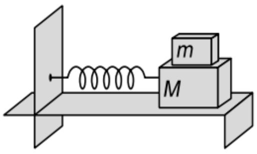
# PRACTICE EXERCISES

## SINGLE CORRECT CHOICE TYPE QUESTIONS

This section contains Single Correct Choice Type Questions. Each question has four choices (A), (B), (C) and (D), out of which ONLY ONE is correct.

**1.** A mass $M$ is attached to a horizontal spring of force constant $K$ fixed on one side to a rigid support. The mass oscillates on a frictionless surface with time period $T$ and amplitude $A$. When the mass $M$ is in equilibrium position, another mass $m$ is gently placed on it. Then the new time period and amplitude of oscillation will be




(A) $2\pi\sqrt{\frac{M+m}{K}}, \sqrt{\frac{M}{M-m}}A$ (B) $2\pi\sqrt{\frac{M+m}{K}}, \sqrt{\frac{M}{M+m}}A$

(C) $2\pi\sqrt{\frac{M-m}{K}}, \sqrt{\frac{M-m}{K}}A$ (D) $2\pi\sqrt{\frac{M}{K}}, \frac{M}{M+m}A$

**2.** Two blocks with masses $m_1 = 1$ kg and $m_2 = 2$ kg are connected by a spring of spring constant 24 $\text{Nm}^{-1}$ and placed on a frictionless horizontal surface. The block $m_1$ is imparted an initial velocity $v_0 = 12\ \text{cms}^{-1}$ to the right. The amplitude of oscillation is

(A) 1 cm (B) 2 cm
(C) 3 cm (D) 4 cm

**3.** The function $x = x_0 \sin^2(\omega t)$ represents

(A) an SHM of amplitude $x_0$ with a period $\frac{2\pi}{\omega}$

(B) an SHM of amplitude $\frac{x_0}{2}$ with a period $\frac{\pi}{\omega}$

(C) a periodic motion with a period $\frac{2\pi}{\omega}$ but not SHM

(D) a periodic motion with a period $\frac{\pi}{\omega}$ but not SHM

**4.** Vertical displacement of a plank with a body of mass $m$ on it is varying according to law $y = \sin(\omega t) + \sqrt{3}\cos(\omega t)$. The minimum value of $\omega$ for which the mass just breaks off the plank and the moment it occurs first after $t = 0$, are given by Assume $y$ to be positive vertically upwards.

(A) $\sqrt{\frac{g}{2}}, \frac{\sqrt{2}}{6}\frac{\pi}{\sqrt{g}}$ (B) $\frac{g}{\sqrt{2}}, \frac{2}{3}\sqrt{\frac{\pi}{g}}$

(C) $\sqrt{\frac{g}{2}}, \frac{\pi}{3}\sqrt{\frac{2}{g}}$ (D) $\sqrt{2g}, \sqrt{\frac{2\pi}{3g}}$

**5.** A charged particle is deflected by two mutually perpendicular oscillating electric fields such that the displacement of the particle due to each one of them is given by $x = a\cos(\omega t)$ and $y = a\cos\left(\omega t + \frac{\pi}{6}\right)$ respectively. The trajectory followed by the charged particle is

(A) a circle with equation $x^2 + y^2 = a^2$.

(B) a straight line with equation $y = \sqrt{3}x$.

(C) an ellipse with equation $x^2 + y^2 - xy = \frac{3a^2}{4}$.

(D) an ellipse with equation $x^2 + y^2 - \sqrt{3}xy = \frac{a^2}{4}$.

**6.** If potential energy of a particle varies with position $x$ according to the relation $U = x^2 - 4x + 4$, then motion of particle will be

(A) periodic but not SHM with mean at $x = 0$
(B) periodic but not SHM with mean position $x = 2$
(C) SHM with mean position $x = 2$
(D) uniformly accelerated motion starting at $x = 2$

**7.** Time period of a simple pendulum of length $L$ is $T_1$ and time period of a uniform rod of the same length $L$ pivoted about one end and oscillating in a vertical plane is $T_2$. Amplitude of oscillations in both the cases is small. Then $\frac{T_1}{T_2}$ is

(A) $\sqrt{\frac{4}{3}}$ (B) 1

(C) $\sqrt{\frac{3}{2}}$ (D) $\sqrt{\frac{1}{3}}$

**8.** A particle is executing SHM according to the equation $x = A\sin(\omega t)$. The average speed of the particle over the interval $0 \le t \le \frac{\pi}{6\omega}$ is

(A) $\frac{\sqrt{3}A\omega}{2\pi}$ (B) $\frac{\sqrt{3}A\omega}{4}$

(C) $\frac{3A\omega}{\pi}$ (D) $(2-\sqrt{3})A\omega$

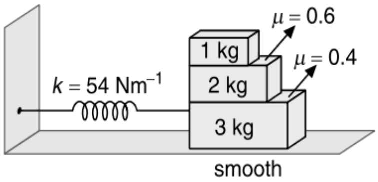
**9.** The potential energy of a particle of mass 1 kg is, $U = 10 + (x-2)^2$, where, $U$ is in joule and $x$ in metre. On the positive $x$-axis particle travels upto $x = +6$ m. Choose the incorrect statement.

(A) On negative $x$-axis particle travels upto $x = -2$ m
(B) The maximum kinetic energy of the particle is 16 J
(C) The period of oscillation of the particle is $\sqrt{2}\pi$ seconds
(D) None of the above

**10.** A particle executing SHM is described by the equation $y = 2\sin(100t) + 1$. The amplitude and mean position of SHM respectively are

(A) 3, 2 (B) 1, 2
(C) 2, 1 (D) $\sqrt{5}$, 1

**11.** In the figure shown, what can be the maximum amplitude of the system so that there is no slipping between any of the blocks?




(A) $\frac{2}{7}$ m (B) $\frac{3}{4}$ m

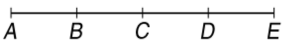
(C) $\frac{4}{9}$ m (D) $\frac{10}{3}$ m

**12.** In PROBLEM 11, if the value of force constant $k$ is increased then the maximum amplitude calculated will

(A) remain same (B) increase

(C) decrease (D) data in insufficient

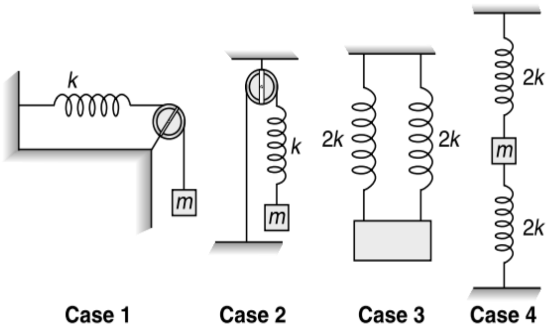
**13.** A body performs SHM along the straight line $ABCDE$ with $C$ as the mid-point of $AE$. Its kinetic energies at $B$ and $D$ are each one fourth of its maximum value. If $AE = 2R$, the distance between $B$ and $D$ is




(A) $\frac{\sqrt{3}}{2}R$ (B) $R$

(C) $\sqrt{3}R$ (D) $\sqrt{2}R$

**14.** A block of mass $m$ is suspended by different springs of force constant shown in figure. Let time period of oscillation in these four positions be $T_1$, $T_2$, $T_3$ and $T_4$. Then




(A) $T_1 = T_2 = T_4$ (B) $T_1 = T_2$ and $T_3 = T_4$

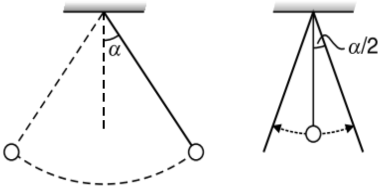
(C) $T_1 = T_2 = T_3$ (D) $T_1 = T_3$ and $T_2 = T_4$

**15.** Springs of constants $k$, $2k$, $4k$, $8k$, ...., $2048k$ are connected in series. A mass $m$ is attached to one end and the system is allowed to oscillate. The time period is approximately

(A) $2\pi\sqrt{\frac{m}{2k}}$ (B) $2\pi\sqrt{\frac{2m}{k}}$

(C) $2\pi\sqrt{\frac{m}{4k}}$ (D) $2\pi\sqrt{\frac{4m}{k}}$

**16.** A simple pendulum swings with an initial angular amplitude $\alpha$. It is now made to oscillate between two walls making an angle $\alpha$ in a symmetrical way as shown in Figure.




Assuming collisions with the walls to be elastic, the ratio of initial time period to new time period is

(A) $2:1$ (B) $3:1$

(C) $3:2$ (D) $4:3$

**17.** Two springs fixed at one end are stretched by 5 cm and 10 cm, respectively, when masses 0.5 kg and 1 kg are suspended at their lower ends. When displaced slightly from their mean positions and released, they will oscillate with time periods in the ratio

(A) $1:\sqrt{2}$ (B) $1:2$

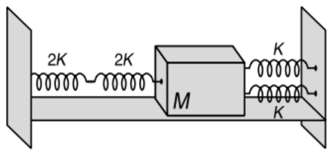
(C) $\sqrt{2}:1$ (D) $2:1$

**18.** Two particles are executing SHM in a straight line. Amplitude $A$ and time period $T$ of both the particles are equal. At time $t = 0$, one particle is at displacement $x_1 = +A$ and the other at $x_2 = -\frac{A}{2}$ and they are approaching towards each other. The time after which they cross each other is equal to

(A) $\frac{T}{3}$ (B) $\frac{T}{4}$

(C) $\frac{5T}{6}$ (D) $\frac{T}{6}$

**19.** A mass $M$ is attached to four springs of spring constants $2K$, $2K$, $K$, $K$ as shown in figure. The mass is capable of oscillating on a frictionless horizontal floor. If it is displaced slightly and released, the frequency of resulting S.H.M. would be




(A) $\frac{1}{2\pi}\sqrt{\frac{3K}{M}}$ (B) $\frac{1}{2\pi}\sqrt{\frac{4K}{M}}$

(C) $\frac{1}{2\pi}\sqrt{\frac{11K}{2M}}$ (D) $\frac{1}{2\pi}\sqrt{\frac{2K}{3M}}$

**20.** A particle performs harmonic oscillations along a straight line with a period $T$ and amplitude $a$. Mean velocity of the particle averaged over the time interval, during which it travels a distance $\frac{a}{2}$ starting from the extreme position, is

(A) $\frac{a}{T}$ (B) $\frac{2a}{T}$

(C) $\frac{3a}{T}$ (D) $\frac{a}{2T}$

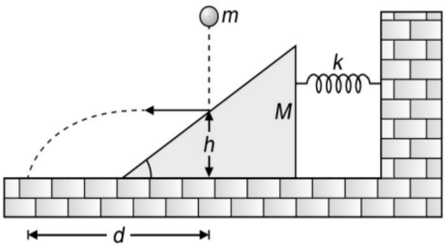
**21.** A small ball of density $\rho_0$ is released from rest from the surface of a liquid whose density varies with depth $h$ as $\rho = \frac{\rho_0}{2}(\alpha + \beta h)$, where $m$ is the mass of the ball. Select the most appropriate one option.

(A) The particle will execute SHM
(B) The maximum speed of the ball is $\left(\frac{2-\alpha}{\sqrt{2\beta}}\right)\sqrt{g}$
(C) Both (A) and (B) are correct
(D) Both (A) and (B) are wrong
Here, $\alpha$ and $\beta$ are positive constants of proper dimensions with $\alpha < 2$.

**22.** Two particles are in SHM along same line with same amplitude $A$ and same time period $T$. At time $t = 0$, particle 1 is at $+A/2$ and moving towards positive $x$-axis. At the same time particle 2 is at $-A/2$ and moving towards negative $x$-axis. Find the time when they will collide
(A) $2T/3$ (B) $5T/12$
(C) $4T/3$ (D) $2T/5$

**23.** The force constant of a linear harmonic oscillator is $3\times10^4\ \text{Nm}^{-1}$, amplitude is $0.1\ \text{m}$ and total energy is $200$ joules. Then its
(A) minimum potential energy is zero
(B) maximum kinetic energy is 200 joules
(C) maximum potential energy is 150 joules
(D) maximum kinetic energy is 150 joules

**24.** A ball of mass $m$ when dropped from certain height as shown in diagram, strikes a wedge kept on smooth horizontal surface and move horizontally just after impact.




If the ball strikes the ground at a distance $d$ from its initial line of fall, then the amplitude of oscillation of wedge after being hit by the ball will be
(A) $\frac{md}{M}\sqrt{\frac{Mg}{2kh}}$ (B) $\frac{d}{m}\sqrt{\frac{kMg}{2h}}$
(C) $d\sqrt{\frac{kg}{2Mh}}$ (D) $d\sqrt{\frac{kg}{2mh}}$

**25.** The table shows the values of the acceleration $a$ of a particle executing SHM at the displacement $x$. The time period of SHM is

| $a(\text{ms}^{-2})$ | 27 | 9 | 0 | −18 | −36 |
|---|---|---|---|---|---|
| $x(\text{m})$ | −3 | −1 | 0 | 2 | 4 |

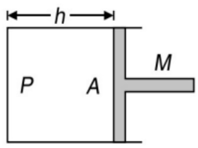
(A) $\frac{\pi}{3}$ s (B) $\pi$ s
(C) $\frac{2\pi}{3}$ s (D) 1 s

**26.** A particle moves such that its acceleration is given by $a = -\beta(x-2)$, where $\beta$ is a positive constant and $x$ the position from origin. The time period of oscillations is
(A) $2\pi\sqrt{\beta}$
(B) $2\pi\sqrt{1/\beta}$
(C) $2\pi\sqrt{\beta+2}$
(D) $2\pi\sqrt{1/(\beta+2)}$

**27.** Two springs of force constant $\frac{k}{5}$ and $\frac{k}{4}$ are joined in series and then connected to a mass $m$. The frequency of oscillation of the mass will be
(A) $\frac{1}{6\pi}\sqrt{\frac{k}{m}}$ (B) $\frac{3}{2\pi}\sqrt{\frac{k}{m}}$
(C) $\frac{1}{2\pi}\sqrt{\frac{k}{m}}$ (D) $\frac{2}{\pi\sqrt{20}}\sqrt{\frac{k}{m}}$

**28.** In PROBLEM 27, if the springs are connected in parallel, the frequency of oscillation will be
(A) $\frac{3}{2\pi}\sqrt{\frac{k}{m}}$ (B) $\frac{3}{2\pi\sqrt{20}}\sqrt{\frac{k}{m}}$
(C) $\frac{2}{\pi\sqrt{20}}\sqrt{\frac{k}{m}}$ (D) $\frac{3}{\pi}\sqrt{\frac{k}{m}}$

**29.** A cylindrical piston of mass $M$ and cross-sectional area $A$ slide smoothly inside a long cylinder closed at one end, enclosing a certain mass of gas. The cylinder is kept with its axis horizontal. If the piston is distributed from its equilibrium position, it oscillates simple harmonically. The period of oscillation is

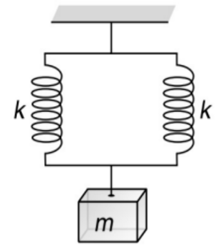



(A) $2\pi\sqrt{\frac{Mh}{PA}}$ (B) $2\pi\sqrt{\frac{MA}{Ph}}$
(C) $2\pi\sqrt{\frac{M}{PAh}}$ (D) $2\pi\sqrt{MPhA}$

**30.** A particle is executing SHM along a straight line and has mean position at $x = 0$. The time period of the SHM is 20 s and its amplitude 5 cm. The time taken by the particle to go from $x = 4$ cm to $x = -3$ cm can be
(A) 10 s (B) 8 s
(C) 5 s (D) 20 s

**31.** Two simple pendulums have time periods $T$ and $\frac{5T}{4}$. They start vibrating at the same instant from the mean position in the same phase. The phase difference between them when the bigger pendulum completes one oscillation will be
(A) $\frac{\pi}{6}$ (B) $\frac{\pi}{4}$
(C) $\frac{\pi}{3}$ (D) $\frac{\pi}{2}$

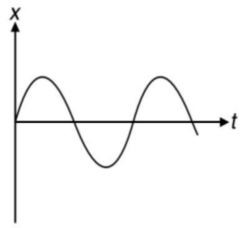
**32.** The two spring mass system, shown in the figure, oscillates with a period $T$. If only one spring is used, the same time period will be



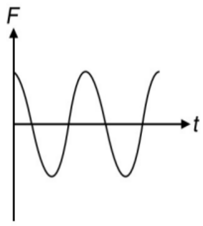

(A) $T/\sqrt{2}$ (B) $T/2$

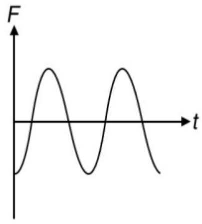
(C) $\sqrt{2}T$ (D) $2T$

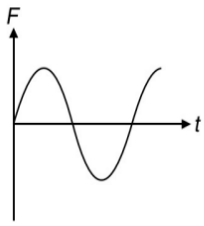
**33.** Displacement-time graph of a particle executing SHM is shown in figure.

