area under curve 2 > area under curve 3

$\therefore \quad W_1 > W_2 > W_3$

According to first law of thermodynamics,

$$Q = W + \Delta U$$

As $W_1 > W_2 > W_3$ and $\Delta U_1 = \Delta U_2 = \Delta U_3$

$\therefore \quad Q_1 > Q_2 > Q_3$

31. (d)

32. (d) : Heat required to melt 1 kg ice at 0°C to water at 0°C is

$Q = m_{\text{ice}} L_{\text{ice}}$ = (1 kg) (80 cal/g)

= (1000 g) (80 cal/g) = 8×10^4 cal

Change in entropy, $\Delta S = \frac{Q}{T} = \frac{8 \times 10^4 \text{ cal}}{(273\text{ K})}$

= 293 cal/K

Note : In the question paper unit of latent heat of ice is given to be cal/°C. It is wrong. The unit of latent heat of ice is cal/g.

33. (d) : For an adiabatic process

$$\frac{T^\gamma}{P^{\gamma-1}} = \text{constant}$$

$$\therefore \quad \left(\frac{T_i}{T_f}\right)^\gamma = \left(\frac{P_i}{P_f}\right)^{\gamma-1} \; ; \; P_f = P_i\left(\frac{T_f}{T_i}\right)^{\frac{\gamma}{\gamma-1}} \quad \text{...(i)}$$

Here, T_i = 27°C = 300 K, T_f = 927°C = 1200 K

P_i = 2 atm, $\gamma = 1.4$

Substituting these values in eqn (i), we get

$$P_f = (2)\left(\frac{1200}{300}\right)^{\frac{1.4}{1.4-1}}$$

$= (2)(4)^{1.4/0.4} = 2(2^2)^{7/2} = (2)(2)^7 = 2^8 = 256$ atm

34. (a) : According to first law of thermodynamics

$$\Delta Q = \Delta U + \Delta W$$

where,

ΔQ = Heat supplied to the system

ΔU = Increase in internal energy of the system
ΔW = Work done by the system

For an adiabatic process
$\Delta Q = 0 \quad \therefore \ \Delta U = -\Delta W$

For an isothermal process
$\Delta U = 0$
$\therefore \ \Delta Q = \Delta W$

Hence, option (a) is true.

35. (c) : Let C_V and C_P be molar specific heats of the ideal gas at constant volume and constant pressure, respectively, then

$C_P = Mc_p$ and $C_V = Mc_v$

$C_P - C_V = R \quad \therefore \ Mc_p - Mc_v = R \Rightarrow c_p - c_v = R/M$

36. (d) : Ideal gas equation, for an adiabatic process is

PV^γ = constant or $P_1V_1^\gamma = P_2V_2^\gamma$

For monoatomic gas $\gamma = \dfrac{5}{3}$

$$\therefore \quad P_1V_1^{5/3} = P_2\left(\frac{V_1}{8}\right)^{5/3}$$

$\Rightarrow \ P_2 = P_1 \times (2)^5 = 32\,P_1.$

37. (c) : Heat energy given $dQ = dU + dW$ where dU is the change in internal energy and dW is the work done.

Given dQ = 2 kcal = 2000 × 4.2 J and dW = 500 J

$\therefore \ 2000 \times 4.2 = dU + 500 \Rightarrow dU = 7900$ J.

38. (a) : In isochoric process, it is volume that is kept constant. If pressure is kept constant, it is an isobaric process.

39. (b) : Mass of the gas = m.

At a fixed temperature and pressure, volume is fixed.

Density of the gas $\rho = \dfrac{m}{V} \Rightarrow \dfrac{m}{V.P} = \dfrac{m}{nRT} = x$

$\therefore \ xT$ = constant.

At 10°C *i.e.*, 283 K, $xT = x$ 283 K

At 110°C, $xT = x'$ 383 K

$$\Rightarrow \ x' = \frac{283}{383}x$$

40. (a) : Internal energy depends only on the initial and final states of temperature and not on the path. In a cyclic process, as initial and final states are the same, change in internal energy is zero. Hence E is ΔU, the change in internal energy.

41. (c) : Efficiency of an engine, $\eta = 1 - \dfrac{T_2}{T_1}$

where T_1 is the temperature of the source and T_2 is the temperature of the sink.

$$\therefore \quad \frac{1}{6} = 1 - \frac{T_2}{T_1} \quad \text{or,} \quad \frac{T_2}{T_1} = \frac{5}{6} \qquad \text{...(i)}$$

When the temperature of the sink is decreased by 62°C (or 62 K), efficiency becomes double.

Since, the temperature of the source remains unchanged

$$\therefore \quad 2 \times \frac{1}{6} = 1 - \frac{(T_2 - 62)}{T_1} \quad \text{or,} \quad \frac{1}{3} = 1 - \frac{(T_2 - 62)}{T_1}$$

$$\text{or,} \quad \frac{2}{3} = \frac{T_2 - 62}{T_1} \quad \text{or,} \quad 2T_1 = 3T_2 - 186$$

$$\text{or,} \quad 2T_1 = 3\left[\frac{5}{6}\right]T_1 - 186 \quad \text{[using (i)]}$$

$$\therefore \quad \left[\frac{5}{2} - 2\right]T_1 = 186 \quad \text{or,} \quad \frac{T_1}{2} = 186$$

or, T_1 = 372 K = 99°C.

42. (d) : Efficiency of a Carnot engine, $\eta = 1 - \dfrac{T_2}{T_1}$

$$\text{or,} \quad \frac{T_2}{T_1} = 1 - \eta = 1 - \frac{40}{100} = \frac{3}{5}$$

$$\therefore \quad T_1 = \frac{5}{3} \times T_2 = \frac{5}{3} \times 300 = 500 \text{ K.}$$

Increase in efficiency = 50% of 40% = 20%

New efficiency, η' = 40% + 20% = 60%

$$\therefore \quad \frac{T_2}{T_1'} = 1 - \frac{60}{100} = \frac{2}{5}$$

$$T_1' = \frac{5}{2} \times T_2 = \frac{5}{2} \times 300 = 750 \text{ K.}$$

Increase in temperature of source = $T_1' - T_1$
= 750 – 500 = 250 K.

43. (b) : Molar specific heat at constant pressure

$$C_P = \frac{7}{2}R$$

$$\therefore \quad C_V = C_P - R = \frac{7}{2}R - R = \frac{5}{2}R.$$

$$\therefore \quad \frac{C_P}{C_V} = \frac{(7/2)R}{(5/2)R} = \frac{7}{5}$$

44. (d) : $1 - \dfrac{T_2}{T_1} = 1 - \dfrac{Q_2}{Q_1} \Rightarrow 1 - \dfrac{400}{500} = 1 - \dfrac{Q_2}{6 \times 10^4}$

$\Rightarrow \ \dfrac{4}{5} = \dfrac{Q_2}{6 \times 10^4} \Rightarrow Q_2 = 4.8 \times 10^4$ cal.

Net heat converted into work
= $6.0 \times 10^4 - 4.8 \times 10^4 = 1.2 \times 10^4$ cal.

45. (c) : Isothermal compression is reversible, for example, Carnot cycle, heat engine.

46. (a) : As $PV = nRT$

$$n = \frac{m}{\text{molecular mass}} = \frac{5}{32} \Rightarrow PV = \left(\frac{5}{32}\right)RT$$

47. (d) : Work done in adiabatic process is given as

$$W = \frac{-1}{\gamma-1}\left(P_f V_f - P_i V_i\right)$$

$$6R = \frac{-1}{5/3-1}R\left(T_f - T_i\right) \quad \text{[using } PV = RT\text{]}$$

$\Rightarrow$ $T_f - T_i = -4 \quad \therefore T_f = (T-4)$ K

48. (d) : Efficiency of Carnot engine

$$= \frac{W}{Q_1} = 1 - \frac{T_2}{T_1}$$

$$\frac{W}{6} = 1 - \frac{400}{500} = \frac{1}{5} \Rightarrow W = \frac{6}{5} = 1.2 \text{ kcal.}$$

49. (c) : Efficiency (η) of a carnot engine is given by

$\eta = 1 - \frac{T_2}{T_1}$, where T_1 is the temperature of the source and T_2 is the temperature of the sink.

Here, T_2 = 500 K

$\therefore \quad 0.5 = 1 - \frac{500}{T_1} \Rightarrow T_1 = 1000 \text{ K}.$

Now, $\eta = 0.6 = 1 - \frac{T_2'}{1000}$ (T_2' is the new sink temperature)

$\Rightarrow$ T_2' = 400 K.

50. (a) : Efficiency is maximum in Carnot engine which is an ideal engine.

$\because \quad \eta = \frac{400-300}{400} \times 100\% = 25\%$

$\therefore$ efficiency 26% is impossible for his heat engine.

51. (b) : $\frac{1}{6} = 1 - \frac{T_2}{T_1}$ or $\frac{5}{6} = \frac{T_2}{T_1}$

and $\frac{1}{3} = 1 - \frac{T_2 - 62}{T_1} = 1 - \frac{5}{6} + \frac{62}{T_1}$

$T_1 = 62 \times 6 = 99°C$ and $T_2 = 37°C$

52. (a) : $\gamma = 1 + \frac{2}{f}$

where f is the degree of freedom

$\therefore \quad \frac{2}{f} = \gamma - 1$ or $f = \frac{2}{\gamma-1}$.

53. (b) : $TV^{\gamma-1}$ = constant (adiabatic).

$\therefore$ (300) $(V_0)^{2/3} = (V_f)^{2/3}\ T$

$$T = 300\left(\frac{27}{8}\right)^{2/3} = 300 \times \left(\frac{3}{2}\right)^{3\times\frac{2}{3}} = \frac{300\times 9}{4} = 675 \text{ K}$$

Temperature rise = 675 – 300 = 375 K

54. (a) : 3 translational, 3 rotational.

55. (a) : Change in internal energy, $\Delta U = nC_V\Delta T$

$$= \frac{nR\Delta T}{(\gamma-1)} = \frac{nP\Delta V}{(\gamma-1)} = \frac{nP(2V-V)}{\gamma-1}.$$

For one mole, n = 1. $\therefore$ $\Delta U = PV/(\gamma - 1)$.

56. (c) : According to first law of thermodynamics

$\Delta Q = \Delta U + W$

For an adiabatic process, $\Delta Q = 0$.

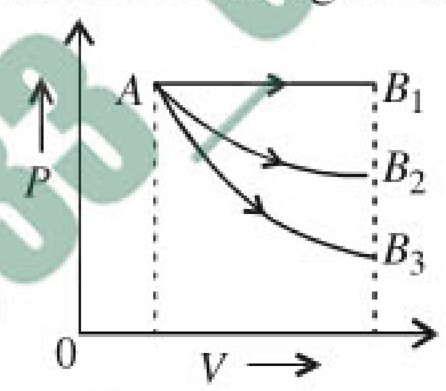
$\therefore \quad \Delta U = -W$.

57. (b) : Reservoir temperature (T_1) = 100°C = 373 K and T_2 = – 23°C = 250 K.

The efficiency of a Carnot engine

$$\eta = \frac{T_1 - T_2}{T_1} = \frac{373-250}{373}.$$

58. (d) : During expansion, work is performed by the gas. The isobaric expansion is represented by the horizontal straight line AB_1, since the adiabatic curve is steeper than the isothermal curve, the adiabatic expansion curve (AB_3) must lie below the isothermal curve (AB_2) as shown in the figure below



Since area under AB_1, is maximum, the work done is maximum in case of isobaric expansion.

59. (a)

60. (b) : For the adiabatic change, PV^{γ} = constant.

And for ideal gas, $V = \frac{RT}{P} \propto \frac{T}{P}$.

Therefore $P^{1-\gamma}T^{\gamma}$ = Constant.

61. (a) : Initial temperature (T_1) = 18°C

= (273 + 18) = 291 K and $V_2 = (1/8)\ V_1$.

For adiabatic compression, $TV^{\gamma-1}$ = constant

or $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$.

$$\text{Therefore } T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$= 291 \times (8)^{1.4-1} = 291 \times (8)^{0.4}$

$= 291 \times 2.297 = 668.4$ K. = 395.4°C.

62. (c)

63. (c) : Efficiency of Carnot engine $(\eta_1) = 40\% = 0.4$;

Heat intake = 500 K and

New efficiency $(\eta_2) = 50\ \% = 0.5$.

The efficiency $(\eta) = 1 - \frac{T_2}{T_1}$ or $\frac{T_2}{T_1} = 1 - \eta$.

For first case, $\frac{T_2}{500} = 1 - 0.4$ or $T_2 = 300$ K.

For second case, $\frac{300}{T_1} = 1 - 0.5$ or $T_1 = 600$ K.

64. (d) : For adiabatic change, PV^{γ} = constant

$\Rightarrow \quad P\left(\frac{RT}{\rho}\right)^{\gamma}$ = constant $\Rightarrow P^{1-\gamma}T^{\gamma}$ = constant

$\Rightarrow \quad P \propto T^{\frac{-\gamma}{1-\gamma}}$.

Therefore, the value of constant $C = \frac{\gamma}{(\gamma - 1)}$. For monoatomic gas, $\gamma = \frac{5}{3}$.

Therefore $C = \frac{5/3}{(5/3)-1} = \frac{5/3}{2/3} = \frac{5}{2}$.

65. (b) : Work done is not a thermodynamical function.

66. (b) : $\Delta Q = \Delta U + \Delta W$

$\Rightarrow \quad \Delta W = \Delta Q - \Delta U = 110 - 40 = 70$ J.

67. (b) : Under isothermal conditions, there is no change in internal energy.

68. (b) : Number of translational degrees of freedom are same for all types of gases.

69. (c) : Work done = Area under curve $ACBDA$

70. (c) : Since $\frac{R}{C_V} = 0.67 \Rightarrow \frac{C_P - C_V}{C_V} = 0.67$

$\Rightarrow \quad \gamma = 1.67 = \frac{5}{3}$

Hence gas is monoatomic.

71. (d) : $C_P - C_V = R$ for all gases.

72. (c) : According to Dalton's law of partial pressure, we have $P = P_1 + P_2 + P_3$

73. (a) : Since AB is a isochoric process. So no work is done. BC is isobaric process

$W = P_B \times (V_D - V_A) = 240$ J

Therefore $\Delta Q = 600 + 200 = 800$ J

Using $\Delta Q = \Delta U + \Delta W$

$\Rightarrow \quad \Delta U = \Delta Q - \Delta W = 800 - 240 = 560$ J

74. (a) : $\frac{1}{3}Nmc^2 = \frac{2}{3}\left(\frac{1}{2}Nm\right)c^2 = \frac{2}{3}E$

75. (d) : Using $C_P - C_V = R$,

C_P is heat needed for raising by 10 K.

$\therefore \quad C_P = 20.7$ J/mole K

Given $R = 8.3$ J/mole K

$\therefore \quad C_V = 20.7 - 8.3 = 12.4$ J/mole K

$\therefore$ For raising by 10 K = 124 J.

76. (c) : According to classical theory all motion of molecules stop at 0 K.

77. (b) : $\gamma = \frac{C_P}{C_V} = \frac{15}{10} = \frac{3}{2} \Rightarrow C_V = \frac{2}{3}C_P$

$C_P - C_V = \frac{R}{J}$ or $C_P - \frac{2}{3}C_P = \frac{R}{J}$

or $\frac{C_P}{3} = \frac{R}{J}$ or $C_P = \frac{3R}{J}$

78. (c) : According to law of equipartition of energy, the energy per degree of freedom is $\frac{1}{2}kT$. For a polyatomic gas with n degrees of freedom, the mean energy per molcule = $\frac{1}{2}nkT$

79. (b) : As the temperature increases, the average velocity increases. So, the collisions are faster.

80. (b) : Vapour pressure does not depend on the amount of substance. It depends on the temperature alone.

81. (b) : Conservation of energy.

Chapter 10 Oscillations

1. A spring of force constant k is cut into lengths of ratio 1 : 2 : 3. They are connected in series and the new force constant is k'. Then they are connected in parallel and force constant is k''. Then $k' : k''$ is

(a) 1 : 9 (b) 1 : 11

(c) 1 : 14 (d) 1 : 6

(NEET 2017)

2. A particle executes linear simple harmonic motion with an amplitude of 3 cm. When the particle is at 2 cm from the mean position, the magnitude of its velocity is equal to that of its acceleration. Then its time period in seconds is

(a) $\frac{\sqrt{5}}{2\pi}$ (b) $\frac{4\pi}{\sqrt{5}}$

(c) $\frac{2\pi}{\sqrt{3}}$ (d) $\frac{\sqrt{5}}{\pi}$

(NEET 2017)

3. A body of mass m is attached to the lower end of a spring whose upper end is fixed. The spring has negligible mass. When the mass m is slightly pulled down and released, it oscillates with a time period of 3 s. When the mass m is increased by 1 kg, the time period of oscillations becomes 5 s. The value of m in kg is

(a) $\frac{3}{4}$ (b) $\frac{4}{3}$

(c) $\frac{16}{9}$ (d) $\frac{9}{16}$

(NEET-II 2016)

4. A particle is executing a simple harmonic motion. Its maximum acceleration is α and maximum velocity is β. Then, its time period of vibration will be

(a) $\frac{\beta^2}{\alpha}$ (b) $\frac{2\pi\beta}{\alpha}$

(c) $\frac{\beta^2}{\alpha^2}$ (d) $\frac{\alpha}{\beta}$ *(2015)*

5. A particle is executing SHM along a straight line. Its velocities at distances x_1 and x_2 from the mean position are V_1 and V_2, respectively. Its time period is

(a) $2\pi\sqrt{\frac{V_1^2+V_2^2}{x_1^2+x_2^2}}$ (b) $2\pi\sqrt{\frac{V_1^2-V_2^2}{x_1^2-x_2^2}}$

(c) $2\pi\sqrt{\frac{x_1^2+x_2^2}{V_1^2+V_2^2}}$ (d) $2\pi\sqrt{\frac{x_2^2-x_1^2}{V_1^2-V_2^2}}$

(2015 Cancelled)

6. When two displacements represented by $y_1 = a\sin(\omega t)$ and $y_2 = b\cos(\omega t)$ are superimposed the motion is

(a) simple harmonic with amplitude $\sqrt{a^2+b^2}$

(b) simple harmonic with amplitude $\frac{(a+b)}{2}$

(c) not a simple harmonic

(d) simple harmonic with amplitude $\frac{a}{b}$

(2015 Cancelled)

7. The oscillation of a body on a smooth horizontal surface is represented by the equation,

$X = A\cos(\omega t)$

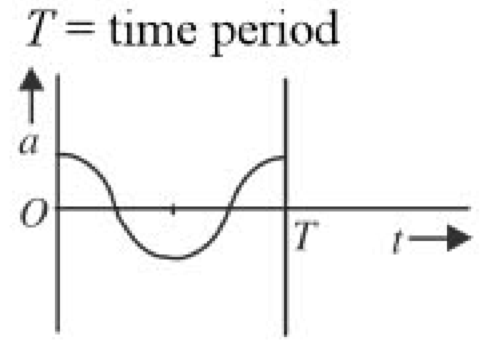
where X = displacement at time t

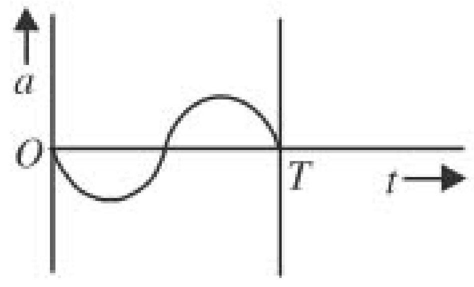
ω = frequency of oscillation

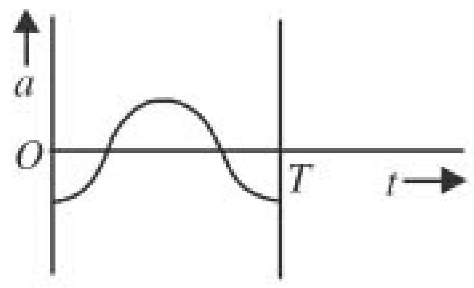
Which one of the following graphs shows correctly the variation a with t?

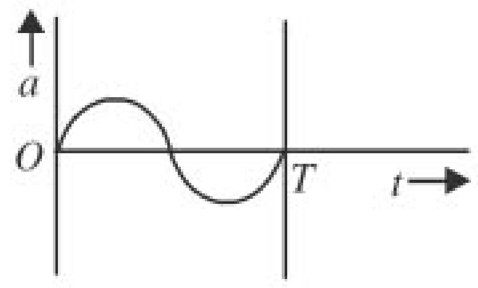
Here a = acceleration at time t

T = time period

(a) 

(b) 

(c) 

(d) 

(2014)

8. A particle of mass m oscillates along x-axis according to equation $x = a\sin\omega t$. The nature of the graph between momentum and displacement of the particle is
(a) Circle
(b) Hyperbola
(c) Ellipse
(d) Straight line passing through origin
(Karnataka NEET 2013)

9. Out of the following functions representing motion of a particle which represents SHM
(1) $y = \sin\omega t - \cos\omega t$
(2) $y = \sin^3\omega t$
(3) $y = 5\cos\left(\frac{3\pi}{4} - 3\omega t\right)$
(4) $y = 1 + \omega t + \omega^2 t^2$
(a) Only (1)
(b) Only (4) does not represent SHM
(c) Only (1) and (3)
(d) Only (1) and (2) *(2011)*

10. Two particles are oscillating along two close parallel straight lines side by side, with the same frequency and amplitudes. They pass each other, moving in opposite directions when their displacement is half of the amplitude. The mean positions of the two particles lie on a straight line perpendicular to the paths of the two particles. The phase difference is
(a) $\frac{\pi}{6}$ (b) 0
(c) $\frac{2\pi}{3}$ (d) π *(Mains 2011)*

11. The displacement of a particle along the x-axis is given by $x = a\sin^2\omega t$. The motion of the particle corresponds to
(a) simple harmonic motion of frequency ω/π
(b) simple harmonic motion of frequency $3\omega/2\pi$
(c) non simple harmonic motion
(d) simple harmonic motion of frequency $\omega/2\pi$
(2010)

12. The period of oscillation of a mass M suspended from a spring of negligible mass is T. If along with it another mass M is also suspended, the period of oscillation will now be
(a) T (b) $\frac{T}{\sqrt{2}}$
(c) $2T$ (d) $\sqrt{2}T$
(2010)

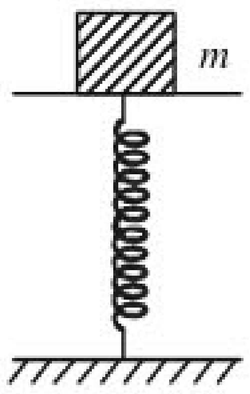
13. A simple pendulum performs simple harmonic motion about $x = 0$ with an amplitude a and time period T. The speed of the pendulum at $x = a/2$ will be
(a) $\frac{\pi a}{T}$ (b) $\frac{3\pi^2 a}{T}$
(c) $\frac{\pi a\sqrt{3}}{T}$ (d) $\frac{\pi a\sqrt{3}}{2T}$
(2009)

14. Which one of the following equations of motion represents simple harmonic motion?
(a) Acceleration = $-k(x + a)$
(b) Acceleration = $k(x + a)$
(c) Acceleration = kx
(d) Acceleration = $-k_0x + k_1x^2$
where k, k_0, k_1 and a are all positive.
(2009)

15. Two simple harmonic motions of angular frequency 100 and 1000 rad s^{-1} have the same displacement amplitude. The ratio of their maximum acceleration is
(a) $1 : 10^3$ (b) $1 : 10^4$
(c) $1 : 10$ (d) $1 : 10^2$ *(2008)*

16. A particle executes simple harmonic oscillation with an amplitude a. The period of oscillation is T. The minimum time taken by the particle to travel half of the amplitude from the equilibrium position is
(a) $T/8$ (b) $T/12$
(c) $T/2$ (d) $T/4$. *(2007)*

17. A mass of 2.0 kg is put on a flat pan attached to a vertical spring fixed on the ground as shown in the figure. The mass of the spring and the pan is negligible. When pressed slightly and released the mass executes a simple harmonic motion. The spring constant is 200 N/m. What should be the minimum amplitude of the motion so that the mass gets detached from the pan (take $g = 10$ m/s^2).