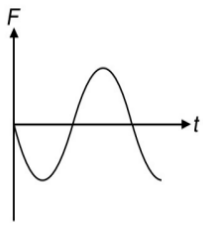



The corresponding force-time graph of the particle is

(A)



(B)



(C)



(D)



**34.** Two simple harmonic motions $y_1 = A\sin(\omega t)$ and $y_2 = A\cos(\omega t)$ are superimposed on a particle of mass $m$. The total mechanical energy of the particle is

(A) $\frac{1}{2}m\omega^2A^2$ (B) $m\omega^2A^2$

(C) $\frac{1}{4}m\omega^2A^2$ (D) ZERO

**35.** A particle of mass 10 g moves on $x$-axis in a field where potential energy per unit mass is given by expression $V = 8\times10^4x^2$ erg/g where $x$ is in cm. If the total energy of the particle is $8\times10^7$ erg, then relation between $x$ and time $t$ is

(A) $x = 10\sin(400t+\phi)$ cm

(B) $x = \sin(400t+\phi)$ m

(C) $x = 10\sin(40t+\phi)$ cm

(D) $x = 100\sin(4t+\phi)$ m

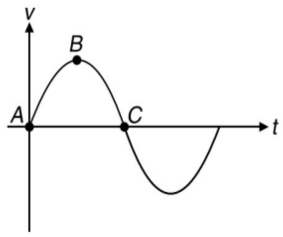
(For all the given four options, $\phi$ is constant)

**36.** A particle moves according to the law $x = a\cos\left(\frac{\pi t}{2}\right)$. The distance covered by it in the time interval between $t = 0$ to $t = 3$ s is

(A) $4a$ (B) $3a$

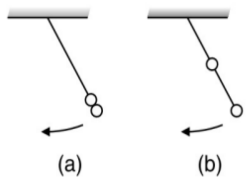
(C) $2a$ (D) $a$

**37.** The $v$-$t$ graph of a particle in SHM is as shown in figure. Select the incorrect statement.




(A) At $A$ particle is at mean position and moving towards positive direction
(B) At $B$ acceleration of particle is zero
(C) At $C$ acceleration of particle is maximum and in positive direction
(D) None of the above

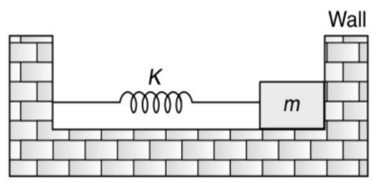
**38.** A long, straight massless rod is pivoted about one end in a vertical plane. In configuration (a), two small identical masses are attached to the free end and in configuration (b), one mass is moved to the center of the rod. The ratio of frequency of small oscillations in configuration (b) to that in configuration (a) is




(A) $\sqrt{6}:\sqrt{5}$ (B) $\sqrt{3}:\sqrt{2}$

(C) $6:5$ (D) $5:3$

**39.** In the figure, the block of mass $m$, attached to the spring of stiffness $k$ is in contact with the completely elastic wall and the compression in the spring is $l$. The spring is compressed further by $l$ by displacing the block towards left and is then released. If the collision between the block and the wall is completely elastic then the time period of oscillations of the block will be




(A) $\frac{2\pi}{3}\sqrt{\frac{m}{k}}$ (B) $2\pi\sqrt{\frac{m}{k}}$

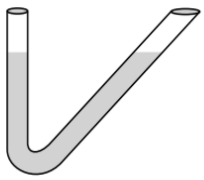
(C) $\frac{\pi}{3}\sqrt{\frac{m}{k}}$ (D) $\frac{\pi}{6}\sqrt{\frac{m}{k}}$

**40.** A particle performs SHM in a straight line. In the first second, starting from rest, it travels a distance $a$ and in the next second it travels a distance $b$ in the same direction. The amplitude of the SHM is

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

(C) $\frac{2a^2}{3a-b}$  (D) $a+b$

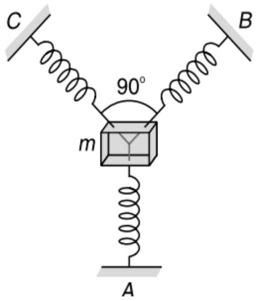
**41.** The period of oscillation of mercury of mass $m$ and density $\rho$ poured into a bent tube of cross sectional area $S$ whose right arm forms an angle $60°$ with the vertical is



(A) $2\pi\sqrt{\frac{m}{\rho g S}}$  (B) $2\pi\sqrt{\frac{2m}{3\rho g S}}$

(C) $2\pi\sqrt{\frac{2m}{(2+\sqrt{3})\rho g S}}$  (D) $2\pi\sqrt{\frac{m}{2\rho g S}}$

**42.** A particle of mass $m$ is attached to three identical springs A, B, C each of force constant $K$. If mass is slightly pushed against the spring A and released the time period of mass $m$ would be




(A) $2\pi\sqrt{m/K}$  (B) $2\pi\sqrt{m/2K}$

(C) $2\pi\sqrt{m/3K}$  (D) $2\pi\sqrt{3K/m}$

**43.** Two pendulums of lengths 1 m and 16 m are in phase at mean position at a certain instant of time. If $T$ is time period of shorter pendulum, the minimum time after which they will again be in phase is

(A) $T/3$  (B) $2T/3$

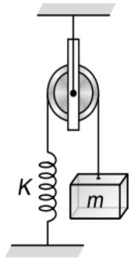
(C) $4T/3$  (D) $8T/3$

**44.** In case of a particle, executing simple harmonic motion, potential energy is $E_1$ at a displacement $x$ and $E_2$ at a displacement $y$. Its potential energy at displacement $(x+y)$ is

(A) $\sqrt{E_1+E_2}$  (B) $\sqrt{E_1}+\sqrt{E_2}$

(C) $E_1+E_2$  (D) $\left(\sqrt{E_1}+\sqrt{E_2}\right)^2$

**45.** Figure shows a mass $m$ suspended with a massless inextensible string passing over a frictionless pulley. The other end of string is connected a spring of force constant $K$, whose other end is connected to a rigid floor. If mass is stretched a little and allowed to vibrate; the time period of oscillations of mass is




(A) $2\pi\sqrt{K/m}$  (B) $2\pi\sqrt{m/K}$

(C) $2\pi\sqrt{2m/K}$  (D) $2\pi\sqrt{m/2K}$

**46.** The maximum tension in the string of a pendulum is two times the minimum tension. Let $\theta_0$ be the angular amplitude, then

(A) $\cos\theta_0 = \frac{1}{2}$  (B) $\cos\theta_0 = \frac{3}{4}$

(C) $\cos\theta_0 = \frac{2}{3}$  (D) $\cos\theta_0 = \frac{3}{5}$

**47.** If the displacement $x$ and velocity $v$ of a particle executing SHM are related to each other by the equation $4v^2 = 25 - x^2$, then the time period of SHM is

(A) $\pi$  (B) $2\pi$

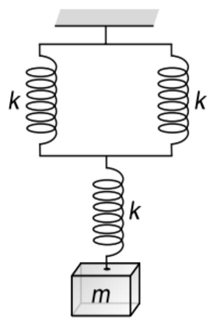
(C) $4\pi$  (D) $6\pi$

**48.** An accurate pendulum clock is mounted on the ground floor of a high building. The time that it will loose or gain in one day when transferred to top storey of a building which is $h = 200$ m higher than the ground floor is (Radius of earth is $6.4\times10^6$ m)

(A) it will lose 6.2 s  (B) it will lose 2.7 s

(C) it will gain 5.2 s  (D) it will gain 1.6 s

**49.** The frequency of a vertical oscillations of the three spring mass system, shown in the figure, is




(A) $\frac{1}{2\pi}\sqrt{\frac{3k}{2m}}$  (B) $\frac{1}{2\pi}\sqrt{\frac{2k}{3m}}$

(C) $\frac{1}{2\pi}\sqrt{\frac{3k}{m}}$  (D) $\frac{1}{2\pi}\sqrt{\frac{k}{3m}}$

**50.** The initial position and velocity of a particle executing SHM described by the equation $y = a\sin(\omega t+\theta)$ are 3 cm and $(1.5\pi)$ cms$^{-1}$ respectively. If angular frequency of particle is $0.5\pi$ rads$^{-1}$, then its amplitude is

(A) 3 cm (B) $2\sqrt{2}$ cm

(C) $3\sqrt{2}$ cm (D) $2\sqrt{3}$ cm

**51.** The potential energy of a particle of mass 1 kg in motion along the $x$-axis is given by $U = 4(1-\cos 2x)$ J, where $x$ is in metre. The period of small oscillations (in second) is

(A) $2\pi$ (B) $\pi$

(C) $\frac{\pi}{2}$ (D) $\sqrt{2}\pi$

**52.** A body of mass 5 g is executing S.H.M. with amplitude 10 cm. Its maximum velocity is 100 cms$^{-1}$. Its velocity will be 50 cms$^{-1}$ at a displacement from the mean position equal to

(A) 5 cm (B) $5\sqrt{3}$

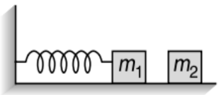
(C) 10 cm (D) $10\sqrt{3}$

**53.** A particle performs SHM of amplitude $A$ along a straight line. When it is at a distance $\frac{\sqrt{3}A}{2}$ from mean position, its kinetic energy suddenly increases by an amount $\frac{1}{2}m\omega^2 A^2$ due to an impulsive force. The new amplitude of oscillation will be

(A) $\frac{\sqrt{5}A}{2}$ (B) $\frac{\sqrt{3}A}{2}$

(C) $\sqrt{2}A$ (D) $\sqrt{5}A$

**54.** The two blocks of mass $m_1$ and $m_2$ are kept on a smooth horizontal table as shown in figure. Block of mass $m_1$ but not $m_2$ is fastened to the spring. If now both the blocks are pushed to the left so that the spring is compressed a distance $d$. The amplitude of oscillation of block of mass $m_1$, after the system is released is




(A) $d\sqrt{\frac{m_1}{m_1+m_2}}$ (B) $d\sqrt{\frac{m_2}{m_1+m_2}}$

(C) $d\sqrt{\frac{2m_2}{m_1+m_2}}$ (D) $d\sqrt{\frac{2m_1}{m_1+m_2}}$

**55.** The displacement of the motion of a particle is represented (in metre) by the equation

$$y = 0\cdot 4\left\{\cos^2\left(\frac{\pi t}{2}\right) - \sin^2\left(\frac{\pi t}{2}\right)\right\}$$

The motion of the particle is

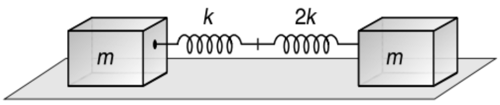
(A) oscillatory but not SHM

(B) SHM of amplitude 0.4 m, frequency 0.5 Hz

(C) SHM of amplitude $0.4\sqrt{2}$ m, frequency 2 Hz

(D) SHM of amplitude 0.8 m, frequency 2 Hz

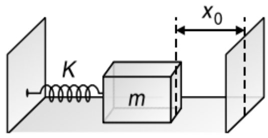
**56.** The time period for small oscillations of the two blocks connected with the springs as shown in Figure is




(A) $2\pi\sqrt{\frac{3m}{k}}$ (B) $2\pi\sqrt{\frac{3m}{4k}}$

(C) $2\pi\sqrt{\frac{3m}{8k}}$ (D) $2\pi\sqrt{\frac{3m}{2k}}$

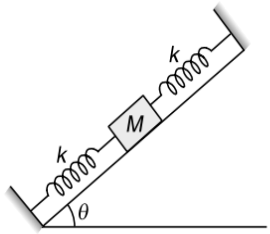
**57.** One end of a spring of force constant $K$ is fixed to a vertical wall and other to a body of mass $m$ resting on a smooth horizontal surface. There is another wall at a distance $x_0$ from the body. The spring is then compressed by $2x_0$ and released. The time taken to strike the wall from its compressed position is




(A) $\frac{4}{3}\pi\sqrt{\frac{m}{K}}$ (B) $\frac{5}{6}\pi\sqrt{\frac{m}{K}}$

(C) $\frac{1}{6}\pi\sqrt{\frac{m}{K}}$ (D) $\frac{2}{3}\pi\sqrt{\frac{m}{K}}$

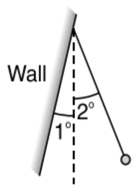
**58.** On a smooth inclined plane a body of mass $M$ is attached between two springs. The other ends of the springs are fixed to firm supports. If each spring has a force constant $k$, the period of oscillation of the body is (assuming the spring as massless)




(A) $2\pi\sqrt{\frac{M}{2k}}$ (B) $2\pi\sqrt{\frac{2M}{k}}$

(C) $2\pi\sqrt{\frac{M\sin\theta}{2k}}$ (D) $2\pi\sqrt{\frac{2M\sin\theta}{k}}$

**59.** A simple pendulum of length 1 m, hanging from an inclined wall, is made to oscillate from an angle 2° with the vertical as shown in Figure.




If collisions with the wall are elastic, time period of oscillation will be (use $g = \pi^2$)

(A) $\frac{2}{3}$ s (B) $\frac{4}{3}$ s

(C) 2 s (D) $\frac{1}{3}$ s

**60.** Two particles execute simple harmonic motion of the same amplitude and frequency along close parallel lines. They pass each other moving in opposite directions each time their displacement is half their amplitude. Their phase difference is

(A) $\frac{5\pi}{6}$ (B) $\frac{4\pi}{3}$

(C) $\frac{\pi}{6}$ (D) $\frac{2\pi}{3}$

**61.** Maximum speed of a particle in simple harmonic motion is $v_{max}$. Then average speed of a particle in SHM is equal to

(A) $\frac{v_{max}}{2}$ (B) $\frac{v_{max}}{\pi}$

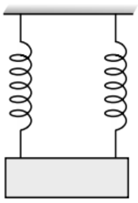
(C) $\frac{\pi v_{max}}{2}$ (D) $\frac{2v_{max}}{\pi}$

**62.** A ring of radius $R$ and mass $M$ is suspended from a point very close to its periphery. If it is displaced in its plane by a small angle and released, the period of oscillations will be

(A) $2\pi\sqrt{\frac{R}{g}}$ (B) $2\pi\sqrt{\frac{2R}{g}}$

(C) $2\pi\sqrt{\frac{3R}{g}}$ (D) $2\pi\sqrt{\frac{R}{2g}}$

**63.** An object suspended from a spring exhibits oscillation of period $T$. Now the spring is cut in two halves and the same object is suspended with two halves as shown in figure. The new time period of oscillation will become



(A) $T/\sqrt{2}$ (B) $2T$

(C) $T/2$ (D) $T/2\sqrt{2}$

**64.** The maximum acceleration of a particle in SHM is made two times keeping the maximum speed to be constant. It is possible when

(A) amplitude of oscillation is doubled while frequency remains constant
(B) amplitude is doubled while frequency is halved
(C) frequency is doubled while amplitude is halved
(D) frequency of oscillation is doubled while amplitude remains constant

**65.** A particle is moving in a circle of radius $R = 1$ m with constant speed $v = 4\ \text{ms}^{-1}$. The ratio of displacement to acceleration of the foot of the perpendicular drawn from the particle on the diameter of the circle is

(A) $\frac{1}{16}(\text{second})^2$ (B) $\frac{1}{2}(\text{second})^2$

(C) $2(\text{second})^2$ (D) $16(\text{second})^2$

**66.** A light spring of force constant $100\ \text{Nm}^{-1}$ is kept straight and unstretched on a smooth horizontal table with its ends fixed. A small bead of mass 40 g is now attached at the middle of the spring. If the bead is slightly displaced along the length of the spring and released, time period of oscillations will be

(A) $\frac{\pi}{50}$ second (B) $\frac{\pi}{100}$ second

(C) $\frac{\pi}{25}$ second (D) $\frac{2\pi}{25}$ second

**67.** A mass $M$ is suspended from a spring of negligible mass. The spring is pulled a little and then released so that it executes simple harmonic oscillations with a period $T$. If the mass is increased by $m$, the period becomes $\frac{5T}{4}$. The ratio $\left(\frac{m}{M}\right)$ is

(A) $\frac{4}{5}$ (B) $\frac{5}{4}$

(C) $\frac{9}{16}$ (D) $\frac{25}{16}$

**68.** A simple pendulum is suspended from the roof of a trolley that moves freely down a plane of inclination $\alpha$. The time period of oscillation is

(A) $2\pi\sqrt{\frac{L}{g}}$ (B) $2\pi\sqrt{\frac{L}{g\cos\alpha}}$

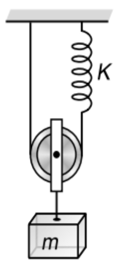
(C) $2\pi\sqrt{\frac{L}{g\sin\alpha}}$ (D) $2\pi\sqrt{\frac{L}{g\tan\alpha}}$

**69.** A particle is in linear simple harmonic motion between two points, $A$ and $B$, 10 cm apart. Taking direction from $A$ to $B$ as the positive direction, respective signs of velocity of the particle at the following positions is

(a) at the mid-point of $AB$ going towards $A$
(b) at 2 cm away from $B$ going towards $A$
(c) at 3 cm away from $A$ going towards $B$
(d) at 4 cm away from $B$ going towards $A$

(A) −, −, +, +
(B) −, −, +, −
(C) +, +, −, −
(D) +, −, +, −

**70.** A mass $m$ is suspended from a massless pulley, which itself is suspended by a massless string and a spring as shown in figure. What will be the time period of oscillations of the mass? The force constant of spring is $K$



(A) $2\pi\sqrt{\frac{m}{2K}}$ (B) $2\pi\sqrt{\frac{m}{K}}$
(C) $\pi\sqrt{\frac{m}{K}}$ (D) $\pi\sqrt{\frac{m}{2K}}$

**71.** Two simple pendulums having lengths 1 m and 16 m are both given small displacements in the same direction at the same instant. They will again be in phase at the mean position after the shorter pendulum has completed $n$ oscillations where $n$ is
(A) $\frac{1}{4}$ (B) 4
(C) 5 (D) 16

**72.** A sphere of radius $R$ is floating half submerged in a liquid of density $\rho$. If the sphere is slightly pushed down and released, the frequency of vertical oscillations is
(A) $\frac{1}{2\pi}\sqrt{\frac{g}{R}}$ (B) $\frac{1}{2\pi}\sqrt{\frac{3g}{2R}}$
(C) $\frac{1}{2\pi}\sqrt{\frac{g}{2R}}$ (D) $\frac{1}{2\pi}\sqrt{\frac{3g}{R}}$

**73.** A small sphere is placed on a concave mirror of radius of curvature 5 m a little away from its centre. When the sphere is released it oscillates. Assuming that the oscillation is simple harmonic, the time period is $\left(g = 10\ \text{ms}^{-2}\right)$
(A) $\frac{\pi}{\sqrt{2}}$ s (B) $\frac{\pi}{2}$ s
(C) $\pi$ s (D) $\pi\sqrt{2}$ s

**74.** If $R$ denotes the radius of the earth, then the time period of a simple pendulum of infinite length is
(A) infinite (B) $2\pi\sqrt{\frac{R}{g}}$
(C) $2\pi\sqrt{\frac{2R}{g}}$ (D) $2\pi\sqrt{\frac{R}{2g}}$

**75.** The period of a particle executing S.H.M. is 8 s. At $t = 0$ it is at the mean position. The ratio of the distances covered by the particle in the 1st second to the 2nd second is
(A) $\frac{1}{\sqrt{2}+1}$ (B) $\sqrt{2}$
(C) $\frac{1}{\sqrt{2}}$ (D) $\sqrt{2}+1$

**76.** A tunnel is dug across earth along one of its diameters. Two masses $m$ and $2m$ are dropped from two opposite ends of the tunnel. The masses collide and stick to each other. If $R$ be the radius of earth, then amplitude of subsequent SHM will be
(A) $R$ (B) $\frac{R}{2}$
(C) $\frac{R}{3}$ (D) $\frac{2R}{3}$