(a) 10.0 cm
(b) any value less than 12.0 cm
(c) 4.0 cm
(d) 8.0 cm. *(2007)*

18. The particle executing simple harmonic motion has a kinetic energy $K_0\cos^2\omega t$. The maximum values of the potential energy and the total energy are respectively

(a) $K_0/2$ and K_0 (b) K_0 and $2K_0$
(c) K_0 and K_0 (d) 0 and $2K_0$. *(2007)*

19. The phase difference between the instantaneous velocity and acceleration of a particle executing simple harmonic motion is

(a) π (b) 0.707π
(c) zero (d) 0.5π. *(2007)*

20. A rectangular block of mass m and area of cross-section A floats in a liquid of density ρ. If it is given a small vertical displacement from equilibrium it undergoes with a time period T, then

(a) $T \propto \frac{1}{\sqrt{m}}$ (b) $T \propto \sqrt{\rho}$
(c) $T \propto \frac{1}{\sqrt{A}}$ (d) $T \propto \frac{1}{\rho}$ *(2006)*

21. The circular motion of a particle with constant speed is

(a) periodic but not simple harmonic
(b) simple harmonic but not periodic
(c) period and simple harmonic
(d) neither periodic not simple harmonic. *(2005)*

22. A particle executing simple harmonic motion of amplitude 5 cm has maximum speed of 31.4 cm/s. The frequency of its oscillation is

(a) 4 Hz (b) 3 Hz
(c) 2 Hz (d) 1 Hz. *(2004)*

23. Two springs of spring constants k_1 and k_2 are joined in series. The effective spring constant of the combination is given by

(a) $\sqrt{k_1k_2}$ (b) $(k_1 + k_2)/2$
(c) $k_1 + k_2$ (d) $k_1k_2/(k_1 + k_2)$ *(2004)*

24. Which one of the following statements is true for the speed v and the acceleration a of a particle executing simple harmonic motion ?

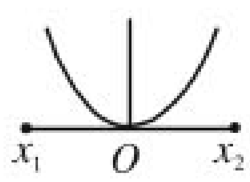
(a) When v is maximum, a is maximum.
(b) Value of a is zero, whatever may be the value of v.
(c) When v is zero, a is zero.
(d) When v is maximum, a is zero. *(2003)*

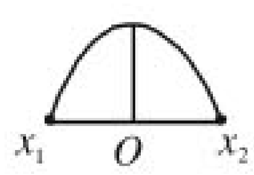
25. The potential energy of a simple harmonic oscillator when the particle is half way to its end point is

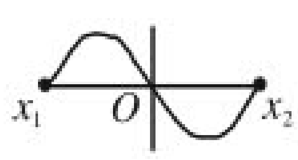
(a) $\frac{2}{3}E$ (b) $\frac{1}{8}E$
(c) $\frac{1}{4}E$ (d) $\frac{1}{2}E$ *(2003)*

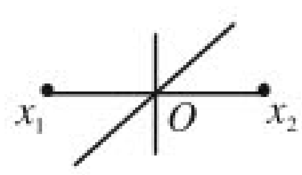
where E is the total energy.

26. A particle of mass m oscillates with simple harmonic motion between points x_1 and x_2, the equilibrium position being O. Its potential energy is plotted. It will be as given below in the graph

(a)


(b)


(c)


(d)


(2003)

27. The time period of mass suspended from a spring is T. If the spring is cut into four equal parts and the same mass is suspended from one of the parts, then the new time period will be

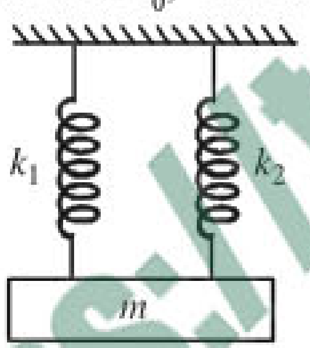
(a) $T/4$ (b) T
(c) $T/2$ (d) $2T$ *(2003)*

28. In case of a forced vibration, the resonance peak becomes very sharp when the
(a) damping force is small
(b) restoring force is small
(c) applied periodic force is small
(d) quality factor is small *(2003)*

29. Displacement between maximum potential energy position and maximum kinetic energy postion for a particle executing simple harmonic motion is
(a) $\pm a/2$ (b) $+a$
(c) $\pm a$ (d) -1. *(2002)*

30. When an oscillator completes 100 oscillations its amplitude reduced to $\frac{1}{3}$ of initial value. What will be its amplitude, when it completes 200 oscillations?
(a) $\frac{1}{8}$ (b) $\frac{2}{3}$
(c) $\frac{1}{6}$ (d) $\frac{1}{9}$. *(2002)*

31. A mass is suspended separately by two different springs in successive order then time periods is t_1 and t_2 respectively. If it is connected by both spring as shown in figure then time period is t_0, the correct relation is



(a) $t_0^2 = t_1^2 + t_2^2$ (b) $t_0^{-2} = t_1^{-2} + t_2^{-2}$
(c) $t_0^{-1} = t_1^{-1} + t_2^{-1}$ (d) $t_0 = t_1 + t_2$. *(2002)*

32. The total energy of particle performing SHM depend on
(a) k, a, m (b) k, a
(c) k, a, x (d) k, x. *(2001)*

33. Two masses M_A and M_B are hung from two strings of length l_A and l_B respectively. They are executing SHM with frequency relation $f_A = 2f_B$, then relation
(a) $l_A = \frac{l_B}{4}$, does not depend on mass
(b) $l_A = 4l_B$, does not depend on mass
(c) $l_A = 2l_B$ and $M_A = 2M_B$
(d) $l_A = \frac{l_B}{2}$ and $M_A = \frac{M_B}{2}$. *(2000)*

34. The bob of simple pendulum having length l, is displaced from mean position to an angular position q with respect to vertical. If it is released, then velocity of bob at equilibrium position
(a) $\sqrt{2gl(1-\cos\theta)}$ (b) $\sqrt{2gl(1+\cos\theta)}$
(c) $\sqrt{2gl\cos\theta}$ (d) $\sqrt{2gl}$. *(2000)*

35. Time period of a simple pendulum is 2 sec. If its length is increased by 4 times, then its period becomes
(a) 8 sec (b) 12 sec
(c) 16 sec (d) 4 sec *(1999)*

36. A particle, with restoring force proportional to displacement and resisting force proportional to velocity is subjected to a force $F \sin \omega t$. If the amplitude of the particle is maximum for $\omega = \omega_1$ and the energy of the particle maximum for $\omega = \omega_2$, then
(a) $\omega_1 \neq \omega_0$ and $\omega_2 = \omega_0$
(b) $\omega_1 = \omega_0$ and $\omega_2 = \omega_0$
(c) $\omega_1 = \omega_0$ and $\omega_2 \neq \omega_0$
(d) $\omega_1 \neq \omega_0$ and $\omega_2 \neq \omega_0$ *(1989, 1998)*

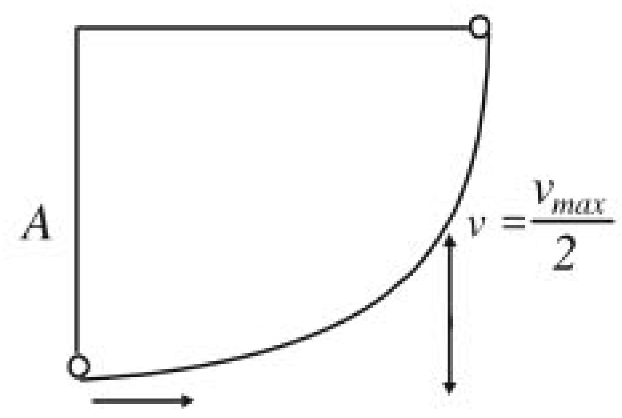
37. Two simple pendulums of length 5 m and 20 m respectively are given small linear displacement in one direction at the same time. They will again be in the phase when the pendulum of shorter length has completed ______ oscillations.
(a) 2 (b) 1
(c) 5 (d) 3 *(1998)*

38. 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) $\frac{n}{2}$ (b) $4n$
(c) $\frac{n}{4}$ (d) $2n$ *(1998)*

39. If the length of a simple pendulum is increased by 2%, then the time period
(a) increases by 1%
(b) decreases by 1%
(c) increases by 2%
(d) decreases by 2%. *(1997)*

40. Two SHM's with same amplitude and time period, when acting together in perpendicular directions with a phase difference of $\pi/2$, give rise to
(a) straight motion (b) elliptical motion
(c) circular motion (d) none of these. *(1997)*

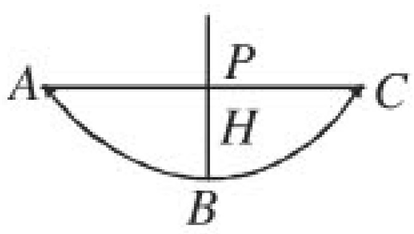
41. A particle starts with S.H.M. from the mean position as shown in the figure. Its amplitude is A and its time period is T. At one time, its speed is half that of the maximum speed. What is this displacement?



(a) $\frac{2A}{\sqrt{3}}$
(b) $\frac{3A}{\sqrt{2}}$
(c) $\frac{\sqrt{2}A}{3}$
(d) $\frac{\sqrt{3}A}{2}$. *(1996)*

42. A linear harmonic oscillator of force constant 2×10^6 N/m and amplitude 0.01 m has a total mechanical energy of 160 J. Its
(a) P.E. is 160 J (b) P.E. is zero
(c) P.E. is 100 J (d) P.E. is 120 J. *(1996)*

43. A simple pendulum with a bob of mass m oscillates from A to C and back to A such that PB is H. If the acceleration due to gravity is g, then the velocity of the bob as it passes through B is



(a) mgH
(b) $\sqrt{2gH}$
(c) zero
(d) $2gH$. *(1995)*

44. In a simple harmonic motion, when the displacement is one-half the amplitude, what fraction of the total energy is kinetic?
(a) 1/2 (b) 3/4
(c) zero (d) 1/4. *(1995)*

45. A body of mass 5 kg hangs from a spring and oscillates with a time period of 2π seconds. If the ball is removed, the length of the spring will decrease by
(a) g/k metres (b) k/g metres
(c) 2π metres (d) g metres. *(1994)*

46. A particle executes S.H.M. along x-axis. The force acting on it is given by
(a) $A\cos(kx)$ (b) Ae^{-kx}
(c) Akx (d) $-Akx$. *(1994, 1988)*

47. A seconds pendulum is mounted in a rocket. Its period of oscillation will decrease when rocket is
(a) moving down with uniform acceleration
(b) moving around the earth in geostationary orbit
(c) moving up with uniform velocity
(d) moving up with uniform acceleration. *(1994)*

48. A loaded vertical spring executes S.H.M. with a time period of 4 sec. The difference between the kinetic energy and potential energy of this system varies with a period of
(a) 2 sec (b) 1 sec
(c) 8 sec (d) 4 sec. *(1994)*

49. A body executes simple harmonic motion with an amplitude A. At what displacement from the mean position is the potential energy of the body is one fourth of its total energy?
(a) $A/4$ (b) $A/2$
(c) $3A/4$
(d) Some other fraction of A *(1993)*

50. A simple harmonic oscillator has an amplitude A and time period T. The time required by it to travel from $X = A$ to $A = A/2$ is
(a) $T/6$ (b) $T/4$
(c) $T/3$ (d) $T/2$ *(1992)*

51. If a simple harmonic oscillator has got a displacement of 0.02 m and acceleration equal to 0.02 m/s^2 at any time, the angular frequency of the oscillator is equal to
(a) 10 rad/s (b) 0.1 rad/s
(c) 100 rad/s (d) 1 rad/s *(1992)*

52. A simple pendulum is suspended from the roof of a trolley which moves in a horizontal direction with an acceleration a, then the time period is given by $T = 2\pi\sqrt{(l/g)}$, where g is equal to
(a) g (b) $g - a$
(c) $g + a$ (d) $\sqrt{(g^2 + a^2)}$ *(1991)*

53. A body is executing simple harmonic motion. When the displacements from the mean position is 4 cm and 5 cm, the corresponding velocities of the body is 10 cm/sec and 8 cm/sec. Then the time period of the body is

(a) 2π sec (b) $\pi/2$ sec
(c) π sec (d) $3\pi/2$ sec

(1991)

54. The angular velocity and the amplitude of a simple pendulum is ω and a respectively. At a displacement x from the mean position if its kinetic energy is T and potential energy is V, then the ratio of T to V is

(a) $\frac{(a^2 - x^2\omega^2)}{x^2\omega^2}$ (b) $\frac{x^2\omega^2}{(a^2 - x^2\omega^2)}$

(c) $\frac{(a^2 - x^2)}{x^2}$ (d) $\frac{x^2}{(a^2 - x^2)}$

(1991)

55. The composition of two simple harmonic motions of equal periods at right angle to each other and with a phase difference of π results in the displacment of the particle along

(a) circle
(b) figure of eight
(c) straight line
(d) ellipse *(1990)*

56. A mass m is suspended from the two coupled springs connected in series. The force constant for springs are k_1 and k_2. The time period of the suspended mass will be

(a) $T = 2\pi\sqrt{\frac{m}{k_1 - k_2}}$

(b) $T = 2\pi\sqrt{\frac{mk_1k_2}{k_1 + k_2}}$

(c) $T = 2\pi\sqrt{\frac{m}{k_1 + k_2}}$

(d) $T = 2\pi\sqrt{\frac{m(k_1 + k_2)}{k_1k_2}}$ *(1990)*

Answer Key

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

EXPLANATIONS

1. **(b)** : Let us assume, the length of spring be l. When we cut the spring into ratio of length 1 : 2 : 3, we get three springs of lengths $\frac{l}{6}, \frac{2l}{6}$ and $\frac{3l}{6}$ with force constant,

$\therefore \quad k_1 = \frac{kl}{l_1} = \frac{kl}{l/6} = 6k$

$k_2 = \frac{kl}{l_2} = \frac{kl}{2l/6} = 3k$

$k_3 = \frac{kl}{l_3} = \frac{kl}{3l/6} = 2k$

When connected in series,

$$\frac{1}{k'} = \frac{1}{6k} + \frac{1}{3k} + \frac{1}{2k} = \frac{1+2+3}{6k} = \frac{1}{k}$$

$\therefore \quad k' = k$

When connected in parallel,

$k'' = 6k + 3k + 2k = 11k$

$$\frac{k'}{k''} = \frac{k}{11k} = \frac{1}{11}$$

2. **(b)** : Given, $A = 3$ cm, $x = 2$ cm

The velocity of a particle in simple harmonic motion is given as

$v = \omega\sqrt{A^2 - x^2}$

and magnitude of its acceleration is

$a = \omega^2 x$

Given $|v| = |a|$

$\therefore \quad \omega\sqrt{A^2 - x^2} - \omega^2 x$

$\omega x = \sqrt{A^2 - x^2}$ or $\omega^2 x^2 = A^2 - x^2$

$$\omega^2 = \frac{A^2 - x^2}{x^2} = \frac{9-4}{4} = \frac{5}{4}$$

$$\omega = \frac{\sqrt{5}}{2}$$

Time period, $T = \frac{2\pi}{\omega} = 2\pi . \frac{2}{\sqrt{5}} = \frac{4\pi}{\sqrt{5}}$ s

3. **(d)** : Time period of spring - block system,

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

For given spring, $T \propto \sqrt{m}$

$$\frac{T_1}{T_2} = \sqrt{\frac{m_1}{m_2}}$$

Here, $T_1 = 3$ s, $m_1 = m$, $T_2 = 5$ s, $m_2 = m + 1$, $m = ?$

$$\frac{3}{5} = \sqrt{\frac{m}{m+1}} \text{ or } \frac{9}{25} = \frac{m}{m+1}$$

$25m = 9m + 9 \Rightarrow 16m = 9$

$\therefore \quad m = \frac{9}{16}$ kg

4. **(b)** : If A and ω be amplitude and angular frequency of vibration, then

$\alpha = \omega^2 A$ ...(i)

and $\beta = \omega A$ ...(ii)

Dividing eqn. (i) by eqn. (ii), we get

$$\frac{\alpha}{\beta} = \frac{\omega^2 A}{\omega A} = \omega$$

$\therefore$ Time period of vibration is

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{(\alpha/\beta)} = \frac{2\pi\beta}{\alpha}$$

5. **(d)** : In SHM, velocities of a particle at distances x_1 and x_2 from mean position are given by

$V_1^2 = \omega^2(a^2 - x_1^2)$ ... (i)

$V_2^2 = \omega^2(a^2 - x_2^2)$ ... (ii)

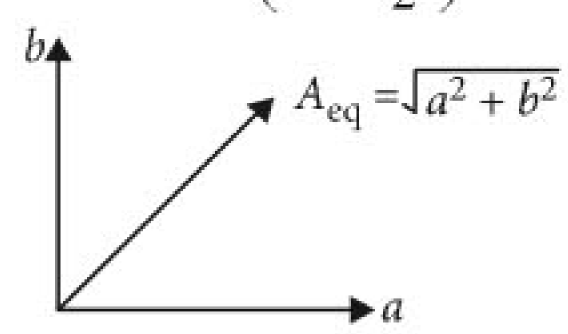
From equations (i) and (ii), we get

$$V_1^2 - V_2^2 = \omega^2(x_2^2 - x_1^2)$$

$$\omega = \sqrt{\frac{V_1^2 - V_2^2}{x_2^2 - x_1^2}} \quad \therefore \quad T = 2\pi\sqrt{\frac{x_2^2 - x_1^2}{V_1^2 - V_2^2}}$$

6. **(a)** : Here, $y_1 = a\sin\omega t$

$$y_2 = b\cos\omega t = b\sin\left(\omega t + \frac{\pi}{2}\right)$$



Hence, resultant motion is SHM with amplitude $\sqrt{a^2 + b^2}$.

7. **(c)**: Here, $X = A\cos\omega t$

$$\therefore \quad \text{Velocity, } v = \frac{dX}{dt} = \frac{d}{dt}(A\cos\omega t) = -A\omega\sin\omega t$$

Acceleration, $a = \frac{dv}{dt} = \frac{d}{dt}(-A\omega \sin \omega t)$
$= -A\omega^2 \cos\omega t$

Hence the variation of a with t is correctly shown by graph (c).

8. **(c) :** $x = a \sin\omega t$ or $\frac{x}{a} = \sin\omega t$ ...(i)

Velocity, $v = \frac{dx}{dt} = a\omega\cos\omega t$

$\frac{v}{a\omega} = \cos\omega t$ ...(ii)

Squaring and adding (i) and (ii), we get

$$\frac{x^2}{a^2} + \frac{v^2}{a^2\omega^2} = \sin^2\omega t + \cos^2\omega t$$

$$\frac{x^2}{a^2} + \frac{v^2}{a^2\omega^2} = 1$$

It is an equation of ellipse.

Hence, the graph between velocity and displacement is an ellipse.

Momentum of the particle = mv

$\therefore$ The nature of graph of the momentum and displacement is same as that of velocity and displacement.

9. **(c) :** $y = \sin\omega t - \cos\omega t$

$$= \sqrt{2}\left[\frac{1}{\sqrt{2}}\sin\omega t - \frac{1}{\sqrt{2}}\cos\omega t\right] = \sqrt{2}\sin\left(\omega t - \frac{\pi}{4}\right)$$

It represents a SHM with time period, $T = \frac{2\pi}{\omega}$.

$$y = \sin^3\omega t = \frac{1}{4}[3\sin\omega t - \sin 3\omega t]$$

It represents a periodic motion with time period $T = \frac{2\pi}{\omega}$ but not SHM.

$$y = 5\cos\left(\frac{3\pi}{4} - 3\omega t\right)$$

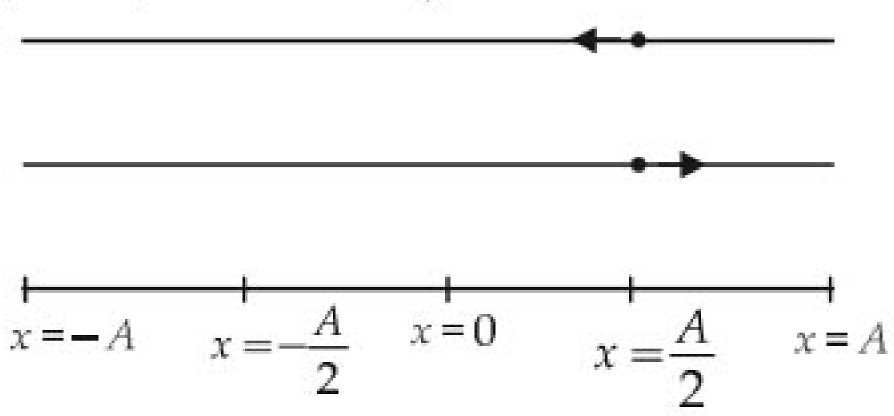
$$= 5\cos\left(3\omega t - \frac{3\pi}{4}\right) \quad [\because \cos(-\theta) = \cos\theta]$$

It represents a SHM with time period, $T = \frac{2\pi}{3\omega}$.

$y = 1 + \omega t + \omega^2 t^2$

It represents a non-periodic motion. Also it is not physically acceptable as the $y \to \infty$ as $t \to \infty$.

10. **(c) :**



The time taken by the particle to travel from $x = 0$ to $x = \frac{A}{2}$ is $\frac{T}{12}$.

The time taken by the particle to travel from $x = A$ to $x = \frac{A}{2}$ is $\frac{T}{6}$.

Time difference $= \frac{T}{6} + \frac{T}{6} = \frac{T}{3}$

Phase difference, $\phi = \frac{2\pi}{T} \times \text{Time difference}$

$$= \frac{2\pi}{T} \times \frac{T}{3} = \frac{2\pi}{3}$$

11. **(c) :** $x = a\sin^2\omega t$

$$= a\left(\frac{1 - \cos 2\omega t}{2}\right) \quad (\because \cos 2\theta = 1 - 2\sin^2\theta)$$

$$= \frac{a}{2} - \frac{a\cos 2\omega t}{2}$$

$\therefore$ Velocity, $v = \frac{dx}{dt} = \frac{2\omega a \sin 2\omega t}{2} = \omega a \sin 2\omega t$

Acceleration, $a = \frac{dv}{dt} = 2\omega^2 a \cos 2\omega t$

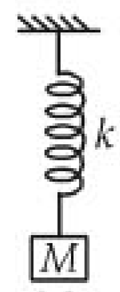
For the given displacement $x = a\sin^2\omega t$, $a \propto -x$ is not satisfied.