**77.** When the particle executing S.H.M. passes through mean position, it has
(A) Minimum kinetic energy and minimum potential energy
(B) Minimum kinetic energy and maximum potential energy
(C) Maximum kinetic energy and minimum potential energy
(D) Maximum kinetic energy and maximum potential energy

**78.** A particle of mass 2 kg is executing S.H.M. given by $y = 6\cos\left(100t + \frac{\pi}{4}\right)$ cm. Its maximum kinetic energy is
(A) 18 J (B) 36 J
(C) $18 \times 10^4$ J (D) $36 \times 10^4$ J

**79.** A particle is executing S.H.M. Then the graph of velocity as a function of displacement is
(A) straight line (B) circle
(C) ellipse (D) hyperbola

**80.** Time period of a simple pendulum is $T$. If its length increased by 2%, the new time period becomes
(A) $0.98T$ (B) $1.02T$
(C) $0.99T$ (D) $1.01T$

**81.** The mass and diameter of a planet are twice those of the earth. The time period of a simple pendulum on this planet, if it is a second's pendulum on earth, is
(A) $\frac{1}{\sqrt{2}}$ s (B) 2 s
(C) $\frac{1}{2}$ s (D) $2\sqrt{2}$ s

**82.** The angular frequency of a spring block system is $\omega_0$. This system is suspended from the ceiling of an elevator moving downwards with a constant speed $v_0$. The block is at rest relative to the elevator. Lift is suddenly stopped. Assuming the downward as a positive directions, choose the incorrect statement.
(A) Amplitude of block is $\frac{v_0}{\omega_0}$
(B) Initial phase of block is $\pi$
(C) Equation of motion for block is $\frac{v_0}{\omega_0}\sin\omega_0 t$
(D) Maximum speed of the block is $v_0$

**83.** A body, hung from a spring, executes vertical oscillations with period $T$. The body is now immersed in a non-viscous liquid having density one-tenth of that of the body. When set into two vertical oscillations with the body remaining fully immersed in the liquid all the time, the period will be
(A) $\sqrt{\frac{10}{9}}T$ (B) $\sqrt{\frac{9}{10}}T$
(C) $T$ (D) $\frac{1}{10}T$

**84.** Four simple harmonic vibrations $x_1 = 8\sin(\omega t)$, $x_2 = 6\sin\left(\omega t + \frac{\pi}{2}\right)$, $x_3 = 4\sin(\omega t + \pi)$ and $x_4 = 2\sin\left(\omega t + \frac{3\pi}{2}\right)$ are superimposed on each other. The resulting amplitude and its phase difference with $x_1$ are respectively

(A) 20, $\tan^{-1}\left(\frac{1}{2}\right)$ (B) $4\sqrt{2}, \frac{\pi}{2}$

(C) 20, $\tan^{-1}(2)$ (D) $4\sqrt{2}, \frac{\pi}{4}$

**85.** Two particles $P$ and $Q$ describe SHM of same amplitude $a$, same frequency $f$ along the same straight line. Maximum distance between the two particles is observed to be $a\sqrt{2}$. Phase difference between the particle is

(A) ZERO (B) $\frac{\pi}{2}$

(C) $\frac{\pi}{6}$ (D) $\frac{\pi}{3}$

**86.** Two masses $M$ and $m$ are suspended together by a light spring of force constant $k$. When the masses are in equilibrium, $M$ is removed without disturbing the system. The amplitude of oscillation is

(A) $\frac{Mg}{k}$ (B) $\frac{mg}{k}$

(C) $\frac{(M+m)g}{k}$ (D) $\frac{(M-m)g}{k}$

**87.** A wire of length $l$, area of cross section $A$ and Young's modulus of elasticity $Y$ is suspended from the roof of a building. A block of mass $m$ is attached at lower end of the wire. If the block is displaced from its mean position and then released the block starts oscillating. Time period of these oscillations will be

(A) $2\pi\sqrt{\frac{Al}{mY}}$ (B) $2\pi\sqrt{\frac{AY}{ml}}$

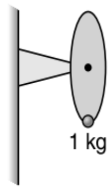
(C) $2\pi\sqrt{\frac{ml}{YA}}$ (D) $2\pi\sqrt{\frac{m}{YAl}}$

**88.** A pan with a set of weights is attached to a light spring. The period of vertical oscillations is 0.5 s. When some additional weights are put on the pan, the period of oscillations increases by 0.1 s. The extension caused by the additional weights is

(A) 1.3 cm (B) 2.7 cm

(C) 3.8 cm (D) 5.5 cm

**89.** A disc of mass 2 kg and radius 5 m is free to rotate about its axis kept horizontal. A particle of mass 1 kg is attached to the bottom most point of the disc as shown in Figure.




Time period (in seconds) of small oscillation of the system about the horizontal axis is

(A) $2\pi$ (B) $\pi$

(C) $4\pi$ (D) $0.5\pi$

**90.** A metallic sphere is filled with water and hung by a long thread. It is made to oscillate. If there is a small hole in the bottom through which water slowly flows out, the time period will

(A) go on increasing till the sphere is empty

(B) go on decreasing till the sphere is empty

(C) remain unchanged throughout

(D) first increase then decrease till the sphere is empty and the period will now be the same as when the sphere was full of water

**91.** A simple pendulum 4 m long swings with an amplitude of 0.2 m. Acceleration of pendulum at the ends of its path is (Take $g = 10\ ms^{-2}$)

(A) ZERO (B) $10\ ms^{-2}$

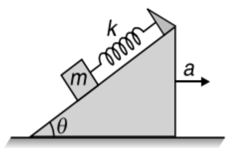
(C) $0.5\ ms^{-2}$ (D) $2.5\ ms^{-2}$

**92.** A uniform disc of radius $R$ is pivoted at point $O$ on its circumference. The time period of small oscillations will be

(A) $2\pi\sqrt{\frac{R}{g}}$ (B) $2\pi\sqrt{\frac{2R}{3g}}$

(C) $2\pi\sqrt{\frac{2R}{g}}$ (D) $2\pi\sqrt{\frac{3R}{2g}}$

**93.** A spring-block system is kept on a smooth wedge of inclination $\theta$ as shown in Figure.




The wedge is moving with constant acceleration $a$. Time period of small oscillation of block, assuming that at all times mass remains in contact with the wedge, is

(A) $2\pi\sqrt{\frac{m}{k\left(1+\frac{g^2}{a^2}\right)}}$ (B) $2\pi\sqrt{\frac{m\sin\theta}{k\left(1+\frac{g^2}{a^2}\right)}}$

(C) $2\pi\sqrt{\frac{m\sin\theta}{k}}$ (D) $2\pi\sqrt{\frac{m}{k}}$

**94.** A body falling freely on a planet covers 8 m in 2 s. The time period of one metre long simple pendulum on the planet will be

(A) 1.57 s (B) 3.14 s

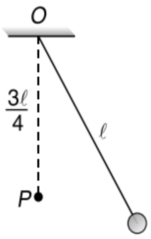
(C) 6.28 s (D) None of these

**95.** A particle of mass $m$ is executing oscillations about the origin on the $x$-axis with amplitude $A$. Its potential energy is given as $U(x) = \alpha x^4$ where $\alpha$ is a positive constant. The $x$-coordinate of mass where potential energy is one third the kinetic energy of particle is

(A) $\pm\frac{1}{2}A$ (B) $\pm\frac{1}{\sqrt{2}}A$

(C) $\pm\frac{1}{3}A$ (D) $\pm\frac{1}{\sqrt{3}}A$

**96.** A pendulum has time period $T$ for small oscillations. An obstacle $P$ is situated below the point of suspension $O$ at a distance $\frac{3l}{4}$. The pendulum is released from rest. Throughout the motion the moving string makes small angle with vertical. Time after which the pendulum returns back to its initial position is




(A) $T$ (B) $\frac{3}{4}T$

(C) $\frac{4}{3}T$ (D) $\frac{5}{4}T$

**97.** A particle performs SHM on $x$-axis from $x = -2$ cm to $x = 6$ cm with time period of 0.5 s. It was located at $x = 4$ cm and moving in positive $x$-direction at $t = 0$, then

(a) equation of the SHM is $x = 2 + 4\sin(4\pi t + 30°)$

(b) equation of the SHM is $x = -2 + 2\cos 4\pi t$

(c) acceleration of the particle at $x = 4$ cm is $32\pi^2$ cms$^{-2}$ towards positive $x$-direction

(A) (a) only (B) (a) and (c)

(C) (b) and (c) (D) (c) only

**98.** A 4 kg particle is moving along the $x$-axis under the action of the force (in newton), $F = -\frac{\pi^2 x}{16}$ where $x$ is the displacement from mean position in meters. At $t = 2$ s, the particle passes through the origin and at $t = 10$ s, its speed is $4\sqrt{2}$ ms$^{-1}$. The amplitude of the motion (in meters) is

(A) $\frac{32\sqrt{2}}{\pi}$ (B) $\frac{16}{\pi}$

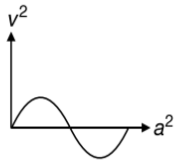
(C) $\frac{4}{\pi}$ (D) $\frac{16\sqrt{2}}{\pi}$

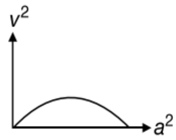
**99.** A particle starts oscillating simple harmonically from its equilibrium position. The ratio of kinetic and potential energy of the particle at time $\frac{T}{12}$, where $T$ is the time period is

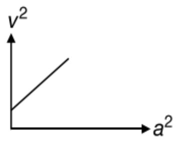
(A) 2 : 1 (B) 3 : 1

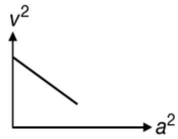
(C) 4 : 1 (D) 1 : 4

**100.** The graph between square of velocity and square of acceleration of a simple harmonic motion is

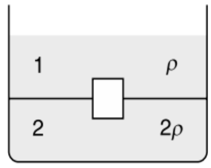
(A)



(B)



(C)



(D)



**101.** A plank of area of cross-section $A$ is half immersed in liquid 1 of density $\rho$ and half in liquid 2 of density $2\rho$. The period of oscillation of the plank when it is slightly depressed downwards is




(A) $2\pi\sqrt{\frac{m}{\rho A g}}$ (B) $\pi\sqrt{\frac{m}{\rho A g}}$

(C) $2\pi\sqrt{\frac{3m}{2\rho A g}}$ (D) $2\pi\sqrt{\frac{m}{3\rho A g}}$

**102.** A particle of mass $5 \times 10^{-5}$ kg is placed at the lowest point of a smooth parabola having the equation $x^2 = 40y$ where $x, y$ are in centimetre. If it is displaced slightly and it moves such that it is constrained to move along the parabola, the angular frequency of oscillation will be, approximately

(A) 0.1 s$^{-1}$ (B) 0.5 s$^{-1}$

(C) 0.7 s$^{-1}$ (D) 9 s$^{-1}$

**103.** Displacement time equation of a particle executing SHM is given by $x = A\sin\left(\omega t + \frac{\pi}{6}\right)$. The minimum time taken by the particle to go from $-\frac{A}{2}$ to $+\frac{A}{2}$ is

(A) $\frac{\pi}{3\omega}$ (B) $\frac{\pi}{2\omega}$

(C) $\frac{2\pi}{\omega}$ (D) $\frac{\pi}{\omega}$

**104.** A $U$ tube of uniform bore of cross-sectional area $A$ is set up vertically with open ends up. A liquid of mass $M$ and density $d$ is poured into it. The liquid column will oscillate with a period

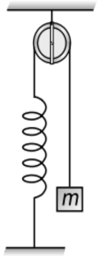
(A) $2\pi\sqrt{\frac{M}{g}}$ (B) $2\pi\sqrt{\frac{MA}{gd}}$

(C) $2\pi\sqrt{\frac{M}{Agd}}$ (D) $2\pi\sqrt{\frac{M}{2Agd}}$

**105.** An object of mass 0.2 kg executes simple harmonic oscillations along the $x$-axis with a frequency $\frac{25}{\pi}$ Hz. At the position $x = 0.04$ m, the object has kinetic energy 0.5 J and potential energy 0.4 J. Assuming the potential energy to be zero at the mean position, the amplitude of oscillation is

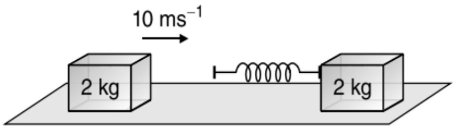
(A) 6 cm (B) 4 cm
(C) 8 cm (D) 2 cm

**106.** A mass $m = 8$ kg is attached to a spring as shown in figure and held in position so that the spring remains unstretched. The spring constant is 200 $\text{Nm}^{-1}$. The mass $m$ is then released and begins to undergo small oscillations. If $g = 10\ \text{ms}^{-2}$, then the maximum velocity of the mass is




(A) 1 $\text{ms}^{-1}$ (B) 2 $\text{ms}^{-1}$
(C) 4 $\text{ms}^{-1}$ (D) 5 $\text{ms}^{-1}$

**107.** A 2 kg block, moving with 10 $\text{ms}^{-1}$, strikes a spring of constant $\pi^2$ $\text{Nm}^{-1}$ attached to 2 kg block at rest kept on a smooth floor as shown in Figure.




The time for which rear moving block remains in contact with the spring is

(A) $\sqrt{2}$ s (B) $\frac{1}{\sqrt{2}}$ s
(C) 1 s (D) $\frac{1}{2}$ s

**108.** A simple pendulum has a length $L$. The mass of the bob is $m$. The bob is given a charge $+q$. The pendulum is suspended between the plates of a charged parallel plate capacitor which are placed vertically. If $E$ is electric field intensity between the plates, then the time period of oscillation will be

(A) $2\pi\sqrt{\frac{L}{g}}$ (B) $2\pi\sqrt{\frac{L}{\sqrt{g+\frac{qE}{m}}}}$

(C) $2\pi\sqrt{\frac{L}{\sqrt{g-\frac{qE}{m}}}}$ (D) $2\pi\sqrt{\frac{L}{\sqrt{g^2+\left(\frac{qE}{m}\right)^2}}}$

**109.** The potential energy of a harmonic oscillator of mass 2 kg in its mean position is 5 J. If its total energy is 9 J and its amplitude is 0.01 m, its time period is

(A) $\left(\frac{\pi}{10}\right)$ s (B) $\left(\frac{\pi}{20}\right)$ s
(C) $\left(\frac{\pi}{50}\right)$ s (D) $\frac{\pi}{100}$ s

**110.** A pendulum having a time period $T$ in air, has a time period $2T$ when made to oscillate in water. Ignoring viscosity of water, the density of the pendulum bob is equal to

(A) 2 $\text{gcc}^{-1}$ (B) 1.33 $\text{gcc}^{-1}$
(C) 1.5 $\text{gcc}^{-1}$ (D) 1.67 $\text{gcc}^{-1}$

**111.** The displacement of two identical particles executing SHM are represented by equations

$$x_1 = 4\sin\left(10t + \frac{\pi}{6}\right) \text{ and } x_2 = 5\cos(\omega t).$$

The value of $\omega$ for which the energy of both the particles will be the same is

(A) 16 unit (B) 6 unit
(C) 4 unit (D) 8 unit

**112.** The displacement-time equation of a particle executing SHM is $x = A\sin(\omega t + \phi)$. At time $t = 0$ position of the particle is $x = \frac{A}{2}$ and it is moving along negative $x$-direction. Then

(A) $\phi = \frac{\pi}{6}$ (B) $\phi = \frac{\pi}{3}$
(C) $\phi = \frac{2\pi}{3}$ (D) $\phi = \frac{5\pi}{6}$

**113.** A simple pendulum has time period $T = 2$ s in air. If the whole arrangement is placed in a non-viscous liquid whose density is $\frac{1}{2}$ time the density of bob. The time period in the liquid will be

(A) $\frac{2}{\sqrt{2}}$ s (B) 4 s
(C) $2\sqrt{2}$ s (D) $4\sqrt{2}$ s

**114.** A simple pendulum suspended from the roof of an elevator at rest has a time period $T_1$. When the elevator moves up with an acceleration $a$, its time period becomes $T_2$. When the elevator moves down with an acceleration $a$, its time period becomes $T_3$. Then

(A) $T_1 = \sqrt{T_2T_3}$ (B) $T_1 = T_2T_3$
(C) $T_1 = \frac{\sqrt{2}T_2T_3}{\sqrt{T_2^2 + T_3^2}}$ (D) $T_1 = \frac{T_2T_3}{\sqrt{T_2^2 + T_3^2}}$

**115.** A simple pendulum has a time period $T$. The pendulum is completely immersed in a non-viscous liquid whose density is one-tenth of that of the material of the bob. The time period of the pendulum immersed in liquid is

(A) $T$ (B) $\sqrt{\frac{9}{10}}T$
(C) $\sqrt{\frac{10}{9}}T$ (D) $\frac{T}{10}$

**116.** A particle executing SHM while moving from one extremity is found at distance $x_1$, $x_2$ and $x_3$ from the centre at the end of three successive second. The time period of oscillation in terms of $\theta = \cos^{-1}\left(\frac{x_1+x_3}{2x_2}\right)$ is

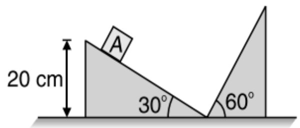
(A) $\frac{2\pi}{\theta}$ (B) $\frac{\pi}{\theta}$

(C) $\theta$ (D) $\frac{\pi}{2\theta}$

**117.** The displacement-time equation of a particle is given by $x = A\sin\left(\omega t+\frac{\pi}{6}\right) - A\cos\left(\omega t+\frac{\pi}{6}\right)$. Select the correct statement.

(A) The motion of the particle is not simple harmonic
(B) At $t=0$, acceleration of particle is positive
(C) At $t=0$, velocity of particle is negative
(D) None of these

**118.** The time period of motion of the block $A$ shown in Figure (if bend at the bottom of fixed wedges, the friction between block and wedges are ignored) is




(A) 0.4 (B) $0.8\left(1+\frac{1}{\sqrt{3}}\right)$

(C) 0.8 (D) $0.4\left(1+\frac{1}{\sqrt{3}}\right)$

**119.** Two bodies $M$ and $N$ of equal masses are suspended from two separate massless springs of spring constants $k_1$ and $k_2$ respectively. If the two bodies oscillate vertically such that their maximum velocities are equal, the ratio of the amplitude of vibration of $M$ to that of $N$ is

(A) $\frac{k_1}{k_2}$ (B) $\sqrt{\frac{k_2}{k_1}}$

(C) $\frac{k_2}{k_1}$ (D) $\sqrt{\frac{k_1}{k_2}}$

**120.** The maximum displacement of the particle executing S.H.M. is 1 cm and the maximum acceleration is $(1.57)^2$ cms$^{-2}$. Its time period is

(A) 0.25 s (B) 4.0 s
(C) 1.57 s (D) 3.14 s

**121.** Two pendulums of length 100 cm and 121 cm start vibrating. At some instant the two are at the mean position in the same phase. After how many vibrations of the longer pendulum will the two be in the same phase at the mean position again

(A) 10 (B) 11
(C) 20 (D) 21

**122.** A bob of mass $m$ is hanging from a point with the help of a light string of length $L$. A small impulse gives the bob a horizontal velocity $v$. The amplitude of resulting SHM is

(A) $v\sqrt{\frac{L}{g}}$ (B) $\frac{v}{2}\sqrt{\frac{L}{g}}$

(C) $\sqrt{\frac{v^2L}{2g}}$ (D) $\sqrt{\frac{v^2L}{8g}}$

**123.** The period of oscillation of a simple pendulum at a place where the acceleration due to gravity is $g$ is $T$. The speed of oscillation at a place where the acceleration due to gravity is $1.02g$ will be

(A) $T$ (B) $1.02T$
(C) $0.99T$ (D) $1.01T$

**124.** A weakly damped harmonic oscillator of frequency $n_1$ is driven by an external periodic force of frequency $n_2$. When the steady state is reached, the frequency of the oscillator will be

(A) $n_1$ (B) $n_2$

(C) $\frac{1}{2}(n_1+n_2)$ (D) $\sqrt{n_1+n_2}$

**125.** A simple pendulum of length $L$ is inside a container filled with a non-viscous liquid of density $\sigma$. The density of material of the pendulum bob is $\rho$. If the container is placed in a lift which is moving down with retardation $a_0$, then time period of simple pendulum is

(A) $2\pi\sqrt{\frac{L}{g\left(1-\frac{\sigma}{\rho}\right)-a_0}}$ (B) $2\pi\sqrt{\frac{L}{g\left(1-\frac{\sigma}{\rho}\right)+a_0}}$

(C) $2\pi\sqrt{\frac{L}{(g+a_0)\left(1-\frac{\sigma}{\rho}\right)}}$ (D) $2\pi\sqrt{\frac{L}{(g-a_0)\left(1-\frac{\sigma}{\rho}\right)}}$

**126.** The displacement-time equation of a particle executing SHM is $x = 4\sin(\omega t)+3\sin\left(\omega t+\frac{\pi}{3}\right)$, where $x$ is in centimetre and $t$ in second. The amplitude of oscillation of the particle is approximately

(A) 7 cm (B) 5 cm
(C) 6 cm (D) 9 cm

**127.** A block is kept on a rough horizontal plank. The coefficient of friction between the block and the plank is $\frac{1}{2}$. The plank is undergoing SHM of angular frequency 10 rads$^{-1}$. If $g = 10$ ms$^{-2}$, then the maximum amplitude of plank in which the block does not slip over the plank is

(A) 4 cm (B) 5 cm
(C) 10 cm (D) 16 cm

**128.** The equation of a particle of mass $m$ executing SHM is given by $y = a\sin\omega t + a\cos\omega t$. The total mechanical energy of particle is

(A) $\frac{1}{2}m\omega^2a^2$ (B) $m\omega^2a^2$

(C) $\frac{1}{4}m\omega^2a^2$ (D) ZERO

**129.** Three masses 0.1 kg, 0.3 kg and 0.4 kg are suspended at end of a spring. When the 0.4 kg mass is removed, the system oscillates with a period 2 s. When the 0.3 kg mass is also removed, the system will oscillate with a period

(A) 1 s (B) 2 s
(C) 3 s (D) 4 s

**130.** A pole is floating in a liquid with 80 cm of its length immersed. It is pushed down a certain distance and then released. Time period of vertical oscillation is

(A) $\frac{4\pi}{7}$ s (B) $\frac{3\pi}{7}$ s
(C) $\frac{2\pi}{7}$ s (D) $\frac{\pi}{7}$ s

**131.** Time period of a simple pendulum of length $R$ suspended over earth is equal to ($R$ is radius of earth and $g$ is acceleration due to gravity on the surface of earth)

(A) $\infty$ (B) $2\pi\sqrt{\frac{R}{g}}$
(C) $2\pi\sqrt{\frac{2R}{g}}$ (D) $2\pi\sqrt{\frac{R}{2g}}$

**132.** A particle executing S.H.M. has an acceleration of 64 $cms^{-2}$ when its displacement is 4 cm. Its time period, in second is

(A) $\frac{\pi}{2}$ (B) $\frac{\pi}{4}$
(C) $\pi$ (D) $2\pi$

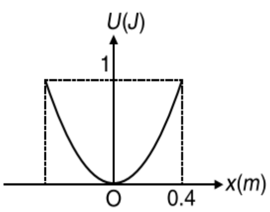
**133.** Two linear simple harmonic motions of equal amplitudes $a$ and frequencies ω and 2ω are impressed on a particle along $x$ and $y$ axis respectively. If the initial phase difference between them is $\frac{\pi}{2}$, the resultant trajectory equation of the particle is

(A) $a^2y^2 = x^2(a^2 - x^2)$
(B) $a^2y^2 = 2x^2(a^2 - x^2)$
(C) $a^2y^2 = 4x^2(a^2 - x^2)$
(D) $a^2y^2 = 8x^2(a^2 - x^2)$

**134.** A man weighing 60 kg stands on the horizontal platform of a spring balance. The platform starts executing simple harmonic motion of amplitude 0.1 m and frequency $\left(\frac{2}{\pi}\right)$ hertz. Then the spring balance reading fluctuates approximately between

(A) 50 kg and 60 kg (B) 60 kg and 70 kg
(C) 40 kg and 50 kg (D) 50 kg and 70 kg

**135.** A particle of mass 2 kg performs simple harmonic motion and its potential energy $U$ varies with position $x$ as shown in Figure. The period of oscillation of the particle is




(A) $\frac{2\pi}{5}$ s (B) $\frac{2\sqrt{2}\pi}{5}$ s
(C) $\frac{\sqrt{2}\pi}{5}$ s (D) $\frac{4\pi}{5}$ s

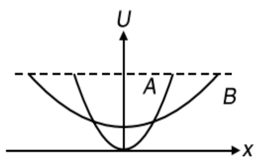
**136.** The minimum phase difference between the two simple harmonic oscillations $y_1 = \frac{1}{2}\sin(\omega t) + \frac{\sqrt{3}}{2}\cos(\omega t)$, and $y_2 = \sin(\omega t) + \cos(\omega t)$ is

(A) $\frac{\pi}{6}$ (B) $-\frac{\pi}{6}$
(C) $\frac{\pi}{12}$ (D) $\frac{7\pi}{12}$

**137.** A mass $m$ attached to a spring oscillates with a period of 3 s. If the mass is increased by 1 kg the period increases by 1 s. The initial mass $m$ in kg is

(A) $\frac{7}{9}$ (B) $\frac{9}{7}$
(C) $\frac{14}{9}$ (D) $\frac{18}{7}$

**138.** Potential energy $(U)$ versus displacement $(x)$ curves for two particles, of same mass, executing SHM about same mean position $(x = 0)$ on $x$-axis are shown in Figure. Then relation between their angular frequencies is

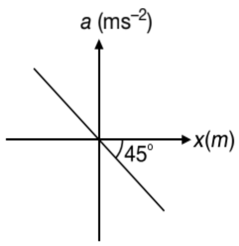



(A) $\omega_A > \omega_B$
(B) $\omega_A < \omega_B$
(C) $\omega_A = \omega_B$
(D) $\omega_B = 2\omega_A$

**139.** A flat horizontal board moves up and down in S.H.M. of amplitude $A$. Then the smallest permissible value of the time period, such that an object on the board may not lose contact with the board

(A) $2\pi\sqrt{\frac{g}{A}}$ (B) $\pi\sqrt{\frac{g}{A}}$
(C) $\pi\sqrt{\frac{A}{g}}$ (D) $2\pi\sqrt{\frac{A}{g}}$

**140.** The acceleration-displacement graph of a particle executing SHM is shown in given figure. The time period of its oscillation in seconds is



(A) $\frac{\pi}{2}$ (B) $2\pi$

(C) $\pi$ (D) $\frac{\pi}{4}$

**141.** A body executes S.H.M. with an amplitude $A$. Its energy is half kinetic and half potential when the displacement is

(A) $\frac{A}{3}$ (B) $\frac{A}{2}$

(C) $\frac{A}{\sqrt{2}}$ (D) $\frac{A}{2\sqrt{2}}$

**142.** A particle of mass $m$ moving along $x$-axis has a potential energy given by $U(x)=a+bx^2$, where $a$ and $b$ are positive constants and $x$ is displacement from mean position. The frequency of SHM executed by the particle depends on

(A) $b$ alone (B) $b$ and $a$ alone

(C) $b$ and $m$ alone (D) $b$, $a$ and $m$ alone

**143.** The frequency of a particle executing SHM is 10 Hz. A particle is suspended from a vertical spring. At the highest point of its oscillation the spring is unstretched. The maximum speed of the particle is

Take $g=10\text{ ms}^{-2}$.

(A) $2\pi\text{ ms}^{-1}$ (B) $\pi\text{ ms}^{-1}$

(C) $\frac{1}{\pi}\text{ ms}^{-1}$ (D) $\frac{1}{2\pi}\text{ ms}^{-1}$

**144.** A particle is vibrating in S.H.M. Its velocities are $v_1$ and $v_2$ when the displacements from the mean position are $y_1$ and $y_2$, respectively, then its time period is

(A) $2\pi\sqrt{\frac{y_1^2+y_2^2}{v_1^2+v_2^2}}$ (B) $2\pi\sqrt{\frac{v_1^2+v_2^2}{y_1^2+y_2^2}}$

(C) $2\pi\sqrt{\frac{v_2^2-v_1^2}{y_1^2-y_2^2}}$ (D) $2\pi\sqrt{\frac{y_1^2-y_2^2}{v_2^2-v_1^2}}$

**145.** A ball of mass 2 kg hanging from a spring oscillates with a time period $2\pi$ second. If the ball is removed when it is in equilibrium position, then the spring shortens by

(A) $g$ metre (B) $\frac{g}{2}$ metre

(C) $2g$ metre (D) $2\pi$ metre

**146.** The potential energy of a simple harmonic oscillator of mass 2 kg at its mean position is 5 J. If its total energy is 9 J and its amplitude is 0.01 m, then its time period in seconds will be

(A) $\frac{\pi}{10}$ (B) $\frac{\pi}{20}$

(C) $\frac{\pi}{50}$ (D) $\frac{\pi}{100}$

**147.** For the particle executing S.H.M. the kinetic energy $E$ is given by $E=E_0\cos^2(\omega t)$. The maximum value of potential energy is

(A) $\frac{E_0}{2}$ (B) $\frac{E_0}{\sqrt{2}}$

(C) $E_0$ (D) None of these

**148.** A particle of mass 0.1 kg executes SHM under a force $F=-(10\,x)$ N, such that the speed of the particle at mean position is $6\text{ ms}^{-1}$. Then amplitude of oscillations is

(A) 0.6 m (B) 0.2 m

(C) 0.4 m (D) 0.1 m

**149.** Time period of a body executing SHM is $\pi$ seconds. The numerical value of its velocity is equal to that of its acceleration when it is at a distance 10 cm from the mean position. Amplitude of oscillation is

(A) $10\sqrt{2}$ cm (B) $10\sqrt{3}$ cm

(C) 20 cm (D) $10\sqrt{5}$ cm

**150.** The period of the simple pendulum in a stationary lift is $T$. If the lift moves upwards with an acceleration $g$, the period will be

(A) infinite (B) $\sqrt{\frac{3}{5}}T$

(C) $\sqrt{\frac{5}{3}}T$ (D) $\frac{T}{\sqrt{2}}$

**151.** The displacement of a simple harmonic oscillator is given by $y=5\cos\left(2\pi t+\frac{\pi}{3}\right)$. The speed of the oscillator will be maximum at

(A) 1 s (B) 0 s

(C) $\frac{1}{12}$ s (D) $\frac{1}{2}$ s

**152.** The vertical extension in a light spring by weight of 1 kg, in equilibrium, is 9.8 cm. The period of oscillation of the spring, in second will be

(A) $\frac{2\pi}{10}$ (B) $\frac{2\pi}{100}$

(C) $20\pi$ (D) $200\pi$

**153.** A girl swinging on a swing in the sitting position. If she stands up the period of the swing will be

(A) shorter

(B) longer

(C) remain unchanged

(D) None of these

## MULTIPLE CORRECT CHOICE TYPE QUESTIONS

This section contains Multiple Correct Choice Type Questions. Each question has four choices (A), (B), (C) and (D), out of which ONE OR MORE is/are correct.

**1.** A cylindrical log of wood is floating in a large pool of water with its length normal to water's surface. The log has a radius $r$, mass $m$, length $l$ and has density σ. If the log is depressed below its equilibrium depth $d$ (but not beneath the surface of water) and then released, it executes harmonic oscillations with time period $T$. (Assume density of water to be $\rho$)

(A) $T = 2\pi\sqrt{\dfrac{m}{2\pi\rho r l g}}$ (B) $T = \dfrac{2\pi}{r}\sqrt{\dfrac{m}{\pi\rho g}}$

(C) $d = \dfrac{m}{2\pi r\rho l}$ (D) $d = \dfrac{m}{\pi r^2\rho}$

**2.** The $x$-$t$ equation of a particle moving along $x$-axis is given by $x = A + A(1-\cos\omega t)$, then the

(A) particle oscillates simple harmonically between points $x = 2A$ and $x = A$

(B) velocity of particle is maximum at $x = 2A$

(C) time taken by particle in travelling from $x = A$ to $x = 3A$ is $\dfrac{\pi}{\omega}$

(D) time taken by particle in travelling from $x = A$ to $x = 2A$ is $\dfrac{\pi}{2\omega}$

**3.** The displacement of a particle of mass 100 g from its mean position is given by $y = 0.05\sin[4\pi(5t+0.4)]$, where $y$ in meter and $t$ in second. Then, select the correct statement(s).

(A) Time period of motion is 0.1 s

(B) Maximum acceleration of particle is $10\pi^2$ ms$^{-2}$

(C) Total energy of SHM of particle is $0.05\pi^2$ J.

(D) Force on particle is zero when displacement is 0.05 m

**4.** A particle is executing SHM on a straight line. $A$ and $B$ are two points at which its velocity is zero. It passes through a certain point $P(AP < BP)$ at successive intervals of 0.5 sec and 1.5 sec with a speed of 3 ms$^{-1}$, then the

(A) maximum speed of particle is $3\sqrt{2}$ ms$^{-1}$

(B) maximum speed of particle is $\sqrt{2}$ ms$^{-1}$

(C) ratio $\dfrac{AP}{BP}$ is $\dfrac{\sqrt{2}-1}{\sqrt{2}+1}$

(D) ratio $\dfrac{AP}{BP}$ is $\dfrac{1}{\sqrt{2}}$

**5.** Time period of spring block system on surface of earth is $T_1$ and that of a simple pendulum is $T_2$. At height $h = R$, the radius of earth the corresponding values are $T_1'$ and $T_2'$ then

(A) $T_1' > T_1$ (B) $T_1' = T_1$

(C) $T_2' > T_2$ (D) $T_2' < T_2$

**6.** A student uses a simple pendulum of exactly 1 m length to determine $g$, the acceleration due to gravity. He uses a stop watch with the least count of 1 s for this and records 40 s for 20 oscillations. For this observation, which of the following statement(s) is (are) true?

(A) Error $\Delta T$ in measuring $T$, the time period, is 0.05 s

(B) Error $\Delta T$ in measuring $T$, the time period, is 1 s

(C) Percentage error in the determination of $g$ is 5%

(D) Percentage error in the determination of $g$ is 2.5%

**7.** In a spring block system, the force constant of spring is $k = 16$ Nm$^{-1}$, mass of the block is 1 kg and the maximum kinetic energy of the block is 8 J. Then

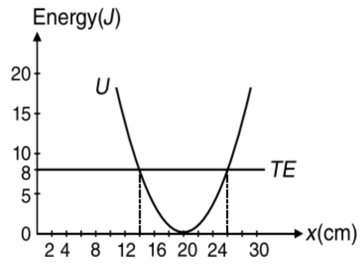
(A) amplitude of oscillation is 1 m

(B) at half the amplitude potential energy stored in the spring is 2 J

(C) at half the amplitude kinetic energy is 6 J

(D) angular frequency of oscillation is 16 rads$^{-1}$

**8.** The potential energy and the total energy line of a particle oscillating by means of a spring are shown in Figure. Then, select the correct statements.




(A) Amplitude of oscillation of particle is 6 cm

(B) Spring constant is 4.44 Nm$^{-1}$

(C) Kinetic energy of particle is maximum at $x = 20$ cm

(D) Spring constant is 4.44 kNm$^{-1}$

**9.** A particle moves along the $x$-axis according to the equation $x = 4 + 3\sin(2\pi t)$. Here $x$ is in cm and $t$ in second. Select the correct alternative(s).

(A) The motion of the particle is simple harmonic with mean position at $x = 4$ cm.

(B) The motion of the particle is simple harmonic with mean position at $x = -4$ cm.

(C) Amplitude of oscillation is 3 cm.

(D) Amplitude of oscillation is 7 cm.

**10.** Two particles are in SHM with same amplitude $A$ and same angular frequency $\omega$. At time $t = 0$, one is at $x = +\dfrac{A}{2}$ and the other is at $x = -\dfrac{A}{2}$. Both the particles start moving in the same direction, then

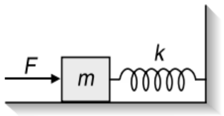
(A) phase difference between the two particles is $\dfrac{\pi}{3}$

(B) phase difference between the two particles is $\dfrac{2\pi}{3}$

(C) the particles will collide after time $t = \dfrac{\pi}{2\omega}$

(D) the particles will collide after time $t = \dfrac{3\pi}{4\omega}$

**11.** A constant force $F$ is applied on a spring block system as shown in figure. The mass of the block is $m$ and spring constant is $k$. Then block is placed over a smooth surface. Initially the spring was unstretched. Select the correct alternative(s).