Hence, the motion of the particle is non simple harmonic motion.

Note : The given motion is a periodic motion with a time period

$$T = \frac{2\pi}{2\omega} = \frac{\pi}{\omega}$$

12. **(d) :** A mass M is suspended from a massless spring of spring constant k as shown in figure (a). Then,

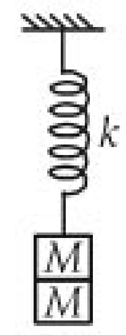


(a)

Time period of oscillation is

$$T = 2\pi\sqrt{\frac{M}{k}} \quad \text{...(i)}$$

When a another mass M is also suspended with it as shown in figure (b). Then,



(b)

Time period of oscillation is

$$T' = 2\pi\sqrt{\frac{M+M}{k}} = 2\pi\sqrt{\frac{2M}{k}}$$

$$= \sqrt{2}\left(2\pi\sqrt{\frac{M}{k}}\right) = \sqrt{2}\,T \quad \text{(Using (i))}$$

13. **(c) :** For simple harmonic motion,

$v = \omega\sqrt{a^2 - x^2}$. When $x = \frac{a}{2}$, When $x = \frac{a}{2}$, $v = \omega\sqrt{a^2 - \frac{a^2}{4}} = \omega\sqrt{\frac{3}{4}a^2}$.

As $\omega = \frac{2\pi}{T}$, $\therefore\ v = \frac{2\pi}{T}\cdot\frac{\sqrt{3}}{2}a \Rightarrow\ v = \frac{\pi\sqrt{3}a}{T}$.

14. (*) : Simple harmonic motion is defined as follows

Acceleration $\frac{d^2y}{dt^2} = -\omega^2 x$

The negative sign is very important in simple harmonic motion. Acceleration is independent of any initial displacement of equilibrium position.

Then acceleration = $-\omega^2 x$.

* Option not given.

15. (d) : $\omega_1 = 100$ rad s^{-1}; $\omega_2 = 1000$ rad s^{-1}.

Maximum acceleration of (1) $= -\omega_1^2 A$

Maximum acceleration of (2) $= -\omega_2^2 A$

$$\therefore\ \frac{\text{accln (1)}}{\text{accln (2)}} = \frac{\omega_1^2}{\omega_2^2} = \frac{(100)^2}{(1000)^2} = \frac{1}{100}$$

$a(1) : a(2) = 1 : 100$.

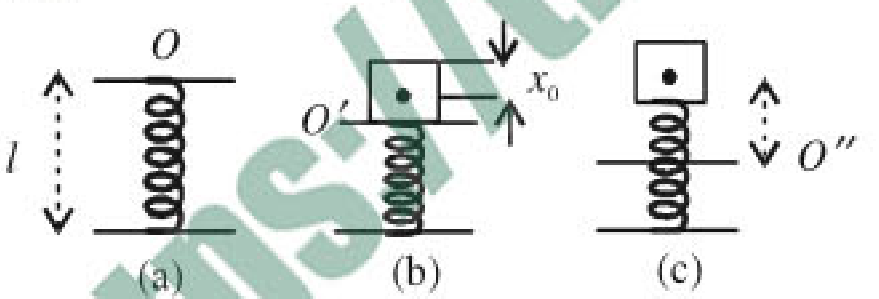
16. (b) : $x(t) = a\sin\omega t$ (from the equilibriuim position)

At $x(t) = a/2$

$$\therefore\ \frac{a}{2} = a\sin(\omega t)$$

$$\Rightarrow\ \sin\left(\frac{\pi}{6}\right) = \sin(\omega t) \quad \text{or,}\quad \frac{\pi}{6} = \frac{2\pi t}{T}\left[\because\ \omega = \frac{2\pi}{T}\right]$$

or $t = T/12$.

17. (a) : 

The spring has a length l. Whem m is placed over it, the equilibrium position becomes O'.

If it is pressed from O' (the equilibrium position) to O'', $O'O''$ is the amplitude.

$$OO' = \frac{mg}{k} = \frac{2\times 10}{200} = 0.10 \text{ m.}$$

$mg = kx_0$.

If the restoring force $mA\omega^2 > mg$, then the mass will move up with acceleration, detached from the pan.

i.e. $A > \frac{g}{k/m}\ \Rightarrow\ A > \frac{20}{200} > 0.10$ m.

The amplitude > 10 cm.

i.e. the minimum is just greater than 10 cm.

(The actual compression will include x_0 also. But when talking of amplitude, it is always from the equilibrium position with respect to which the mass is oscillating.

18. (c) : Kinetic energy + potential energy = total energy

When kinetic energy is maximum, potential energy is zero and vice versa.

$\therefore$ Maximum potential energy = total energy.

$0 + K_0 = K_0$

(K.E. + P.E. = total energy).

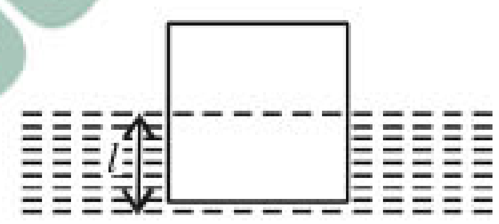
19. (d) : Let $y = A\sin\omega t$

$$\frac{dy}{dt} = A\omega\cos\omega t = A\omega\sin\left(\omega t + \frac{\pi}{2}\right)$$

Acceleration $= -A\omega^2\sin\omega t$

The phase difference between acceleration and velocity is $\pi/2$.

20. (c) : Let l be the length of block immersed in liquid as shown in the figure. When the block is floating,



$\therefore\ mg = Al\rho m$

If the block is given vertical displacement y then the effective restoring force is

$$F = -[A(l+y)\rho g - mg) = -[A(l+y)\rho g - Al\rho g]$$
$$= -Al\rho g y$$

Restoring force $= -[Al\rho g]y$. As this F is directed towards its equilibrium position of block, so if the block is left free, it will execute simple harmonic motion.

Here inertia factor = mass of block = m

Spring factor = $A\rho g$

$$\therefore\ \text{Time period} = T = 2\pi\sqrt{\frac{m}{A\rho g}}$$

i.e. $T \propto \frac{1}{\sqrt{A}}$.

21. (a)

22. (d) : $a = 5$ cm, $v_{max} = 31.4$ cm/s

$v_{max} = \omega a \ \Rightarrow\ 31.4 = 2\pi\upsilon \times 5$

$\Rightarrow\ 31.4 = 10 \times 3.14 \times \upsilon\ \Rightarrow\ \upsilon = 1$ Hz.

23. (d) : When the spring joined in series the total extension in spring is

$$\Rightarrow\ y = y_1 + y_2 = \frac{-F}{k_1} - \frac{F}{k_2}$$

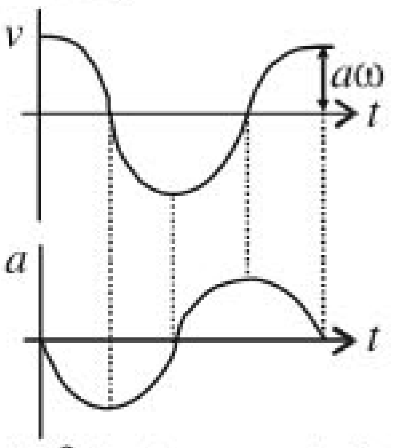
$$\Rightarrow\ y = -F\left[\frac{1}{k_1} + \frac{1}{k_2}\right]$$

Thus spring constant in this case becomes

$$\Rightarrow k = \frac{k_1 k_2}{k_1 + k_2}$$

24. (d) : In simple harmonic motion velocity

$= A\omega\sin(\omega t + \pi/2)$



acceleration $= A\omega^2\sin(\omega t + \pi)$ from this we can easily find out that when v is maximum, then a is zero.

25. (c) : Potential energy of simple harmonic oscillator $= \frac{1}{2}m\omega^2 y^2$

for $y = \frac{a}{2}$, P.E. $= \frac{1}{2}m\omega^2\frac{a^2}{4}$

$\Rightarrow$ P.E. $= \frac{1}{4}\left(\frac{1}{2}m\omega^2 a^2\right) = \frac{E}{4}$.

26. (a) : Potential energy of particle performing SHM varies parabolically in such a way that at mean position it becomes zero and maximum at extreme position.

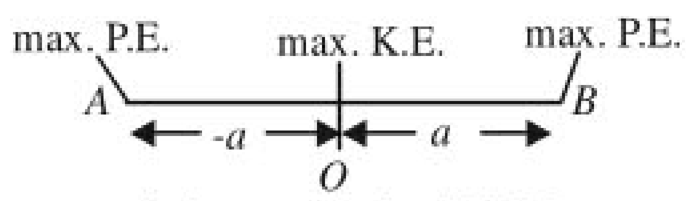
27. (c) : Let k be the force constant of spring. If k' is the force constant of each part, then

$$\frac{1}{k} = \frac{4}{k'} \Rightarrow k' = 4k.$$

$\therefore$ Time period $= 2\pi\sqrt{\frac{m}{4k}} = \frac{1}{2}\times 2\pi\sqrt{\frac{m}{k}} = \frac{T}{2}$.

28. (a) : Smaller damping gives a taller and narrower resonance peak.

29. (c) : For a simple harmonic motion between A and B, with O as the mean position, maximum kinetic energy of the particle executing SHM will be at O and maximum potential energy will be at A and B.



a is the amplitude of SHM

$\therefore$ Displacement between maximum potential energy and maximum kinetic energy is $\pm a$.

30. (d) : This is a case of damped vibration as the amplitude of vibration is decreasing with time.

Amplitude of vibrations at any instant t is given by $a = a_0 e^{-bt}$, where a_0 is the initial amplitude of vibrations and b is the damping constant.

Now, when $t = 100T$, $a = a_0/3$ [T is time period]

Let the amplitude be a' at $t = 200T$.

i.e. after completing 200 oscillations.

$\therefore \quad a = a_0/3 = a_0 e^{-100Tb}$ ...(i)

and $a' = a_0 e^{-200Tb}$ ...(ii)

From (i), $\frac{1}{3} = e^{-100Tb}$. $\quad \therefore \quad e^{-200Tb} = 1/9$.

From (ii), $a' = a_0 \times \frac{1}{9} = \frac{a_0}{9}$.

$\therefore$ The amplitude will be reduced to 1/9 of initial value.

31. (b) : The time period of a spring mass system as shown in figure 1 is given by $T = 2\pi\sqrt{m/k}$, where k is the spring constant.

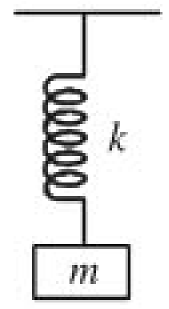


Figure 1

$\therefore \quad t_1 = 2\pi\sqrt{m/k_1}$ ...(i)

and $t_2 = 2\pi\sqrt{m/k_2}$ ...(ii)

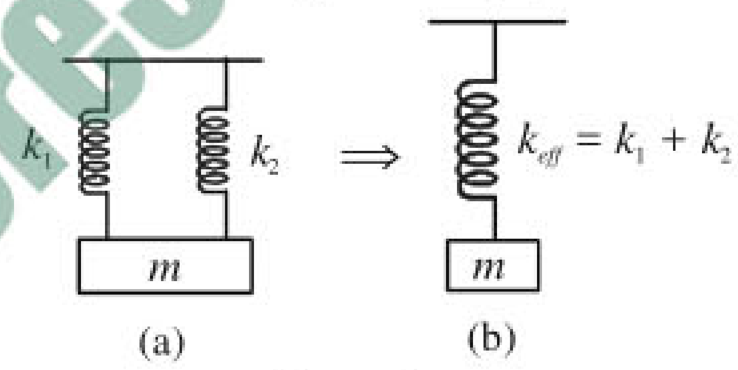


figure 2

Now, when they are connected in parallel as shown in figure 2(a), the system can be replaced by a single spring of spring constant, $k_{eff} = k_1 + k_2$.