(A) The block will execute SHM

(B) The amplitude of oscillation is $\frac{F}{2k}$

(C) The time period of oscillation is $2\pi\sqrt{\frac{m}{k}}$

(D) The maximum speed of block is $\sqrt{\frac{2Fx - kx^2}{m}}$

**12.** In a linear SHM, if $\vec{v}$ is velocity, $\vec{r}$ is displacement from mean position and $\vec{F}$ is the restoring force on the body, then select the correct statement(s).

(A) $\vec{v}\cdot\vec{r}$ is always negative

(B) $\vec{F}\cdot\vec{r}$ is always negative

(C) $\vec{v}\times\vec{r}$ is always zero

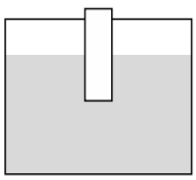
(D) $\vec{F}\times\vec{r}$ is always zero

**13.** A particle starts SHM at time $t = 0$. Its amplitude is $A$ and angular frequency is $\omega$. At time $t = 0$ its kinetic energy is $\frac{E}{4}$. Assuming potential energy to be zero at mean position, the displacement-time equation of the particle can be written as

(A) $x = A\cos\left(\omega t - \frac{\pi}{6}\right)$ (B) $x = A\sin\left(\omega t - \frac{2\pi}{3}\right)$

(C) $x = A\sin\left(\omega t + \frac{\pi}{3}\right)$ (D) $x = A\cos\left(\omega t + \frac{\pi}{6}\right)$

**14.** A plank is floating in a non-viscous liquid as shown in Figure. Select the correct statement(s).



(A) Plank is in stable vertical equilibrium.

(B) For small vertical displacement of the plank, motion is periodic but not simple harmonic.

(C) Even if oscillations are large, motion is simple harmonic till the plank gets fully immersed.

(D) For small oscillations of plank in vertical direction, motion is simple harmonic.

**15.** The density of a liquid $\rho$, varies with the depth $h$ as $\rho = \alpha h$, where $\alpha$ is a positive constant. A small ball of density $\rho_0$ is released from the free surface of the liquid. Then the ball will

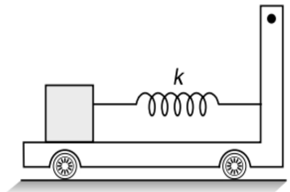
(A) execute SHM of amplitude $\frac{\rho_0}{\alpha}$.

(B) have its mean position at a depth $\frac{\rho_0}{2\alpha}$ below the free surface.

(C) sink to a maximum depth of $\frac{2\rho_0}{\alpha}$.

(D) all of the above are true.

**16.** A block of mass $m$ is attached to a massless spring of force constant $k$, the other end of which is fixed from the wall of a truck as shown in figure. The block is placed over a smooth surface and initially the spring is unstretched. Suddenly the truck starts moving towards right with a constant acceleration $a_0$. As seen from the truck




(A) the particle will execute SHM

(B) the time period of oscillations will be $2\pi\sqrt{\frac{m}{k}}$

(C) the amplitude of oscillations will be $\frac{ma_0}{k}$

(D) the energy of oscillations will be $\frac{m^2a_0^2}{k}$

**17.** A rectangular block of mass $m$ and area of cross-section $A$ floats in a liquid of density $\rho$. If it is given a small vertical displacement from equilibrium, it undergoes oscillation with a time period $T$, then select the correct alternative(s)

(A) $T^2 \propto m$ (B) $T^2 \propto g$

(C) $T^2 \propto \frac{1}{A}$ (D) $T^2 \propto \frac{1}{\rho}$

**18.** A simple pendulum of length 1 m with a bob of mass $m$ swings with an angular amplitude $30°$. If $g = 9.8\ \text{ms}^{-2}$, then

(A) time period of pendulum is 2 s

(B) tension in the string is greater than $mg\cos(15°)$ at angular displacement $15°$

(C) rate of change of speed at angular displacement $15°$ is $g\sin(15°)$

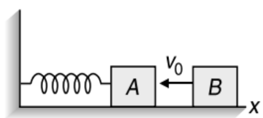
(D) tension in the string is $mg\cos(15°)$ at angular displacement $15°$

**19.** Let $E$, $K$ and $U$ represent total energy, average kinetic energy over one period and average potential energy over one period respectively in case of a particle executing SHM. Then select the correct relation(s).

(A) $E = K = U$ (B) $K = U$

(C) $E = 2K$ (D) $E = 0.5U$

**20.** A block $A$ of mass $m$ connected with a spring of force constant $k$ is executing SHM. The displacement-time equation of the block is $x = x_0 + a\sin\omega t$. An identical block $B$ moving towards negative $x$-axis with velocity $v_0$ collides elastically with block $A$ at time $t = 0$. Then



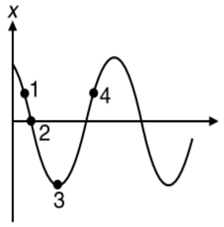
(A) displacement time equation of $A$ after collision will be $x = x_0 - v_0\sqrt{\frac{m}{k}}\sin(\omega t)$

(B) displacement time equation of $A$ after collision will be $x = x_0 + v_0\sqrt{\frac{m}{k}}\sin(\omega t)$

(C) velocity of $B$ just after collision will be $a\ \omega$ towards positive $x$-direction

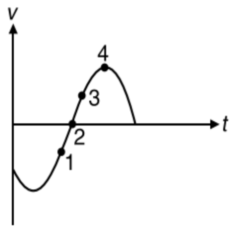
(D) velocity of $B$ just after collision will be $v_0$ towards positive $x$-direction

**21.** The acceleration-time graph of a particle executing SHM is as shown in figure. Select the correct alternative(s).




(A) Displacement of particle at 1 is negative.
(B) Velocity of particle at 2 is positive.
(C) Potential energy of particle at 3 is maximum.
(D) Speed of particle at 4 is decreasing.

**22.** The velocity-time graph of a particle executing SHM is shown in figure. Select the correct alternative(s).




(A) At position 1, displacement of particle may be positive or negative.
(B) At position 2, displacement of particle is negative.
(C) At position 3, acceleration of particle is positive.
(D) At position 4, acceleration of particle is positive.

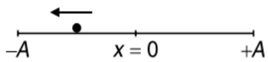
**23.** For a particle executing simple harmonic motion, the
(A) potential energy and kinetic energy may not be equal in mean position
(B) potential energy and kinetic energy may be equal in extreme position
(C) potential energy may be zero at extreme position
(D) kinetic energy plus potential energy oscillates simple harmonically

**24.** A person normally weighing $60$ kg stands on a platform which oscillates up and down simple harmonically with a frequency $2$ Hz and an amplitude $5$ cm. If a machine on the platform gives the person's weight, then the $(g = 10\ \text{ms}^{-2}, \pi^2 = 10)$
(A) maximum reading of the machine is 108 kg
(B) maximum reading of the machine is 90 kg
(C) minimum reading of the machine is 12 kg
(D) minimum reading of the machine is zero

**25.** Potential energy (in joule) of a particle of mass $0.1$ kg, moving along the $x$-axis, is given by $U = 5x(x-4)$ J, where $x$ is in metre, then the
(A) particle is acted upon by a constant force
(B) speed of the particle is maximum at $x = 2$ m
(C) particle executes simple harmonic motion
(D) particle is acted upon by a force that varies linearly with $x$

**26.** The speed $v$ of a particle moving along a straight line, when it is at a distance $x$ from a fixed point on the line is given by $v^2 = 144 - 9x^2$. Select the correct alternative(s).
(A) The motion of the particle is SHM with time period $T = \frac{2\pi}{3}$ unit.
(B) The maximum displacement of the particle from the fixed point is 4 unit.
(C) The magnitude of acceleration at a distance 3 unit from the fixed points is 27 unit.
(D) The motion of the particle is periodic but not simple harmonic.

**27.** Two particles undergo SHM along the same line with the same time period $(T)$ and equal amplitudes $(A)$. At a particular instant on particle is at $x = -A$ and the other is at $x = 0$. They move in the same direction. They will cross each other at




(A) $t = \frac{4T}{3}$
(B) $t = \frac{3T}{8}$
(C) $x = \frac{A}{2}$
(D) $x = \frac{A}{\sqrt{2}}$

**28.** Two small particles $P$ and $Q$ each of mass $m$ are fixed along $x$-axis at points $(a,\ 0)$ and $(-a,\ 0)$. A third particle $R$ is kept at origin. Then
(A) if particle $R$ is displaced along $x$-axis it will start oscillating
(B) oscillations of $R$ along $x$-axis are not simple harmonic in nature
(C) if $R$ is displaced along $y$-axis are not simple harmonic in nature
(D) oscillations along $y$-axis are not simple harmonic in nature

**29.** A body of mass $m$ is suspended from two light springs of force constants $k_1$ and $k_2$ separately. The period of vertical oscillations are $T_1$ and $T_2$ respectively. Now the same body is suspended from the same two springs which are first connected in series and then in parallel. The period of vertical oscillations are $T_s$ and $T_p$ respectively
(A) $T_p < T_1 < T_2 < T_s$ and $k_1 > k_2$
(B) $\frac{1}{T_p^2} = \frac{1}{T_1^2} + \frac{1}{T_2^2}$
(C) $T_s^2 = T_1^2 + T_2^2$
(D) $\sqrt{T_s} = \sqrt{T_1} + \sqrt{T_2}$

30. A particle of mass $m$ is moving in a potential well, for which the potential energy is given by $U(x) = U_0(1 - \cos ax)$ where $U_0$ and $a$ are constants. Then (for the small oscillations)

(A) the time period of small oscillations is $T = 2\pi\sqrt{\dfrac{m}{aU_0}}$

(B) the speed of the particle is maximum at $x = 0$

(C) the amplitude of oscillations is $\dfrac{\pi}{2a}$

(D) the time period of small oscillations is $T = 2\pi\sqrt{\dfrac{m}{a^2U_0}}$

31. In simple harmonic motion of a particle maximum kinetic energy is 40 J and maximum potential energy is 60 J. Then

(A) minimum potential energy will be 20 J

(B) potential energy at half the displacement will be 30 J

(C) kinetic energy at half the displacement is 40 J

(D) potential energy or kinetic energy at some intermediate position cannot be found from the given data

## REASONING BASED QUESTIONS

This section contains Reasoning type questions, each having four choices (A), (B), (C) and (D) out of which ONLY ONE is correct. Each question contains STATEMENT 1 and STATEMENT 2. You have to mark your answer as

**Bubble (A)** If both statements are TRUE and STATEMENT 2 is the correct explanation of STATEMENT 1.
**Bubble (B)** If both statements are TRUE but STATEMENT 2 is not the correct explanation of STATEMENT 1.
**Bubble (C)** If STATEMENT 1 is TRUE and STATEMENT 2 is FALSE.
**Bubble (D)** If STATEMENT 1 is FALSE but STATEMENT 2 is TRUE.

1. **Statement-1:** The simple harmonic motion is to and fro and periodic.
**Statement-2:** The motion of the earth is periodic.

2. **Statement-1:** The bob of a simple pendulum is a hollow ball full of water. If a fine hole is made at the bottom of the ball, then the time period will vary till the ball gets empty and then becomes constant.
**Statement-2:** The time period of simple pendulum does not depend upon mass.

3. **Statement-1:** The periodic time of hard spring is less as compared to that of a soft spring.
**Statement-2:** The periodic time is inversely proportional to the square root of the spring constant.

4. **Statement-1:** In a simple harmonic motion the kinetic and potential energies become equal when the displacement is $\dfrac{1}{\sqrt{2}}$ times the amplitude.
**Statement-2:** In SHM kinetic energy is zero when potential energy is maximum.

5. **Statement-1:** In simple harmonic motion the velocity is maximum when the acceleration is maximum.
**Statement-2:** Displacement and velocity of SHM differ in phase by $\dfrac{\pi}{2}$.

6. **Statement-1:** The time period of a pendulum, on a satellite orbiting the earth is infinity.
**Statement-2:** Time period of a pendulum is inversely proportional to square root of acceleration due to gravity.

7. **Statement-1:** In SHM, acceleration is always directed towards the mean position.
**Statement-2:** The body stops momentarily at the extreme positions and then moves back to mean position.

8. **Statement-1:** The length of a simple pendulum is increased by 4%, the corresponding decrease in time period will be 2%.
**Statement-2:** $T \propto \sqrt{l}$

9. **Statement-1:** The time period of a simple pendulum of infinite length is infinite.
**Statement-2:** The time period of a simple pendulum is directly proportional to the square root of length.

10. **Statement-1:** Simple harmonic motion is not a uniform motion.
**Statement-2:** It is the projection of uniform circular motion along two mutually perpendicular diameters.

11. **Statement-1:** The graph of PE and KE of a particle in SHM with respect to position is a parabola.
**Statement-2:** This is because PE and KE do not vary linearly with position.

12. **Statement-1:** Water in a $U$-tube executes SHM, the time period for mercury filled up to the same height in the $U$-tube be greater than that in case of water.
**Statement-2:** The amplitude of an oscillating pendulum goes on decreasing.

13. **Statement-1:** Damped vibrations indicate loss of energy.
**Statement-2:** The loss may be due to friction, air resistance.

14. **Statement-1:** If the earth suddenly contracts, then duration of day will decrease.
**Statement-2:** The angular velocity of the earth's rotation will decrease.

15. **Statement-1:** A hole were drilled through the centre of earth and a ball is dropped into the hole at the end, it will not get out of other end of the hole.
**Statement-2:** It will execute SHM and will be seen at the other end after 43.2 minutes from the time it is dropped.

16. **Statement-1:** The graph between velocity and displacement for a harmonic oscillator is a parabola.
**Statement-2:** Velocity does not change uniformly with displacement in simple harmonic motion.

17. **Statement-1:** If the amplitude of a simple harmonic oscillator is doubled, its total energy also becomes doubled.
**Statement-2:** The total energy is directly proportional to the square amplitude of vibration of the harmonic oscillator.

18. **Statement-1:** The height of a liquid column in a $U$-tube is $0.3$ m. If the liquid in one of the limbs is depressed and then released the time period of a liquid column will be $1.1$ s.
**Statement-2:** This follows from, the relation $t = 2\pi\sqrt{\frac{L}{g}}$.

19. **Statement-1:** For a simple pendulum the graph between $g$ and $T^2$ is a rectangular hyperbola.
**Statement-2:** $T = 2\pi\sqrt{\frac{g}{l}}$

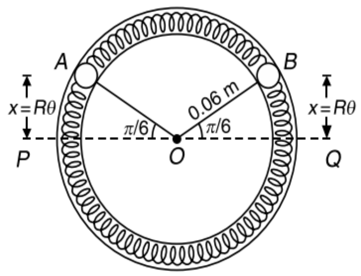
20. **Statement-1:** A man with a watch (spring wound) on his hand falls from the top of a tower. The watch will show the correct time.
**Statement-2:** The acceleration due to gravity will have no effect on time period of watch at the time of falling.

## LINKED COMPREHENSION TYPE QUESTIONS

This section contains Linked Comprehension Type Questions or Paragraph based Questions. Each set consists of a Paragraph followed by questions. Each question has four choices (A), (B), (C) and (D), out of which only one is correct. (For the sake of competitiveness there may be a few questions that may have more than one correct options)

### Comprehension I

Two identical balls $A$ and $B$, each of mass $0.1$ kg, are attached to two identical massless springs. The springs-mass system is constrained to move inside a rigid smooth pipe bent in the form of a circle as shown in figure. The pipe is fixed in a horizontal plane. The centres of the balls can move in a circle of radius $0.06$ m. Each spring has a natural length of $0.06\pi$ metre and spring constant $0.1\ \text{Nm}^{-1}$. Initially, both the balls are displaced by an angle $\theta = \frac{\pi}{6}$ radian with respect to the diameter $PQ$ of the circle (as shown in figure) and released from rest.




Based on the above facts, answer the following questions.

1. The frequency of oscillation of ball $B$ is
(A) $\frac{3}{\pi}$ Hz (B) $\frac{2}{\pi}$ Hz
(C) $\frac{1}{\pi}$ Hz (D) None of these is correct

2. Assume the balls $A$ and $B$ to be at the two ends of the diameter. The speed of the ball $A$ at this instant is
(A) $0.0268\ \text{ms}^{-1}$ (B) $0.063\ \text{ms}^{-1}$
(C) $0.63\ \text{ms}^{-1}$ (D) $6.3\ \text{ms}^{-1}$

3. Total energy of the system is denoted by $E$. Then
(A) $E = 19\times10^{-4}$ J (B) $E = 29\times10^{-4}$ J
(C) $E = 39\times10^{-4}$ J (D) $E = 49\times10^{-4}$ J

### Comprehension 2

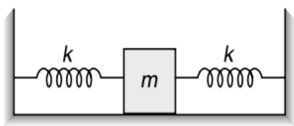
A force acting on a block is $F = (-4x+8)$, where $F$ is in Newton and $x$ the position of block on $x$-axis in metres. The energy of oscillation is 18 J. Based on the information given, answer the following questions.

4. The motion of the block is
(A) periodic but not simple harmonic.
(B) not periodic.
(C) simple harmonic about origin, $x = 0$.
(D) simple harmonic about $x = 2$ m.

5. The block will oscillate between the points
(A) $x = 0$ and $x = 4$ m
(B) $x = -1$ m and $x = 5$ m
(C) $x = -2$ m and $x = 6$ m
(D) $x = 1$ m and $x = 3$ m

### Comprehension 3

A block of mass $m$ is attached to two springs, each of force constant $k$ as shown. In the equilibrium position, the springs are in their natural length. The mass oscillates along the line of springs with amplitude $A_0$. At $t = 0$ the mass is at $+\frac{A_0}{2}$ from the equilibrium position and is moving to the right. At this very instant the right spring is removed without changing the velocity of the block. Based on the information given, answer the following questions.




Frictionless

6. The new time period of oscillation in terms of its original period $T_0$ is
(A) $2T_0$ (B) $\sqrt{2}T_0$
(C) $\frac{T_0}{2}$ (D) $\frac{T_0}{\sqrt{2}}$

7. The new amplitude $A$, of mass is

(A) $A_0$ (B) $\frac{\sqrt{3}A_0}{2}$

(C) $\frac{\sqrt{7}A_0}{2}$ (D) $\frac{3A_0}{2}$

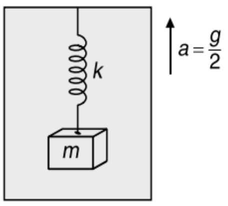
8. The velocity of the mass, when it passes through the equilibrium position is

(A) $\frac{\sqrt{19}\pi A_0}{T_0}$ (B) $\frac{\sqrt{2}\pi A_0}{T_0}$

(C) $\frac{\sqrt{14}\pi A_0}{T_0}$ (D) $\frac{\sqrt{14}\pi A_0}{2T_0}$

## Comprehension 4

Consider a spring attached to the roof of the lift compartment. To the other end of the spring a block of mass $m$ is attached. The lift is moving upwards with an acceleration $a = \frac{g}{2}$. Based on the information given, answer the following questions.




9. In mean position of the block's oscillations, the spring is

(A) compressed by $\frac{mg}{2k}$ (B) elongated by $\frac{mg}{k}$

(C) elongated by $\frac{mg}{2k}$ (D) elongated by $\frac{3mg}{2k}$

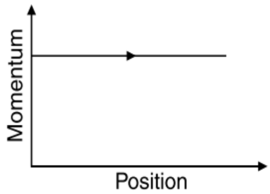
10. If maximum extension in the spring is $\frac{5mg}{2k}$, then maximum upward acceleration $(a_1)$ and maximum downward acceleration $(a_2)$ of the block are

(A) $a_1 = \frac{g}{2}$ (B) $a_1 = \frac{3g}{2}$

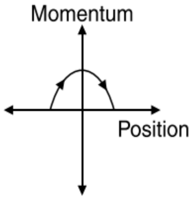
(C) $a_2 = \frac{g}{2}$ (D) $a_2 = \frac{3g}{2}$

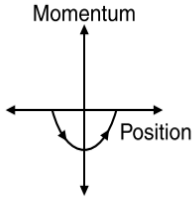
## Comprehension 5

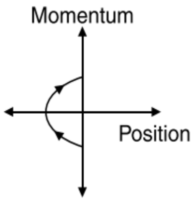
Phase space diagrams are useful tools in analysing all kinds of dynamical problems. They are especially useful in studying the changes in motion as initial position and momentum are changed. Here we consider some simple dynamical systems in one-dimension. For such systems, phase space is a plane in which position is plotted along horizontal axis and momentum is plotted along vertical axis. The phase space diagram is $x(t)$ vs $p(t)$ curve in this plane. The arrow on the curve indicates the time flow. For example, the phase space diagram for a particle moving with constant velocity is a straight line as shown in the figure. We use the sign convention in which position or momentum upwards (or to right) is positive and downwards (or to left) is negative. Based on the above facts, answer the following questions.

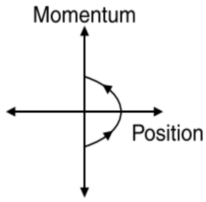



11. The phase space diagram for a ball thrown vertically up from ground is

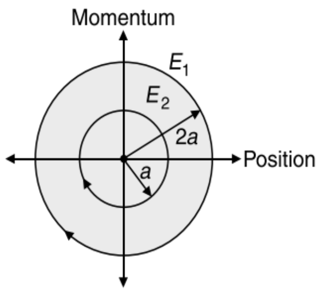
(A)



(B)



(C)



(D)


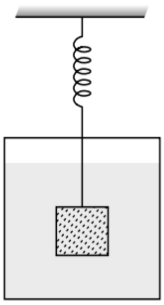

12. The phase space diagram for simple harmonic motion is a circle centred at the origin. In the figure, the two circles represent the same oscillator but for different initial conditions and $E_1$ and $E_2$ are the total mechanical energies respectively. Then

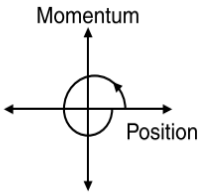


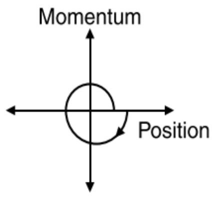

(A) $E_1 = \sqrt{2}E_2$ (B) $E_1 = 2E_2$

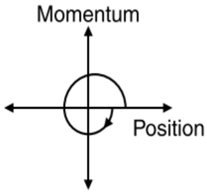
(C) $E_1 = 4E_2$ (D) $E_1 = 16E_2$

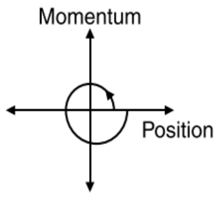
13. Consider the spring-mass system, with the mass submerged in water, as shown in the figure. The phase space diagram for one cycle of this system is



(A)



(B)



(C)



(D)



## Comprehension 6

A point performs SHM along a straight line with a period $T = 0.60$ s and amplitude $a = 10$ cm. Based on the above facts, answer the following questions.

**14.** Starting from extreme position, in what time, the point travels a distance $\frac{a}{2}$?

(A) 10 s (B) 1.0 s
(C) 0.1 s (D) 0.01 s

**15.** In PROBLEM 14, the mean velocity of the point is

(A) 0.5 $ms^{-1}$ (B) 1 $ms^{-1}$
(C) 1.5 $ms^{-1}$ (D) 1.005 $ms^{-1}$

**16.** Starting from the stable equilibrium position, the point travels a distance $\frac{a}{2}$ in a time of

(A) 0.01 s (B) 0.03 s
(C) 0.04 s (D) 0.05 s

**17.** In PROBLEM 16, the mean velocity of the point is

(A) 0.5 $ms^{-1}$ (B) 1 $ms^{-1}$
(C) 1.5 $ms^{-1}$ (D) 1.005 $ms^{-1}$

## Comprehension 7

A particle of mass 0.5 kg executes simple harmonic motion such that the force acting on the particle is given by $F = -4x$. The total mechanical energy of the particle is 10 J and amplitude of oscillations is 2 m. The initial acceleration of the particle is $-16$ $ms^{-2}$. Based on the information given, answer the following questions.

**18.** The kinetic energy of the particle at the mean position is

(A) 10 J (B) 8 J
(C) 6 J (D) 2 J

**19.** The displacement-time equation of the particle is

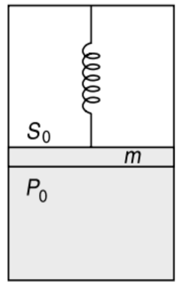
(A) $x = 2\sin(2t)$ (B) $x = 2\sin(4t)$
(C) $x = 2\cos(2t)$ (D) None of these

**20.** At $x = +1$ m, potential energy and kinetic energy of the particle are

(A) 2 J and 8 J
(B) 8 J and 2 J
(C) 6 J and 4 J
(D) 4 J and 6 J

## Comprehension 8

A non-conducting piston of mass $m$ and area $S_0$ divides a non-conducting, closed cylinder as shown in figure. Piston having mass $m$ is connected with top wall of cylinder by a spring of force constant $k$. The upper part of the cylinder is evacuated and the lower part contains an ideal gas at pressure $P_0$ in equilibrium position. Assuming the adiabatic constant for the gas to be $\gamma$, the equilibrium length of each part to be $l$ and neglecting friction. Based on the information given, answer the following questions.




**21.** Assuming $P_0S_0 > mg$, the compression in the spring at equilibrium position is

(A) ZERO (B) $\frac{2P_0S_0 - mg}{k}$
(C) $\frac{P_0S_0 - mg}{k}$ (D) $\frac{P_0S_0 - mg}{2k}$

**22.** Find angular frequency for small oscillation

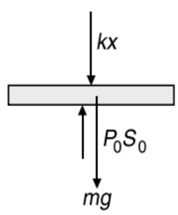
(A) $\sqrt{\frac{kl + \gamma P_0S_0}{2ml}}$ (B) $\sqrt{\frac{2kl + \gamma P_0S_0}{ml}}$
(C) $\sqrt{\frac{k}{m}}$ (D) $\sqrt{\frac{kl + \gamma P_0S_0}{ml}}$

**23.** If spring is removed and the upper part of the cylinder is opened, then the angular frequency for small oscillation (Assuming pressure of gas at equilibrium position is $P_1$ and length of gas column is $\ell_1$) is

(A) $\sqrt{\frac{\gamma P_1S_0}{m\ell_1}}$ (B) $\sqrt{\frac{2\gamma P_1S_0}{m\ell_1}}$
(C) $\sqrt{\frac{\gamma P_1S_0}{4m\ell_1}}$ (D) $\sqrt{\frac{\gamma P_1S_0}{2m\ell_1}}$

## Comprehension 9

A uniform thin cylindrical disk of mass $M$ and radius $R$ is attached to two identical massless springs of spring constant $k$ which are fixed to the wall as shown in the figure.




The springs are attached to the axle of the disk symmetrically on either side at a distance $d$ from its centre. The axle is massless and both the springs and the axle are in a horizontal plane. The unstretched length of each spring is $L$. The disk is initially at its equilibrium position with its centre of mass $(CM)$ at a distance $L$ from the wall. The disk rolls without slipping with velocity $\vec{v}_0 = v_0\hat{i}$. The coefficient of friction is $\mu$. Based on the above facts, answer the following questions.

**24.** The net external force acting on the disk when its centre of mass is at displacement $x$ with respect to its equilibrium position is

(A) $-kx$ (B) $-2kx$

(C) $-\dfrac{2kx}{3}$ (D) $-\dfrac{4kx}{3}$

**25.** The centre of mass of the disk undergoes simple harmonic motion with angular frequency $\omega$ equal to

(A) $\sqrt{\dfrac{k}{M}}$ (B) $\sqrt{\dfrac{2k}{M}}$

(C) $\sqrt{\dfrac{2k}{3M}}$ (D) $\sqrt{\dfrac{4k}{3M}}$

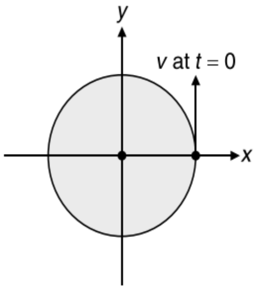
**26.** The maximum value of $v_0$ for which the disk will roll without slipping is

(A) $\mu g\sqrt{\dfrac{M}{k}}$ (B) $\mu g\sqrt{\dfrac{M}{2k}}$

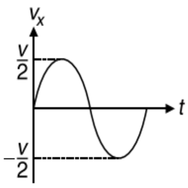
(C) $\mu g\sqrt{\dfrac{3M}{k}}$ (D) $\mu g\sqrt{\dfrac{5M}{2k}}$

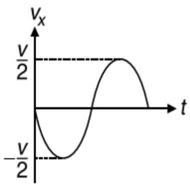
## Comprehension 10

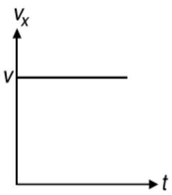
An object is fixed to the edge of a disk that is rotating with uniform circular motion. At time $t = 0$ the position and the velocity of the object are shown in the figure. The object travels around with the disk for a full rotation. Based on the information given, answer the following questions.

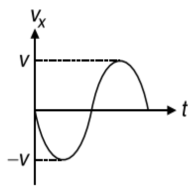



**27.** The $x$-component of the velocity, when plotted against time is represented by

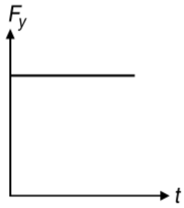
(A)


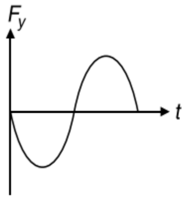

(B)


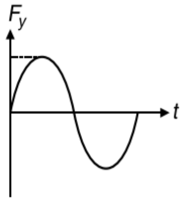

(C)


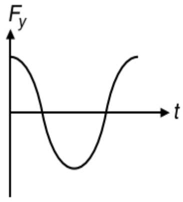

(D)



**28.** The $y$-component of the force (plotted against time) that keeps the object moving in a circle is represented by

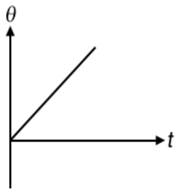
(A)


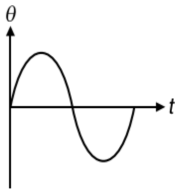

(B)


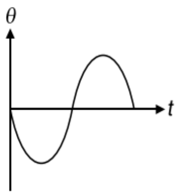

(C)


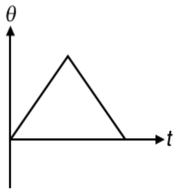

(D)



**29.** The graph of the angle of the object's position (that it makes with the $x$-axis) plotted against the time $t$ is best represented by

(A)


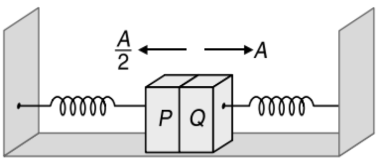

(B)



(C)



(D)



## Comprehension 11

Two identical blocks $P$ and $Q$ each has a mass $m$. They are attached to identical springs which are initially unstretched. Now the left spring (along with $P$) is compressed by $A$. Both the blocks are released simultaneously. They collide perfectly inelastically. Initially time period of each block was $T$.




Based on the information given, answer the following questions.

**30.** The time period of oscillation of combined mass is

(A) $\dfrac{T}{\sqrt{2}}$ (B) $\sqrt{2}T$

(C) $T$ (D) $\dfrac{T}{2}$

**31.** The amplitude of combined mass is

(A) $\dfrac{A}{4}$ (B) $\dfrac{A}{2}$

(C) $\dfrac{2A}{3}$ (D) $\dfrac{3A}{4}$

**32.** The energy of oscillation of the combined mass is

(A) $\frac{1}{2}kA^2$ (B) $\frac{1}{4}kA^2$

(C) $\frac{1}{8}kA^2$ (D) $\frac{1}{16}kA^2$

## Comprehension 12

A point performs SHM along a straight line with a period $T = 0.60$ s and amplitude $a = 10$ cm. Based on the information given, answer the following questions.

**33.** Starting from extreme position, the time taken by the point to travel a distance $\frac{a}{2}$ is

(A) 10 s (B) 1 s

(C) 0.1 s (D) 0.01 s

**34.** The average velocity of the point is

(A) 0.5 $ms^{-1}$ (B) 1 $ms^{-1}$

(C) 1.5 $ms^{-1}$ (D) 1.005 $ms^{-1}$

## Comprehension 13

You know very well that a block attached to an elastic spring performs SHM. Consider such a spring block system lying on a smooth horizontal table with a block of mass $m = 2$ kg attached at one end of a spring $(k = 200\ \text{Nm}^{-1})$ whose other end is fixed. The block is pulled so that the spring is extended by 0.05 m. If at this moment $(t = 0)$, the block is projected with a speed of 1 $ms^{-1}$ in the direction of increasing extension of the spring. Based on the above facts, answer the following questions.

**35.** The angular frequency $(\omega)$ of motion is

(A) 100 $sec^{-1}$ (B) 10 $sec^{-1}$

(C) 20 $sec^{-1}$ (D) 0

**36.** If the displacement $(x)$ of the block is measured from the equilibrium position, it can be written as a function of time as $x = A\sin(\omega t + \delta)$. The constants $A$ and $\delta$ have values

(A) 0.112 m, $\cos^{-1}(0.446)$

(B) 0.0025 m, $\sin^{-1}(0.446)$

(C) 0.112 m, $\sin^{-1}(0.446)$

(D) 0.1 m, $\sin^{-1}(0.446)$

**37.** First time $(t)$ when spring attains maximum extension is $\left(\text{given, } \sin^{-1}(0.446) = 26.5°\right)$

(A) 0.11 s (B) 0.22 s

(C) 0.33 s (D) 0.44 s

## Comprehension 14

A particle of mass $m$ is attached between two identical springs on a frictionless rectangular horizontal table of sides $l$ and $b$. Each spring has a spring constant $k$ and is initially unstretched as shown in Figure (A). The particle is pulled a distance $y$ in a direction perpendicular to the initial length of the springs along as shown in Figure (B). Assume the initial lengths of the springs to be along $X$-axis such that the displacement of the particle is along $Y$-axis. Based on the information given, answer the following questions.

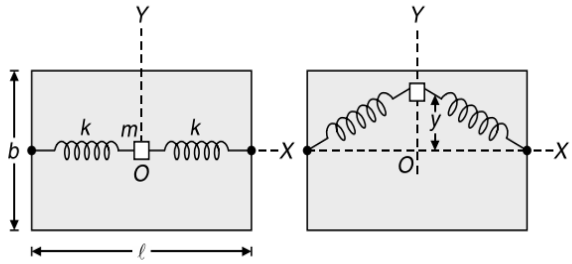



Figure (A) Figure (B)

**38.** Force exerted by the springs on the particle when it is at distance $y$ from its initial position $O$ is

(A) ZERO (B) $(2ky)\hat{j}$

(C) $2ky\left(\frac{\frac{l}{2}}{\sqrt{\frac{l^2}{4}+y^2}}-1\right)\hat{j}$ (D) $-2ky\left(\frac{\frac{l}{2}}{\sqrt{\frac{l^2}{4}+y^2}}+1\right)\hat{j}$

**39.** Assuming position $O$ of the particle to be the position of zero potential energy, the potential energy of the system at a displacement $y$ from $O$, as shown in Figure (B) is

(A) ZERO

(B) $k\left(y^2 + l\left(\frac{l}{2} - \sqrt{\frac{l^2}{4}+y^2}\right)\right)$

(C) $-k\left(y^2 + l\left(\frac{l}{2} + \sqrt{\frac{l^2}{4}+y^2}\right)\right)$

(D) $\frac{1}{2}ky^2$

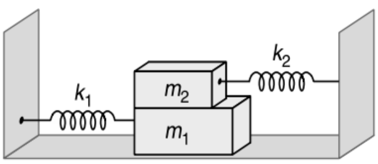
**40.** If $k = 100\ \text{Nm}^{-1}$, $l = 10$ m, $m = 2$ kg and the particle is released from a displacement $y = \sqrt{11}$ m from $O$, then the speed of the particle as it reaches the point $O$ is

(A) 4.5 $ms^{-1}$ (B) 12 $ms^{-1}$

(C) 10 $ms^{-1}$ (D) 3.2 $ms^{-1}$

## Comprehension 15

In the arrangement shown, both the springs are relaxed. The coefficient of friction between $m_2$ and $m_1$ is $\mu$. There is no friction between $m_1$ and surface. When the blocks are displaced slightly from their mean position, they perform SHM together. Based on the information given, answer the following questions.