[Since $mg = k_1 x + k_2 x = k_{eff} x$]

$\therefore \quad t_0 = 2\pi\sqrt{m/k_{eff}} = 2\pi\sqrt{m/(k_1+k_2)}$ ...(iii)

From (i), $\frac{1}{t_1^2} = \frac{1}{4\pi^2}\times\frac{k_1}{m}$ ...(iv)

From (ii), $\frac{1}{t_2^2} = \frac{1}{4\pi^2}\times\frac{k_2}{m}$ ...(v)

From (iii), $\frac{1}{t_0^2} = \frac{1}{4\pi^2}\times\frac{k_1+k_2}{m}$ ...(vi)

(iv) + (v) $= \frac{1}{t_1^2} + \frac{1}{t_2^2} = \frac{1}{4\pi^2 m}(k_1 + k_2) = \frac{1}{t_0^2}$

$\therefore \quad t_0^{-2} = t_1^{-2} + t_2^{-2}$.

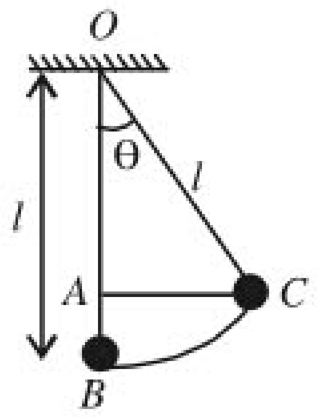
32. (b) : Energy $= \frac{1}{2}m\omega^2 a^2 = \frac{1}{2}ka^2$

33. (a) : $f_A = 2f_B$

$\Rightarrow \quad \frac{1}{2\pi}\sqrt{\frac{g}{l_A}} = 2\times\frac{1}{2\pi}\sqrt{\frac{g}{l_B}}$ or, $\frac{1}{l_A} = 4\times\frac{1}{l_B}$

or, $l_A = \frac{l_B}{4}$, which does not depend on mass.

34. (a) : In ΔOAC, $\cos\theta = A/l$
or, $OA = l\cos\theta$
$\therefore$ $AB = l(1 - \cos\theta) = h$
At point, C the velocity of bob = 0.
The vertical acceleration = g
$\therefore$ $v^2 = 2gh$
or, $v = \sqrt{2gl(1-\cos\theta)}$.



35. (d) : Time period of a simple pendulum is given by $T = 2\pi\sqrt{\frac{l}{g}}$ $\Rightarrow$ $T \propto \sqrt{l}$.

$\therefore$ $\frac{T_1}{T_2} = \sqrt{\frac{l_1}{l_2}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$ or, $T_2 = 2T_1 = 4$ sec.

36. (b) : The amplitude and velocity resonance occurs at the same frequency.
At resonance, *i.e.*, $\omega_1 = \omega_0$ and $\omega_2 = \omega_0$ the amplitude and energy of the particle would be maximum.

37. (a): Frequency of the pendulum $\upsilon_{l=5} = \frac{1}{2\pi}\sqrt{\frac{g}{5}}$

$\upsilon_{l=20} = \frac{1}{2\pi}\sqrt{\frac{g}{20}}$

$\therefore$ $\frac{\upsilon_{l=5}}{\upsilon_{l=20}} = \sqrt{\frac{20}{5}} = 2 \Rightarrow \upsilon_{l=5} = 2\upsilon_{l=20}$

As shorter length pendulum has frequency double the larger length pendulum. Therefore shorter pendulum should complete 2 oscillations before they will be again in phase.

38. (a) : $n = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$; $n' = \frac{1}{2\pi}\sqrt{\frac{k}{4m}}$
$\therefore n' = n/2$

39. (a) : $l_2 = 1.02l_1$. Time period $(T) = 2\pi \times \sqrt{\frac{l}{g}} \propto \sqrt{l}$

Therefore $\frac{T_2}{T_1} = \sqrt{\frac{l_2}{l_1}} = \sqrt{\frac{1.02l_1}{l_1}} = 1.01$.

Thus time period increased by 1%.

40. (c) : $x = a\sin\omega t$
$y = a\sin(\omega t + \pi/2) = a\cos\omega t$

or, $\frac{x}{y} = \frac{\sin\omega t}{\cos\omega t} = \tan\omega t$ or, $\frac{x}{y} = \frac{x}{\sqrt{a^2 - x^2}}$,

or, $y^2 = a^2 - x^2$ or, $x^2 + y^2 = a^2$.
It is an equation of a circle.

41. (d) : Maximum velocity, $v_{max} = A\omega$

According to question, $\frac{v_{max}}{2} = \frac{A\omega}{2} = \omega\sqrt{A^2 - y^2}$

$$\frac{A^2}{4} = A^2 - y^2 \Rightarrow y^2 = A^2 - \frac{A^2}{4} \Rightarrow y = \frac{\sqrt{3}A}{2}.$$

42. (c) : Force constant $(k) = 2 \times 10^6$ N/m; Amplitude $(x) = 0.01$ m and total mechanical energy = 160 J.

Potential energy $= \frac{1}{2}k x^2 = \frac{1}{2}\times(2\times10^6)\times(0.01)^2$
$= 100$ J.

43. (b) : Potential energy at A (or C) = Kinetic energy at B. Thus $\frac{1}{2}mv_B^2 = mgH$ or $v_B = \sqrt{2gH}$.

44. (b) : Displacement $(x) = \frac{a}{2}$.

Total energy $= \frac{1}{2}m\omega^2 a^2$ and kinetic energy when displacement is (x)

$$= \frac{1}{2}m\omega^2(a^2 - x^2)$$

$$= \frac{1}{2}m\omega^2\left(a^2 - \left(\frac{a}{2}\right)^2\right) = \frac{3}{4}\left(\frac{1}{2}m\omega^2 a^2\right).$$

Therefore fraction of the total energy at

$$x = \frac{\frac{3}{4}\left(\frac{1}{2}m\omega^2 a^2\right)}{\frac{1}{2}m\omega^2 a^2} = \frac{3}{4}.$$

45. (d) : Mass $(m) = 5$ kg and time period $(T) = 2\pi$ sec.

Therefore time period $T = 2\pi \times \sqrt{\frac{m}{k}}$ $\Rightarrow$ $\sqrt{\frac{5}{k}} = 1$

or $k = 5$ N/m. According to Hooke's Law, $F = -kl$.

Therefore decrease in length $(l) = -\frac{F}{k} = -\frac{5g}{5}$
$= -g$ metres

46. (d) : For simple harmonic motion, $\frac{d^2x}{dt^2} \propto -x$.
Therefore force acting on the particle $= -Akx$.

47. (d) : Period of oscillation $T = 2\pi\sqrt{\frac{l}{g}}$. Therefore T will decrease when acceleration (g) increases. And g will increase when the rocket moves up with a uniform acceleration.

48. (a) : Time period = 4 sec. In one simple harmonic oscillation, the same kinetic and potential energies are repeated two times. So the difference will be 2 seconds.

49. (b) : $P.E = \frac{1}{2}M\omega^2x^2 = \frac{1}{4}E = \frac{1}{4}\left(\frac{1}{2}M\omega^2A^2\right)$

where total energy $E = \frac{1}{2}M\omega^2A^2$ $\therefore x = \frac{A}{2}$

50. (a) : For S.H.M., $x = A\sin\left(\frac{2\pi}{T}t\right)$

when $x = A$, $A = A\sin\left(\frac{2\pi}{T}t\right)$

$\therefore \quad \sin\left(\frac{2\pi}{T}\cdot t\right) = 1 \Rightarrow \sin\left(\frac{2\pi}{T}\cdot t\right) = \sin\left(\frac{\pi}{2}\right)$

$\Rightarrow \quad t = (T/4)$

When $x = \frac{A}{2}, \frac{A}{2} = A\sin\left(\frac{2\pi}{T}.t\right)$

or $\sin\frac{\pi}{6} = \sin\left(\frac{2\pi}{T}t\right)$ or $t = (T/12)$

Now, time taken to travel from $x = A$ to $x = A/2 = T/4 - T/12 = T/6$

51. (a) : Acceleration $= -\omega^2$ displacement

$$\omega^2 = \frac{\text{acceleration}}{\text{displacement}} = \frac{2.0}{0.02}$$

$\omega^2 = 100$ or $\omega = 10$ rad/s

52. (d) : The effective value of acceleration due to gravity is $\sqrt{(a^2 + g^2)}$

53. (c) : For simple harmonic motion velocity $v = \omega\sqrt{a^2 - x^2}$ at displacement x.

$$10 = \omega\sqrt{a^2 - 16} \quad \text{...(i)}$$

$$8 = \omega\sqrt{a^2 - 25} \quad \text{...(ii)}$$

$$\frac{100}{\omega^2} = a^2 - 16 \quad \text{...(iii)}$$

$$\frac{64}{\omega^2} = a^2 - 25 \quad \text{...(iv)}$$

$\therefore$ Equation (iii) – (iv) gives $\frac{36}{\omega^2} = 9$

$\Rightarrow \quad \omega = 2$ rad/s

or $T = \frac{2\pi}{\omega} = \frac{2\pi}{2} = \pi$ sec

54. (c) : P.E, $V = \frac{1}{2}m\omega^2 x^2$

and KE, $T = \frac{1}{2}m\omega^2(a^2 - x^2)$

$\therefore \quad \frac{T}{V} = \frac{a^2 - x^2}{x^2}$

55. (c) : $x = a\sin\omega t$

and $y = b\sin(\omega t + \pi) = -b\sin\omega t$.

or $\frac{x}{a} = -\frac{y}{b}$ or $y = -\frac{b}{a}x$

It is an equation of a straight line

56. (d) : The effective spring constant of two springs in series is $k = \frac{k_1 k_2}{k_1 + k_2}$

Time period, $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{m(k_1 + k_2)}{k_1 k_2}}$

Chapter 11 Waves

1. The two nearest harmonics of a tube closed at one end and open at other end are 220 Hz and 260 Hz. What is the fundamental frequency of the system?
(a) 20 Hz (b) 30 Hz
(c) 40 Hz (d) 10 Hz
(NEET 2017)

2. Two cars moving in opposite directions approach each other with speed of 22 m s^{-1} and 16.5 m s^{-1} respectively. The driver of the first car blows a horn having a frequency 400 Hz. The frequency heard by the driver of the second car is (velocity of sound is 340 m s^{-1})
(a) 361 Hz (b) 411 Hz
(c) 448 Hz (d) 350 Hz
(NEET 2017)

3. The second overtone of an open organ pipe has the same frequency as the first overtone of a closed pipe L metre long. The length of the open pipe will be
(a) L (b) $2L$
(c) $\frac{L}{2}$ (d) $4L$
(NEET-II 2016)

4. Three sound waves of equal amplitudes have frequencies $(n-1)$, n, $(n+1)$. They superimpose to give beats. The number of beats produced per second will be
(a) 1 (b) 4
(c) 3 (d) 2
(NEET-II 2016)

5. A siren emitting a sound of frequency 800 Hz moves away from an observer towards a cliff at a speed of 15 m s^{-1}. Then, the frequency of sound that the observer hears in the echo reflected from the cliff is
(Take velocity of sound in air = 330 m s^{-1})
(a) 838 Hz (b) 885 Hz
(c) 765 Hz (d) 800 Hz
(NEET-I 2016)