**41.** The frequency of oscillation of the system is

(A) $2\pi\sqrt{\frac{m_1+m_2}{k_1+k_2}}$ (B) $\frac{1}{2\pi}\sqrt{\frac{k_1+k_2}{m_1+m_2}}$

(C) $2\pi\sqrt{\frac{k_1+k_2}{m_1+m_2}}$ (D) $\frac{1}{2\pi}\sqrt{\frac{m_1+m_2}{k_1+k_2}}$

**42.** If the small displacement of blocks is $x$ then acceleration of $m_2$ is

(A) $\frac{k_2 x}{m_2}$ (B) $\frac{(k_1+k_2)x}{m_2}$

(C) $\left(\frac{k_1+k_2}{m_1+m_2}\right)x$ (D) None of these

**43.** The condition in which frictional force on $m_2$ acts in the direction of its displacement from mean position is

(A) $\frac{m_1}{m_2} > \frac{k_1}{k_2}$ (B) $\frac{m_2}{m_1} > \frac{k_1}{k_2}$

(C) $\frac{m_1}{m_2} = \frac{k_1}{k_2}$ (D) None of these

**44.** If frictional force on $m_2$ acts in the direction of its displacement from mean position, then the maximum amplitude of oscillation is

(A) $\frac{\mu m_2 g(m_1+m_2)}{m_1k_2 - m_2k_1}$ (B) $\frac{\mu m_2 g(m_1+m_2)}{m_1k_1 - m_2k_2}$

(C) $\frac{\mu m_2 g(m_1+m_2)}{m_1k_2 + m_2k_1}$ (D) None of these

## Comprehension 16

The displacement-time equation for two particles moving along $x$-axis are given by

$$x_1 = (8 + 3\sin\omega t)m \text{ and } x_2 = (4\cos\omega t)m$$

where $\omega = \pi$ rads$^{-1}$. Based on the information given, answer the following questions.

**45.** The two particles will collide after time

(A) $t = 1$ s (B) $t = 2$ s

(C) $t = 4$ s (D) $t \to \infty$

**46.** The two particles are at minimum distance after time

(A) $t = 1$ s (B) $t = 2$ s

(C) $t = 3$ s (D) $t = 4$ s

## Comprehension 17

There are three type of equilibriums

**(a)** unstable equilibrium when potential energy is maximum
**(b)** stable equilibrium when potential energy is minimum
**(c)** Neutral equilibrium when potential energy is constant

Whenever the particle is displaced from its position of stable equilibrium it performs an oscillatory motion. A single conservative force $F(x)$ acts on a 1 kg particle that moves along the $x$-axis. The potential energy $U(x)$ is given by:

$$U(x) = 20 + (x-2)^2$$

where $x$ is in meter. At $x = 5$ m the particle has a kinetic energy of 20 J. Based on the above facts, answer the following questions.

**47.** The maximum kinetic energy of a particle is

(A) 49 J (B) 20 J

(C) 29 J (D) 19 J

**48.** The position of equilibrium is at $x =$

(A) 2 m (B) 1 m

(C) 0.5 m (D) ZERO

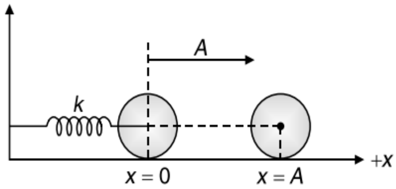
**49.** The angular frequency of the particle is

(A) $\sqrt{2}$ (B) 2

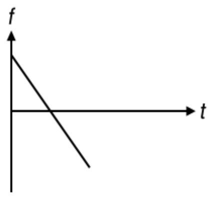
(C) $\sqrt{3}$ (D) $\sqrt{2}-2$

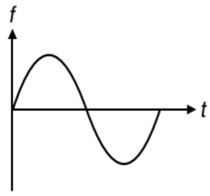
## Comprehension 18

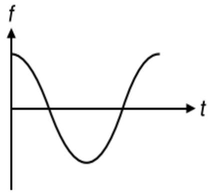
A disc of mass $m$ and radius $R$ is attached with a spring of force constant $k$ at its centre as shown in figure. At $x = 0$, the spring is unstretched. The disc is moved to $x = A$ and then released. There is no slipping between disc and ground. Let $f$ be the force of friction on the disc from the ground. Based on the information given, answer the following questions.

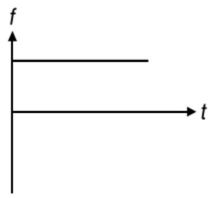



**50.** The $f$ versus $t$ (time) graph will be as

(A)



(B)



(C)



(D)



**51.** If $k = 10$ Nm$^{-1}$, $m = 2$ kg, $R = 1$ m and $A = 2$ m, then the linear speed of the disc at mean position is

(A) $\sqrt{\frac{40}{3}}$ ms$^{-1}$ (B) $\sqrt{20}$ ms$^{-1}$

(C) $\sqrt{\frac{10}{3}}$ ms$^{-1}$ (D) $\sqrt{\frac{50}{3}}$ ms$^{-1}$

## Comprehension 19

A point moves along the $x$-axis according to the law:

$$x = a\sin^2\left(\omega t - \frac{\pi}{4}\right)$$

Based on the above facts, answer the following questions.

**52.** The amplitude of the particle is

(A) $a$ (B) $\frac{a}{2}$

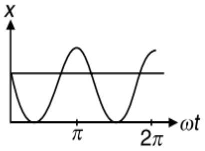
(C) $\frac{a}{4}$ (D) $\frac{a}{5}$

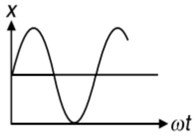
**53.** The time period of oscillations is

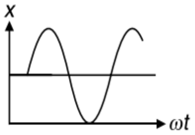
(A) $\frac{\pi}{\omega}$ (B) $\frac{2\pi}{\omega}$

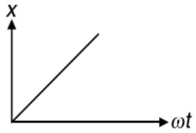
(C) $\frac{3\pi}{\omega}$ (D) $\frac{4\pi}{\omega}$

**54.** The plot of $x$ as a function of $\omega t$ is

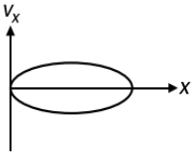
(A) 

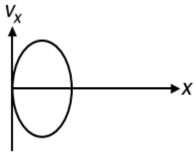

(B) 

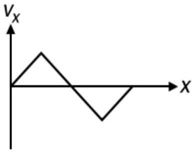

(C) 

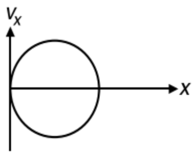

(D) 


**55.** The plot of velocity projection $v_x$ as a function of $x$ is

(A) 

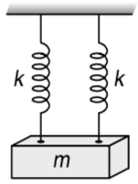

(B) 


(C) 


(D) 


## *Comprehension 20*

A block of mass $m = \frac{1}{2}$ kg is attached with two springs each of force constant $k = 10\ \text{Nm}^{-1}$ as shown. The block is oscillation vertically up and down with amplitude $A = 25$ cm. When the block is at its mean position one of the spring breaks without changing momentum of block. Based on the information given, answer the following questions.




**56.** The new amplitude of oscillation is

(A) 10.6 cm
(B) 25 cm
(C) 43.3 cm
(D) 62.2 cm

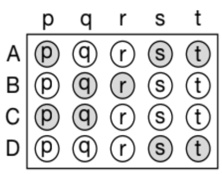
**57.** If instead of breaking one spring, the $\frac{m}{2}$ mass would have fallen from the block, then the new amplitude is

(A) 15.8 cm
(B) 16.9 cm
(C) 21.6 cm
(D) 26.2 cm

## MATRIX MATCH/COLUMN MATCH TYPE QUESTIONS

Each question in this section contains statements given in two columns, which have to be matched. The statements in **COLUMN-I** are labelled A, B, C and D, while the statements in **COLUMN-II** are labelled p, q, r, s (and t). Any given statement in **COLUMN-I** can have correct matching with **ONE OR MORE** statement(s) in **COLUMN-II**. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following examples:

If the correct matches are A → p, s and t; B → q and r; C → p and q; and D → s and t; then the correct darkening of bubbles will look like the following:



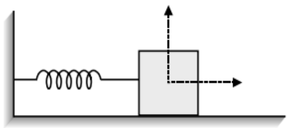

**1.** In $y = A\sin(\omega t) + A\sin\left(\omega t + \frac{2\pi}{3}\right)$ match the following table

| COLUMN-I | COLUMN-II |
|---|---|
| (A) Motion | (p) is periodic but not SHM |
| (B) Amplitude | (q) is SHM |
| (C) Initial phase | (r) $A$ |
| (D) Maximum velocity | (s) $\frac{\pi}{3}$ |
| | (t) $\omega A$ |

**2.** The displacement vs time function for a particle of 250 g in simple harmonic motion is $x = 1\sin(12\pi t)$. Match the **COLUMN-I** with **COLUMN-II**.

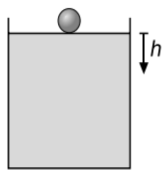
| COLUMN-I | COLUMN-II |
|---|---|
| (A) Frequency with which kinetic energy oscillates is | (p) $\frac{1}{12}$ |
| (B) Speed of particle is maximum at time given by | (q) $18\pi^2$ |
| (C) Maximum potential energy is | (r) 12 |
| (D) Force constant $k$ is | (s) $36\pi^2$ |

**3.** A block of mass $m = 2$ kg is connected with spring of spring constant $k = 3200\ \text{Nm}^{-1}$ and placed on a frictionless horizontal surface as shown in figure. Initially it is compressed by a distance 10 cm. It is then released at $t = 0$. Match the times in **COLUMN-I** with their respective values (in second) in **COLUMN-II**.



| COLUMN-I | COLUMN-II |
|---|---|
| (A) Time taken by the mass to move by the first 5 cm is | (p) $\frac{\pi}{160}$ |
| (B) Time taken by the mass to move by the next 5 cm is | (q) $\frac{\pi}{240}$ |
| (C) Time at which kinetic energy and potential energy become equal for the first time is | (r) $\frac{\pi}{120}$ |
| (D) Time at which kinetic energy becomes one-fourth of its maximum value is | (s) $\frac{\pi}{40}$ |

**4.** In the arrangement shown, a ball of density $\rho$ is released from the surface of a liquid whose density varies with depth $h$ as $\rho_l = \alpha h$, where $\alpha$ is a positive constant. Assuming the liquid to be ideal, match the contents of **COLUMN-I** with those given in **COLUMN-II**.

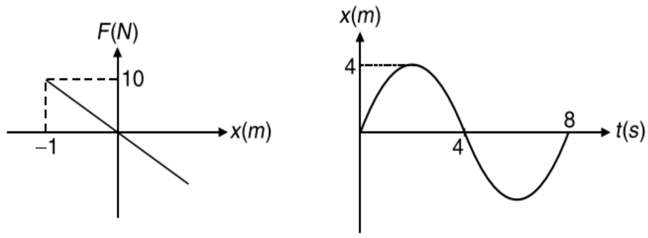



| COLUMN-I | COLUMN-II |
|---|---|
| (A) Upthrust on ball | (p) will continuously decrease |
| (B) Speed of ball | (q) will continuously increase |
| (C) Net force on ball | (r) first increase then decrease |
| (D) Gravitational potential energy of ball | (s) first decrease then increase |

**5.** A particle of mass 2 kg, released from $x = 7$ m is moving on a straight line under the action of force $F = (8 - 2x)$ N. For the subsequent motion match the following (all values in **COLUMN-II** are in S.I. units).

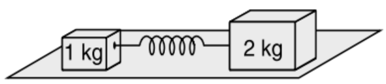
| COLUMN-I | COLUMN-II |
|---|---|
| (A) Amplitude of SHM is | (p) 0.5 |
| (B) Time taken to move from $x = 2.5$ m to $x = 4$ m (approx.) | (q) 3 |
| (C) Total energy of SHM system | (r) 6 |
| (D) Velocity of particle at $x = 4$ m | (s) 9 |

**6.** $F$-$x$ and $x$-$t$ graph of a particle of mass $m$ attached to a spring of force constant $k$, in SHM are as shown in figure. Match the **COLUMN-I** with **COLUMN-II** (having all quantities in SI units).




| COLUMN-I | COLUMN-II |
|---|---|
| (A) Mass of the particle | (p) $\frac{\pi}{4}$ |
| (B) Maximum kinetic energy of particle | (q) $\left(\frac{160}{\pi^2}\right)$ |
| (C) Angular frequency of particle | (r) 10 |
| (D) Spring constant | (s) 80 |
| | (t) None of these |

**7.** In the two block spring system, force constant of spring is $k = 6\ \text{Nm}^{-1}$. Spring is stretched by 12 cm and then left. Match the following

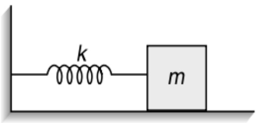



| COLUMN-I | COLUMN-II |
|---|---|
| (A) Angular frequency of oscillation | (p) $14.4 \times 10^{-3}$ |
| (B) Maximum kinetic energy of 1 kg | (q) 3 |
| (C) Maximum kinetic energy of 2 kg | (r) $\frac{2}{3}$ |
| (D) Reduced mass of the system | (s) 28.8 |

**8.** In SHM match the following

| COLUMN-I | COLUMN-II |
|---|---|
| (A) Displacement and velocity | (p) Phase difference of zero |
| (B) Displacement and acceleration | (q) Phase difference of $\frac{\pi}{2}$ |
| (C) Velocity and acceleration | (r) Phase difference of $\pi$ |
| (D) Momentum and force | (s) None of these |

**9.** For a mass attached to a spring placed on a horizontal frictionless table, match the following




| COLUMN-I | COLUMN-II |
|---|---|
| (A) If mass of the block is doubled | (p) Energy of oscillation becomes 4 times |
| (B) If amplitude of oscillation is doubled | (q) Speed of particle becomes 2 times |
| (C) If force constant is doubled | (r) Time period becomes $\sqrt{2}$ times |
| (D) If angular frequency is doubled | (s) Potential energy becomes 2 times |

**10.** For a particle executing SHM match the **COLUMN-I** with **COLUMN-II**.

| COLUMN-I | COLUMN-II |
|---|---|
| (A) Acceleration-displacement graph | (p) Parabola |
| (B) Velocity-acceleration graph | (q) Straight line |
| (C) Acceleration-time graph | (r) Circle |
| (D) Velocity-time graph | (s) None of these |

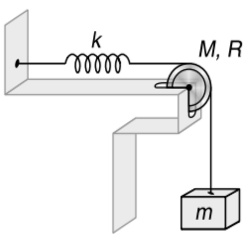
**11.** In case of second's pendulum, match the following (consider shape of each also)

| COLUMN-I | COLUMN-II |
|---|---|
| (A) At pole | (p) $T > 2$ s |
| (B) On a satellite | (q) $T < 2$ s |
| (C) At mountain | (r) $T = 2$ s |
| (D) At centre of earth | (s) $T = 0$ |
| | (t) $T \to \infty$ |

## INTEGER/NUMERICAL ANSWER TYPE QUESTIONS

In this section, the answer to each question is a numerical value obtained after doing series of calculations based on the data given in the question(s).

**1.** In the Figure shown, a cord is attached between a 2 kg block and a spring with force constant $k = 20\ \text{Nm}^{-1}$. The other end of the spring is attached to the wall, and the cord is placed over a pulley $(I = 0.60MR^2)$ of mass 5 kg and radius 0.5 m. Assuming no slipping occurs, what is the frequency of the oscillations when the body is set into motion?

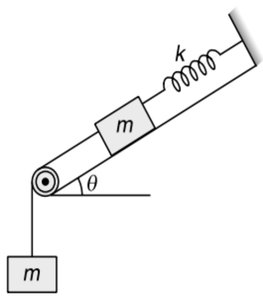



**2.** A 1.1 kg object is suspended from a vertical spring whose spring constant is $120\ \text{Nm}^{-1}$.

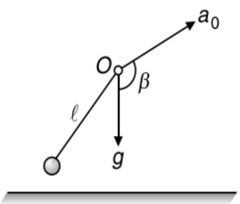
(a) Find the amount, in cm, by which the spring is stretched from its unstrained length.

(b) If the object is pulled straight down by an additional distance of 0.20 m and released from rest, then find the speed, to the nearest integer in $\text{ms}^{-1}$, with which the object passes through its original position on its way up.

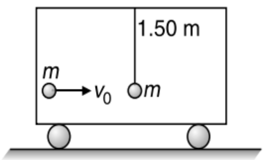
**3.** Calculate the natural angular frequency $\omega$, in $\text{rads}^{-1}$, of the system shown in Figure. The mass and friction of the pulleys are negligible. Given $m = 2.5$ kg, $k = 20\ \text{Nm}^{-1}$



4. Find the period of small oscillations of a mathematical pendulum of length $l$ if its points of suspension $O$ moves relative to the Earth's surface in an arbitrary direction with a constant acceleration $a_0$. The period if $l = 21$ cm, $a_0 = \frac{g}{2}$, and the angle between the vectors $a_0$ and $g$ equals $\beta = 120°$ is $T$ second. Find $10T$.



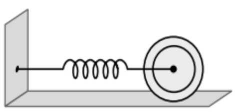

5. A ball of mass $m = 1$ kg is hung vertically by a thread of length $l = 1.50$ m. Upper end of the thread is attached to the ceiling of a trolley of mass $M = 4$ kg. Initially, trolley is stationary and it is free to move along horizontal rails without friction.



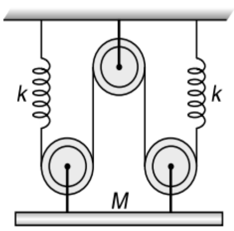

A shell of mass $m = 1$ kg, moving horizontally with velocity $v_0 = 6$ ms$^{-1}$, collides with the ball and gets stuck with it. As a result, thread starts to deflect towards right. If $\theta$ be the maximum deflection with the vertical, $g = 10$ ms$^{-2}$, then $\cos\theta = \frac{x}{y}$, where $x$ and $y$ are single digit integral values. Find $x$ and $y$.

6. The period of small oscillations in a vertical plane performed by a ball of mass $m = 40$ g fixed at the middle of a horizontally stretched string $l = 1$ m in length is $T$ second. The tension of the string is assumed to be constant and equal to $F = 10$ N. Find $5T$.

7. A solid cylinder of mass $m = 4$ kg is attached to a horizontal spring with force constant $k = 3$ Nm$^{-1}$. The cylinder can roll without slipping along the horizontal plane as shown in Figure. The centre of mass of the cylinder executes simple harmonic motion with a period $T = 2\pi\sqrt{*}$, where $*$ is not readable. Find $*$.



8. The natural frequency of the system shown in Figure is $f = \frac{1}{\pi}\sqrt{\frac{xk}{M}}$. The pulleys are smooth and massless. Find $x$.