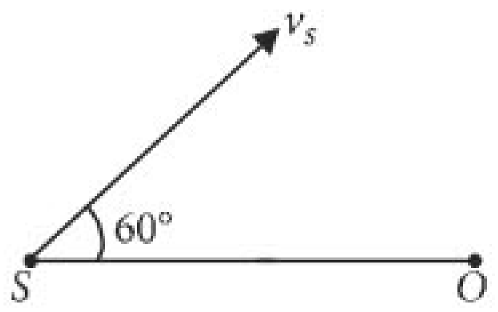
6. An air column, closed at one end and open at the other, resonates with a tuning fork when the smallest length of the column is 50 cm. The next larger length of the column resonating with the same tuning fork is
(a) 150 cm (b) 200 cm
(c) 66.7 cm (d) 100 cm
(NEET-I 2016)

7. A uniform rope of length L and mass m_1 hangs vertically from a rigid support. A block of mass m_2 is attached to the free end of the rope. A transverse pulse of wavelength λ_1 is produced at the lower end of the rope. The wavelength of the pulse when it reaches the top of the rope is λ_2. The ratio λ_2/λ_1 is
(a) $\sqrt{\frac{m_2}{m_1}}$ (b) $\sqrt{\frac{m_1+m_2}{m_1}}$
(c) $\sqrt{\frac{m_1}{m_2}}$ (d) $\sqrt{\frac{m_1+m_2}{m_2}}$
(NEET-I 2016)

8. A string is stretched between fixed points separated by 75.0 cm. It is observed to have resonant frequencies of 420 Hz and 315 Hz. There are no other resonant frequencies between these two. The lowest resonant frequency for this string is
(a) 10.5 Hz (b) 105 Hz
(c) 155 Hz (d) 205 Hz
(2015)

9. 4.0 g of a gas occupies 22.4 litres at NTP. The specific heat capacity of the gas at constant volume is 5.0 J K^{-1} mol^{-1}. If the speed of sound in this gas at NTP is 952 m s^{-1}, then the heat capacity at constant pressure is
(Take gas constant R = 8.3 J K^{-1} mol^{-1})
(a) 7.0 J K^{-1} mol^{-1} (b) 8.5 J K^{-1} mol^{-1}
(c) 8.0 J K^{-1} mol^{-1} (d) 7.5 J K^{-1} mol^{-1}
(2015)

10. A source of sound S emitting waves of frequency 100 Hz and an observer O are located at some distance from each other. The source is moving with a speed of 19.4 m s^{-1} at an angle of 60° with the source observer line as shown in the figure. The observer is at rest. The apparent frequency observed by the observer (velocity of sound in air 330 m s^{-1}), is



(a) 106 Hz (b) 97 Hz
(c) 100 Hz (d) 103 Hz *(2015)*

11. The fundamental frequency of a closed organ pipe of length 20 cm is equal to the second overtone of an organ pipe open at both the ends. The length of organ pipe open at both the ends is

(a) 120 cm (b) 140 cm
(c) 80 cm (d) 100 cm *(2015)*

12. If n_1, n_2 and n_3 are the fundamental frequencies of three segments into which a string is divided, then the original fundamental frequency n of the string is given by

(a) $\frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3}$

(b) $\frac{1}{\sqrt{n}} = \frac{1}{\sqrt{n_1}} + \frac{1}{\sqrt{n_2}} + \frac{1}{\sqrt{n_3}}$

(c) $\sqrt{n} = \sqrt{n_1} + \sqrt{n_2} + \sqrt{n_3}$

(d) $n = n_1 + n_2 + n_3$ *(2014)*

13. The number of possible natural oscillations of air column in a pipe closed at one end of length 85 cm whose frequencies lie below 1250 Hz are (Velocity of sound = 340 m s^{-1})

(a) 4 (b) 5
(c) 7 (d) 6 *(2014)*

14. A speeding motorcyclist sees traffic jam ahead him. He slows down to 36 km hour^{-1}. He finds that traffic has eased and a car moving ahead of him at 18 km hour^{-1} is honking at a frequency of 1392 Hz. If the speed of sound is 343 m s^{-1}, the frequency of the honk as heard by him will be

(a) 1332 Hz (b) 1372 Hz
(c) 1412 Hz (d) 1454 Hz *(2014)*

15. If we study the vibration of a pipe open at both ends, then the following statement is not true.

(a) All harmonics of the fundamental frequency will be generated.
(b) Pressure change will be maximum at both ends.
(c) Open end will be antinode.
(d) Odd harmonics of the fundamental frequency will be generated.

(NEET 2013)

16. A wave travelling in the +ve x-direction having displacement along y-direction as 1 m, wavelength 2π m and frequency of $\frac{1}{\pi}$ Hz is represented by

(a) $y = \sin(10\pi x - 20\pi t)$
(b) $y = \sin(2\pi x + 2\pi t)$
(c) $y = \sin(x - 2t)$
(d) $y = \sin(2\pi x - 2\pi t)$ *(NEET 2013)*

17. A source of unknown frequency gives 4 beats/s when sounded with a source of known frequency 250 Hz. The second harmonic of the source of unknown frequency gives five beats per second, when sounded with a source of frequency 513 Hz. The unknown frequency is

(a) 240 Hz (b) 260 Hz
(c) 254 Hz (d) 246 Hz

(NEET 2013)

18. The length of the wire between two ends of a sonometer is 100 cm. What should be the positions of two bridges below the wire so that the three segments of the wire have their fundamental frequencies in the ratio 1 : 3 : 5.

(a) $\frac{1500}{23}$ cm, $\frac{500}{23}$ cm

(b) $\frac{1500}{23}$ cm, $\frac{300}{23}$ cm

(c) $\frac{300}{23}$ cm, $\frac{1500}{23}$ cm

(d) $\frac{1500}{23}$ cm, $\frac{2000}{23}$ cm

(Karnataka NEET 2013)

19. Two sources P and Q produce notes of frequency 660 Hz each. A listener moves from P to Q with a speed of 1 ms^{-1}. If the speed of sound is 330 m/s, then the number of beats heard by the listener per second will be

(a) 4 (b) 8
(c) 2 (d) zero

(Karnataka NEET 2013)

20. When a string is divided into three segments of length l_1, l_2 and l_3 the fundamental frequencies of these three segments are υ_1, υ_2 and υ_3 respectively. The original fundamental frequency (υ) of the string is

(a) $\sqrt{\upsilon} = \sqrt{\upsilon_1} + \sqrt{\upsilon_2} + \sqrt{\upsilon_3}$

(b) $\upsilon = \upsilon_1 + \upsilon_2 + \upsilon_3$

(c) $\frac{1}{\upsilon} = \frac{1}{\upsilon_1} + \frac{1}{\upsilon_2} + \frac{1}{\upsilon_3}$

(d) $\frac{1}{\sqrt{\upsilon}} = \frac{1}{\sqrt{\upsilon_1}} + \frac{1}{\sqrt{\upsilon_2}} + \frac{1}{\sqrt{\upsilon_3}}$ *(2012)*

21. Two sources of sound placed close to each other, are emitting progressive waves given by
$y_1 = 4\sin 600\pi t$ and $y_2 = 5\sin 608\pi t$
An observer located near these two sources of sound will hear

(a) 4 beats per second with intensity ratio 25 : 16 between waxing and waning.
(b) 8 beats per second with intensity ratio 25 : 16 between waxing and waning.
(c) 8 beats per second with intensity ratio 81 : 1 between waxing and waning.
(d) 4 beats per second with intensity ratio 81 : 1 between waxing and waning. *(2012)*

22. The equation of a simple harmonic wave is given by

$$y = 3\sin\frac{\pi}{2}(50t - x),$$

where x and y are in metres and t is in seconds. The ratio of maximum particle velocity to the wave velocity is

(a) 2π (b) $\frac{3}{2}\pi$
(c) 3π (d) $\frac{2}{3}\pi$ *(Mains 2012)*

23. A train moving at a speed of 220 m s^{-1} towards a stationary object, emits a sound of frequency 1000 Hz. Some of the sound reaching the object gets reflected back to the train as echo. The frequency of the echo as detected by the driver of the train is
(Speed of sound in air is 330 m s^{-1})

(a) 3500 Hz (b) 4000 Hz
(c) 5000 Hz (d) 3000 Hz *(Mains 2012)*

24. Two waves are represented by the equations
$y_1 = a\sin(\omega t + kx + 0.57)$ m and
$y_2 = a\cos(\omega t + kx)$ m, where x is in meter and t in sec. The phase difference between them is

(a) 1.0 radian (b) 1.25 radian
(c) 1.57 radian (d) 0.57 radian *(2011)*

25. Sound waves travel at 350 m/s through a warm air and at 3500 m/s through brass. The wavelength of a 700 Hz acoustic wave as it enters brass from warm air

(a) decrease by a factor 10
(b) increase by a factor 20
(c) increase by a factor 10
(d) decrease by a factor 20 *(2011)*

26. Two identical piano wires, kept under the same tension T have a fundamental frequency of 600 Hz. The fractional increase in the tension of one of the wires which will lead to occurrence of 6 beats/s when both the wires oscillate together would be

(a) 0.01 (b) 0.02
(c) 0.03 (d) 0.04 *(Mains 2011)*

27. A transverse wave is represented by $y = A\sin(\omega t - kx)$. For what value of the wavelength is the wave velocity equal to the maximum particle velocity?

(a) $\pi A/2$ (b) πA
(c) $2\pi A$ (d) A *(2010)*

28. A tuning fork of frequency 512 Hz makes 4 beats per second with the vibrating string of a piano. The beat frequency decreases to 2 beats per sec when the tension in the piano string is slightly increased. The frequency of the piano string before increasing the tension was

(a) 510 Hz (b) 514 Hz
(c) 516 Hz (d) 508 Hz *(2010)*

29. Each of the two strings of length 51.6 cm and 49.1 cm are tensioned separately by 20 N force. Mass per unit length of both the strings is same and equal to 1 g/m. When both the strings vibrate simultaneously the number of beats is

(a) 7 (b) 8
(c) 3 (d) 5 *(2009)*

30. The driver of a car travelling with speed 30 m/s towards a hill sounds a horn of frequency 600 Hz. If the velocity of sound in air is 330 m/s, the frequency of reflected sound as heard by driver is

(a) 555.5 Hz (b) 720 Hz
(c) 500 Hz (d) 550 Hz *(2009)*

31. A wave in a string has an amplitude of 2 cm. The wave travels in the +ve direction of x axis with a speed of 128 m/s. and it is noted that 5 complete waves fit in 4 m length of the string.

The equation describing the wave is
(a) $y = (0.02)$ m $\sin(15.7x - 2010t)$
(b) $y = (0.02)$ m $\sin(15.7x + 2010t)$
(c) $y = (0.02)$ m $\sin(7.85x - 1005t)$
(d) $y = (0.02)$ m $\sin(7.85x + 1005t)$ *(2009)*

32. A point performs simple harmonic oscillation of period T and the equation of motion is given by $x = a\sin(\omega t + \pi/6)$. After the elapse of what fraction of the time period the velocity of the point will be equal to half of its maximum velocity?
(a) $T/3$ (b) $T/12$
(c) $T/8$ (d) $T/6$ *(2008)*

33. Two periodic waves of intensities I_1 and I_2 pass through a region at the same time in the same direction. The sum of the maximum and minimum intensities is
(a) $(\sqrt{I_1} - \sqrt{I_2})^2$ (b) $2(I_1 + I_2)$
(c) $I_1 + I_2$ (d) $(\sqrt{I_1} + \sqrt{I_2})^2$ *(2008)*

34. The wave described by $y = 0.25\sin(10\pi x - 2\pi t)$, where x and y are in meters and t in seconds, is a wave travelling along the
(a) +ve x direction with frequency 1 Hz and wavelength $\lambda = 0.2$ m.
(b) –ve x direction with amplitude 0.25 m and wavelength $\lambda = 0.2$ m.
(c) –ve x direction with frequency 1 Hz.
(d) +ve x direction with frequency π Hz and wavelength $\lambda = 0.2$ m. *(2008)*

35. Two vibrating tuning forks produce waves given by $y_1 = 4\sin 500\pi t$ and $y_2 = 2\sin 506\pi t$. Number of beats produced per minute is
(a) 360 (b) 180
(c) 60 (d) 3 *(2006)*

36. Two sound waves with wavelengths 5.0 m and 5.5 m respectively, each propagate in a gas with velocity 330 m/s. We expect the following number of beats per second.
(a) 6 (b) 12
(c) 0 (d) 1. *(2006)*

37. The time of reverberation of a room A is one second. What will be the time (in seconds) of reverberation of a room, having all the dimensions double of those of room A?
(a) 1 (b) 2
(c) 4 (d) 1/2. *(2006)*

38. A transverse wave propagating along x-axis is represented by $y(x, t) = 8.0\sin(0.5\pi x - 4\pi t - \pi/4)$ where x is in metres and t is in seconds. The speed of the wave is
(a) 8 m/s (b) 4π m/s
(c) 0.5π m/s (d) $\pi/4$ m/s. *(2006)*

39. Which one of the following statements is true?
(a) both light and sound waves can travel in vacuum
(b) both light and sound waves in air are transverse
(c) the sound waves in air are longitudinal while the light waves are transverse
(d) both light and sound waves in air are longitudinal. *(2006)*

40. A point source emits sound equally in all directions in a non-absorbing medium. Two points P and Q are at distances of 2 m and 3 m respectively from the source. The ratio of the intensities of the waves at P and Q is
(a) 3 : 2 (b) 2 : 3
(c) 9 : 4 (d) 4 : 9. *(2005)*

41. The phase difference between two waves, represented by
$$y_1 = 10^{-6}\sin[100t + (x/50) + 0.5] \text{ m}$$
$$y_2 = 10^{-6}\cos[100t + (x/50)] \text{ m},$$
where x is expressed in metres and t is expressed in seconds, is approximately
(a) 1.07 radians (b) 2.07 radians
(c) 0.5 radians (d) 1.5 radians *(2004)*

42. A car is moving towards a high cliff. The driver sounds a horn of frequency f. The reflected sound heard by the driver has frequency $2f$. If v is the velocity of sound, then the velocity of the car, in the same velocity units, will be
(a) $v/\sqrt{2}$ (b) $v/3$
(c) $v/4$ (d) $v/2$ *(2004)*

43. An observer moves towards a stationary source of sound with a speed 1/5th of the speed of sound. The wavelength and frequency of the source emitted are λ and f respectively. The apparent frequency and wavelength recorded by the observer are respectively
(a) $1.2f$, 1.2λ (b) $1.2f$, λ
(c) f, 1.2λ (d) $0.8f$, 0.8λ *(2003)*

44. A whistle revolves in a circle with angular speed $\omega = 20$ rad/s using a string of length 50 cm. If the frequency of sound from the whistle is 385 Hz, then what is the minimum frequency

heard by an observer which is far away from the centre (velocity of sound = 340 m/s)
(a) 385 Hz (b) 374 Hz
(c) 394 Hz (d) 333 Hz. *(2002)*

45. A wave travelling in positive X-direction with $a = 0.2\ \text{ms}^{-2}$, velocity $= 360\ \text{ms}^{-1}$ and $\lambda = 60$ m, then correct expression for the wave is

(a) $y = 0.2\sin\left[2\pi\left(6t + \frac{x}{60}\right)\right]$

(b) $y = 0.2\sin\left[\pi\left(6t + \frac{x}{60}\right)\right]$

(c) $y = 0.2\sin\left[2\pi\left(6t - \frac{x}{60}\right)\right]$

(d) $y = 0.2\sin\left[\pi\left(6t - \frac{x}{60}\right)\right]$ *(2002)*

46. The equation of a wave is represented by $y = 10^{-4}\sin\left(100t - \frac{x}{10}\right)$ m, then the velocity of wave will be
(a) 100 m/s (b) 4 m/s
(c) 1000 m/s (d) 10 m/s *(2001)*

47. Two waves having equation
$x_1 = a\sin(\omega t - kx + \phi_1)$, $x_2 = a\sin(\omega t - kx + \phi_2)$
If in the resultant wave the frequency and amplitude remain equal to amplitude of superimposing waves, the phase difference between them is

(a) $\frac{\pi}{6}$ (b) $\frac{2\pi}{3}$

(c) $\frac{\pi}{4}$ (d) $\frac{\pi}{3}$. *(2001)*

48. If the tension and diameter of a sonometer wire of fundamental frequency n is doubled and density is halved then its fundamental frequency will become

(a) $\frac{n}{4}$ (b) $\sqrt{2}n$

(c) n (d) $\frac{n}{\sqrt{2}}$. *(2001)*

49. The equations of two waves acting in perpendicular directions are given as $x = a\cos(\omega t + \delta)$ and $y = a\cos(\omega t + \alpha)$, where $\delta = \alpha + \frac{\pi}{2}$, the resultant wave represents
(a) a parabola (b) a circle
(c) an ellipse (d) a straight line
(2000)

50. A string is cut into three parts, having fundamental frequencies n_1, n_2, n_3 respectively. Then original fundamental frequency n related by the expression as

(a) $\frac{1}{n} = \frac{1}{n_1} + \frac{1}{n_2} + \frac{1}{n_3}$ (b) $n = n_1 \times n_2 \times n_3$

(c) $n = n_1 + n_2 + n_3$ (d) $n = \frac{n_1 + n_2 + n_3}{3}$.
(2000)

51. Two stationary sources each emitting waves of wavelength λ, an observer moves from one source to another with velocity u. Then number of beats heard by him

(a) $\frac{2u}{\lambda}$ (b) $\frac{u}{\lambda}$

(c) $\sqrt{u\lambda}$ (d) $\frac{u}{2\lambda}$ *(2000)*

52. Two waves of lengths 50 cm and 51 cm produced 12 beats per sec. The velocity of sound is
(a) 340 m/s (b) 331 m/s
(c) 306 m/s (d) 360 m/s *(1999)*

53. A transverse wave is represented by the equation
$y = y_0 \sin \frac{2\pi}{\lambda}(vt - x)$
For what value of λ, is the maximum particle velocity equal to two times the wave velocity?

(a) $\lambda = \frac{\pi y_0}{2}$ (b) $\lambda = \frac{\pi y_0}{3}$

(c) $\lambda = 2\pi y_0$ (d) $\lambda = \pi y_0$ *(1998)*

54. A vehicle, with a horn of frequency n is moving with a velocity of 30 m/s in a direction perpendicular to the straight line joining the observer and the vehicle. The observer perceives the sound to have a frequency $n + n_1$. Then (if the sound velocity in air is 300 m/s)
(a) $n_1 = 0.1n$ (b) $n_1 = 0$
(c) $n_1 = 10n$ (d) $n_1 = -0.1n$
(1998)

55. A standing wave having 3 nodes and 2 antinodes is formed between two atoms having a distance 1.21 Å between them. The wavelength of the standing wave is
(a) 6.05 Å (b) 2.42 Å
(c) 1.21 Å (d) 3.63 Å *(1998)*

56. In a sinusoidal wave, the time required for a particular point to move from maximum displacement to zero displacement is 0.170 s. The frequency of wave is
(a) 0.73 Hz (b) 0.36 Hz
(c) 1.47 HZ (d) 2.94 Hz *(1998)*

57. Standing waves are produced in 10 m long stretched string. If the string vibrates in 5 segments and wave velocity is 20 m/s, the frequency is
(a) 5 Hz (b) 10 Hz
(c) 2 Hz (d) 4 Hz *(1997)*

58. A cylindrical tube, open at both ends has fundamental frequency f in air. The tube is dipped vertically in water, so that half of it is in water. The fundamental frequency of air column is now
(a) $f/2$ (b) $3f/4$
(c) $2f$ (d) f *(1997)*

59. The equation of a sound wave is $y = 0.0015 \sin (62.4x + 316t)$. The wavelength of this wave is
(a) 0.3 unit (b) 0.2 unit
(c) 0.1 unit
(d) cannot be calculated. *(1996)*

60. Two sound waves having a phase difference of 60° have path difference of
(a) $\frac{\lambda}{6}$ (b) $\frac{\lambda}{3}$
(c) 2λ (d) $\frac{\lambda}{2}$ *(1996)*

61. The length of a sonometer wire AB is 110 cm. Where should the two bridges be placed from A to divide the wire in 3 segments whose fundamental frequencies are in the ratio of 1 : 2 : 3?
(a) 60 cm and 90 cm
(b) 30 cm and 60 cm
(c) 30 cm and 90 cm
(d) 40 cm and 80 cm. *(1995)*

62. A hospital uses an ultrasonic scanner to locate tumours in a tissue. The operating frequency of the scanner is 4.2 MHz. The speed of sound in a tissue is 1.7 km/s. The wavelength of sound in the tissue is close to
(a) 4×10^{-3} m (b) 8×10^{-3} m
(c) 4×10^{-4} m (d) 8×10^{-4} m. *(1995)*

63. A source of sound gives 5 beats per second, when sounded with another source of frequency 100 second^{-1}. The second harmonic of the source, together with a source of frequency 205 sec^{-1} gives 5 beats per second. What is the frequency of the source?
(a) 105 second^{-1} (b) 205 second^{-1}
(c) 95 second^{-1} (d) 100 second^{-1} *(1995)*

64. A star, which is emitting radiation at a wavelength of 5000 Å, is approaching the earth with a velocity of 1.5×10^4 m/s. The change in wavelength of the radiation as received on the earth is
(a) 25 Å (b) 100 Å
(c) zero (d) 2.5 Å *(1995)*

65. Which one of the following represents a wave?
(a) $y = A \sin (\omega t - kx)$
(b) $y = A \cos (at - bx + c)$
(c) $y = A \sin kx$
(d) $y = A \sin \omega t$. *(1994)*

66. A wave of frequency 100 Hz travels along a string towards its fixed end. When this wave travels back, after reflection, a node is formed at a distance of 10 cm from the fixed end. The speed of the wave (incident and reflected) is
(a) 20 m/s (b) 40 m/s
(c) 5 m/s (d) 10 m/s. *(1994)*

67. A stationary wave is represented by $y = A \sin (100t) \cos (0.01x)$, where y and A are in millimetres, t is in seconds and x is in metres. The velocity of the wave is
(a) 10^4 m/s (b) not derivable
(c) 1 m/s (d) 10^2 m/s. *(1994)*

68. A source of frequency υ gives 5 beats/second when sounded with a source of frequency 200 Hz. The second harmonic of frequency 2υ of source gives 10 beats/second when sounded with a source of frequency 420 Hz. The value of υ is
(a) 205 Hz (b) 195 Hz
(c) 200 Hz (d) 210 Hz. *(1994)*

69. Wave has simple harmonic motion whose period is 4 seconds while another wave which also possesses simple harmonic motion has its period 3 second. If both are combined, then the resultant wave will have the period equal to
(a) 4 s (b) 5 s
(c) 12 s (d) 3 s *(1993)*

70. A stretched string resonates with tuning fork frequency 512 Hz when length of the string is 0.5 m. The length of the string required to vibrate resonantly with a tuning fork of frequency 256 Hz would be
(a) 0.25 m (b) 0.5 m
(c) 1 m (d) 2 m *(1993)*

71. The temperature at which the speed of sound becomes double as was at 27°C is
(a) 273°C (b) 0°C
(c) 927°C (d) 1027°C *(1993)*