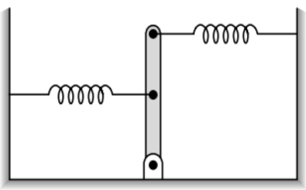

9. A spring of spring constant 1200 Nm$^{-1}$ is hanging from the ceiling of an elevator, and a 5 kg object is attached to the lower end. By how much does the spring stretch (relative to its unstrained length), in cm, when the elevator is accelerating upward at $a = 2.2$ ms$^{-2}$? Take $g = 9.8$ ms$^{-2}$.

10. A spring is hanging vertically. An object of unknown mass is hung on the end of the unstretched spring and released from rest and it falls 4.9 cm before first coming to rest. If $g = 9.8$ ms$^{-2}$, then the period of motion is $\frac{\pi}{*}$, where $*$ is not readable. Find $*$.

11. A point of the surface of a solid sphere of radius 5 cm is attached directly to a pivot on the ceiling. The sphere swings back and forth as a physical pendulum with a small amplitude. What is the length of a simple pendulum, in cm, that has the same period as this physical pendulum?

12. A block with a mass of 3 kg is suspended from an ideal spring having negligible mass and stretches the spring 0.2 m.
(a) What is the force constant, in Nm$^{-1}$, of the spring.
(b) What is the angular frequency, in rads$^{-1}$, of oscillation of the block if it is pulled down and released?

13. A rod of length $l$ and mass $m$, pivoted at one end, is held by a spring at its mid-point a spring at far end, both pulling in opposite directions. The springs have spring constant $k$, and at equilibrium their pull is perpendicular to the rod. The frequency of small oscillations about the equilibrium position is $f = \frac{1}{2\pi}\sqrt{\frac{*k}{2ml}}$, where $*$ is not readable. Find $*$.

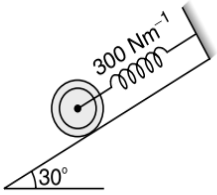


14. A 100 g object executes simple harmonic motion with a frequency of 20 Hz and amplitude of 0.5 cm. If $\pi^2 = 10$, then find the
(a) spring constant $k$, in Nm$^{-1}$, for the force acting on it.
(b) maximum acceleration, in ms$^{-2}$.
(c) total energy of the motion in mJ.

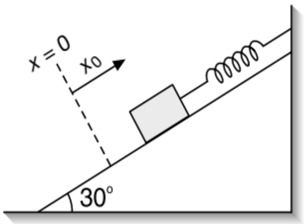
15. Find the angular frequency, in rads$^{-1}$, of small oscillations of a uniform rod with length $l = 14.7$ cm, pivoted at one end. Given: $g = 9.8$ ms$^{-2}$.

16. Suppose a block of mass 1 kg is resting on the smooth floor of a truck, attached to its front by a spring of force constant 100 Nm$^{-1}$. At $t = 0$, the truck begins to move with constant acceleration 2 ms$^{-2}$. Find the amplitude, in cm, and the angular frequency, in rads$^{-1}$, of oscillations of the block relative to floor of the truck.

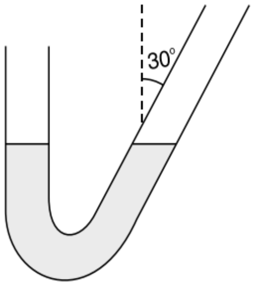
17. Determine the angular frequency of vibration, in rads$^{-1}$, of the 500 g disk attached to a support with a spring of force constant 300 Nm$^{-1}$, as shown in Figure. Assume the disk does not slip on the inclined surface.




**18.** The drawing shows a block $(m = 1.7 \text{ kg})$ and a spring $(k = 310 \text{ Nm}^{-1})$ on a frictionless incline. The spring is compressed by $x_0 = 0.31$ m relative to its unstrained position of $x = 0$ m and then released. What is the speed of the block, in ms$^{-1}$ to the nearest integer, when the spring is still compressed by $x_f = 0.14$ m?




**19.** The period of oscillations of mercury of mass $m = 200$ g poured into a bent tube, as shown in Figure, whose right arm forms an angle $\theta = 30°$ with the vertical and whose left arm is vertical is $T$ seconds. The cross-sectional area of the tube is $S = 0.50 \text{ cm}^2$. The viscosity of mercury is to be neglected. Find $10T$.




**20.** A pendulum beats seconds at the surface of the earth. Calculate how much it loses or gains per day, in second to the nearest integer, if it is taken to

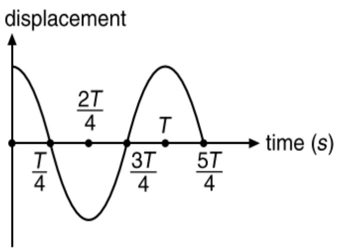
(a) a mine 8 km below

(b) a point 8 km above the surface.

Given: Radius of the earth is $R = 6.4 \times 10^6$ m.

## ARCHIVE: JEE MAIN

**1.** **[Online September 2020]**
The displacement time graph of a particle executing S.H.M. is given in Figure (sketch is schematic and not to scale)




Which of the following statements is/are true for this motion?

(1) The force is zero $t = \frac{3T}{4}$

(2) The acceleration is maximum at $t = T$

(3) The speed is maximum at $t = \frac{T}{4}$

(4) The P.E. is equal to K.E. of the oscillation at $t = \frac{T}{2}$

(A) (1), (2) and (4)
(B) (2), (3) and (4)
(C) (1) and (4)
(D) (1), (2) and (3)

**2.** **[Online September 2020]**
A ring is hung on a nail. It can oscillate, without slipping or sliding (1) in its plane with a time period $T_1$ and (2) back and forth in a direction perpendicular to its plane, with a period $T_2$ the ratio $\frac{T_1}{T_2}$ will be

(A) $\frac{2}{\sqrt{3}}$ (B) $\frac{\sqrt{2}}{3}$

(C) $\frac{2}{3}$ (D) $\frac{3}{\sqrt{2}}$

**3.** **[Online September 2020]**
An object of mass $m$ is suspended at the end of a massless wire of length $L$ and area of cross-section, $A$. Young modulus of the material of the wire is $Y$. If the mass is pulled down slightly its frequency of oscillation along the vertical direction is

(A) $f = \frac{1}{2\pi}\sqrt{\frac{YA}{mL}}$ (B) $f = \frac{1}{2\pi}\sqrt{\frac{YL}{mA}}$

(C) $f = \frac{1}{2\pi}\sqrt{\frac{mA}{YL}}$ (D) $f = \frac{1}{2\pi}\sqrt{\frac{mL}{YA}}$

**4.** **[Online September 2020]**
When a particle of mass $m$ is attached to a vertical spring of spring constant $k$ and released, its motion is described by $y(t) = y_0 \sin^2 \omega t$, where $y$ is measured from the lower end of unstretched spring. Then $\omega$ is

(A) $\sqrt{\frac{g}{y_0}}$ (B) $\sqrt{\frac{g}{2y_0}}$

(C) $\frac{1}{2}\sqrt{\frac{g}{y_0}}$ (D) $\sqrt{\frac{2g}{y_0}}$

**5.** **[Online April 2019]**
A damped harmonic oscillator has a frequency of 5 oscillations per second. The amplitude drops to half its value for every 10 oscillations. The time it will take to drop to $\frac{1}{1000}$ of the original amplitude is close to

(A) 100 s (B) 10 s
(C) 50 s (D) 20 s

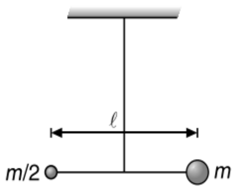
6. **[Online April 2019]**
A simple pendulum oscillating in air has period $T$. The bob of the pendulum is completely immersed in a non-viscous liquid. The density of the liquid is $\frac{1}{16}$th of the material of the bob. If the bob is inside liquid all the time, its period of oscillation in this liquid is

(A) $2T\sqrt{\frac{1}{14}}$ (B) $4T\sqrt{\frac{1}{15}}$
(C) $4T\sqrt{\frac{1}{14}}$ (D) $2T\sqrt{\frac{1}{10}}$

7. **[Online April 2019]**
The displacement of a damped harmonic oscillator is given by $x(t)=e^{-0.1t}\cos(10\pi t+\phi)$. Here $t$ is in seconds. The time taken for its amplitude of vibration to drop to half of its initial value is close to
(A) 7 s (B) 27 s
(C) 13 s (D) 4 s

8. **[Online April 2019]**
A person of mass $M$ is, sitting on a swing of length $L$ and swinging with an angular amplitude $\theta_0$. If the person stands up when the swing passes through its lowest point, the work done by him, assuming that his centre of mass moves by a distance $l\,(l \ll L)$, is close is
(A) $Mgl$ (B) $Mgl(1+\theta_0^2)$
(C) $Mgl\left(1+\frac{\theta_0^2}{2}\right)$ (D) $Mgl(1-\theta_0^2)$

9. **[Online January 2019]**
Two masses $m$ and $\frac{m}{2}$ are connected at the two ends of a massless rigid rod of length $l$. The rod is suspended by a thin wire of torsional constant $k$ at the centre of mass of the rod-mass system (see figure). Because of torsional constant $k$, the restoring torque is $\tau = k\theta$ for angular displacement $\theta$. If the rod is rotated by $\theta_0$ and released, the tension in it when it passes through its mean position will be




(A) $\frac{k\theta_0^2}{2l}$ (B) $\frac{k\theta_0^2}{l}$
(C) $\frac{2k\theta_0^2}{l}$ (D) $\frac{3k\theta_0^2}{l}$

10. **[Online January 2019]**
A rod of mass $M$ and length $2L$ is suspended at its middle by a wire. It exhibits torsional oscillations. If two masses each of $m$ are attached at distance $\frac{L}{2}$ from its centre on both sides, it reduces the oscillation frequency by 20%. The value of ratio $\frac{m}{M}$ is close to
(A) 0.77 (B) 0.17
(C) 0.37 (D) 0.57

11. **[Online January 2019]**
A particle is executing simple harmonic motion (SHM) of amplitude $A$, along the $x$-axis, about $x=0$. When its potential energy (PE) equals kinetic energy (KE), the position of the particle will be
(A) $\frac{A}{\sqrt{2}}$ (B) $A$
(C) $\frac{A}{2\sqrt{2}}$ (D) $\frac{A}{2}$

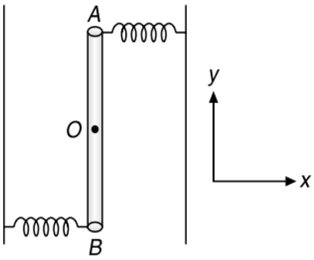
12. **[Online January 2019]**
A particle executes simple harmonic motion with an amplitude of 5 cm. When the particle is at 4 cm from the mean position, the magnitude of its velocity in SI units is equal to that of its acceleration. Then, its periodic time in seconds is
(A) $\frac{4\pi}{3}$ (B) $\frac{3}{8}\pi$
(C) $\frac{8\pi}{3}$ (D) $\frac{7}{3}\pi$

13. **[Online January 2019]**
A particle undergoing simple harmonic motion has time dependent displacement given by $x(t)=A\sin\left(\frac{\pi t}{90}\right)$. The ratio of kinetic to potential energy of this particle at $t = 210$ s will be
(A) 1 (B) 3
(C) 2 (D) $\frac{1}{9}$

14. **[Online January 2019]**
A simple pendulum of length 1 m is oscillating with an angular frequency 10 rads$^{-1}$. The support of the pendulum starts oscillating up and down with a small angular frequency of 1 rads$^{-1}$ and an amplitude of $10^{-2}$ m. The relative change in the angular frequency of the pendulum is best given by
(A) $10^{-3}$ rads$^{-1}$ (B) $10^{-1}$ rads$^{-1}$
(C) $10^{-5}$ rads$^{-1}$ (D) 1 rads$^{-1}$

15. **[Online January 2019]**
The mass and the diameter of a planet are three times the respective values for the Earth. The period of oscillation of a simple pendulum on the Earth is 2 s. The period of oscillation of the same pendulum on the planet would be
(A) $\frac{2}{\sqrt{3}}$ s (B) $\frac{3}{2}$ s
(C) $\frac{\sqrt{3}}{2}$ s (D) $2\sqrt{3}$ s

**16. [Online January 2019]**
Two light identical springs of spring constant $k$ are attached horizontally at the two ends of a uniform horizontal rod $AB$ of length $\ell$ and mass $m$. The rod is pivoted at its centre $O$ and can rotate freely in horizontal plane. The other ends of the two springs are fixed to rigid supports as shown in Figure. The rod is gently pushed through a small angle and released. The frequency of resulting oscillation is




(A) $\frac{1}{2\pi}\sqrt{\frac{k}{m}}$ (B) $\frac{1}{2\pi}\sqrt{\frac{2k}{m}}$

(C) $\frac{1}{2\pi}\sqrt{\frac{3k}{m}}$ (D) $\frac{1}{2\pi}\sqrt{\frac{6k}{m}}$

**17. [Online January 2019]**
A simple harmonic motion is represented by $y = 5(\sin 3\pi t + \sqrt{3}\cos 3\pi t)$ cm

The amplitude and time period of the motion are

(A) 10 cm, $\frac{2}{3}$ s (B) 5 cm, $\frac{2}{3}$ s

(C) 10 cm, $\frac{3}{2}$ s (D) 5 cm, $\frac{3}{2}$ s

**18. [Online January 2019]**
A cylindrical plastic bottle of negligible mass is filled with 310 ml of water and left floating in a pond with still water. If pressed downward slightly and released, it starts performing simple harmonic motion at angular frequency $\omega$. If the radius of the bottle is 2.5 cm then $\omega$ is close to: (density of water $= 10^3$ kgm$^{-3}$)

(A) 2.50 rads$^{-1}$ (B) 3.75 rads$^{-1}$

(C) 5.00 rads$^{-1}$ (D) 1.25 rads$^{-1}$

**19. [2018]**
A silver atom in a solid oscillates in simple harmonic motion in some direction with a frequency of $10^{12}$ s$^{-1}$. What is the force constant of the bonds connecting one atom with the other? (Mole wt. of silver $= 108$ and Avogadro number $= 6.02 \times 10^{23}$ gmmole$^{-1}$)

(A) 6.4 Nm$^{-1}$ (B) 7.1 Nm$^{-1}$

(C) 2.2 Nm$^{-1}$ (D) 5.5 Nm$^{-1}$

**20. [Online 2018]**
Two simple harmonic motions, as shown here, are at right angles. They are combined to form Lissajous figures.
If $x(t) = A\sin(at + \delta)$ and $y(t) = B\sin(bt)$
Identify the correct match below.

| Parameters | Curve |
|---|---|
| (A) $A = B,\ a = b,\ \delta = \frac{\pi}{2}$ | Line |
| (B) $A \neq B,\ a = b,\ \delta = 0$ | Parabola |
| (C) $A = B,\ a = 2b,\ \delta = \frac{\pi}{2}$ | Circle |
| (D) $A \neq B,\ a = b,\ \delta = \frac{\pi}{2}$ | Ellipse |

**21. [Online 2018]**
An oscillator of mass $M$ is at rest in its equilibrium position in a potential $V = \frac{1}{2}k(x - X)^2$. A particle of mass $m$ comes from right with speed $u$ and collides completely inelastically with $M$ and sticks to it. This process repeats every time the oscillator crosses its equilibrium position. The amplitude of oscillations after 13 collisions is $(M = 10,\ m = 5,\ u = 1,\ k = 1)$

(A) $\frac{1}{\sqrt{3}}$ (B) $\frac{2}{3}$

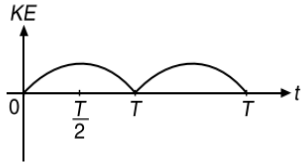
(C) $\sqrt{\frac{3}{5}}$ (D) $\frac{1}{2}$

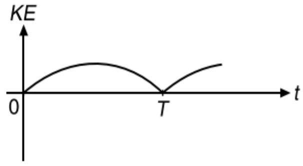
**22. [Online 2018]**
A particle executes simple harmonic motion and is located at $x = a$, $b$ and $c$ at times $t_0$, $2t_0$ and $3t_0$ respectively. The frequency of the oscillation is

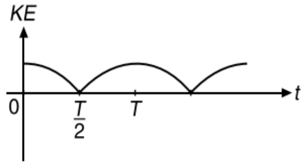
(A) $\frac{1}{2\pi t_0}\cos^{-1}\left(\frac{a+b}{2c}\right)$ (B) $\frac{1}{2\pi t_0}\cos^{-1}\left(\frac{2a+3c}{b}\right)$

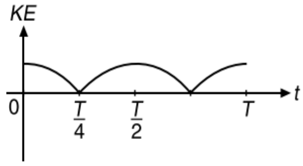
(C) $\frac{1}{2\pi t_0}\cos^{-1}\left(\frac{a+2b}{3c}\right)$ (D) $\frac{1}{2\pi t_0}\cos^{-1}\left(\frac{a+c}{2b}\right)$

**23. [2017]**
A particle is executing simple harmonic motion with a time period $T$. At time $t = 0$. It is at its position of equilibrium. The kinetic energy-time graph of the particle will look like

(A)



(B)



(C)



(D)


**24. [Online 2017]**
A 1 kg block attached to a spring vibrates with a frequency of 1 Hz on a frictionless horizontal table. Two springs identical to the original spring are attached in parallel to an 8 kg block placed on the same table. So, the frequency of vibration of the 8 kg block is

(A) $\frac{1}{2\sqrt{2}}$ Hz (B) $\frac{1}{2}$ Hz
(C) 2 Hz (D) $\frac{1}{4}$ Hz

**25. [Online 2017]**
The ratio of maximum acceleration to maximum velocity in a simple harmonic motion is $10\ s^{-1}$. At, $t=0$, the displacement is 5 m. What is the maximum acceleration? The initial phase is $\frac{\pi}{4}$.

(A) $500\sqrt{2}\ ms^{-2}$ (B) $500\ ms^{-2}$
(C) $750\sqrt{2}\ ms^{-2}$ (D) $750\ ms^{-2}$

**26. [Online 2017]**
A block of mass 0.1 kg is connected to an elastic spring of spring constant $640\ Nm^{-1}$ and oscillates in a damping medium of damping constant $10^{-2}\ kgs^{-1}$. The system dissipates its energy gradually. The time taken for its mechanical energy of vibration to drop to half of its initial value, is closest to

(A) 2 s (B) 3.5 s
(C) 7 s (D) 5 s

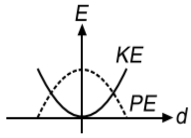
**27. [2016]**
A particle performs simple harmonic motion with amplitude $A$. Its speed is trebled at the instant that it is at a distance $\frac{2A}{3}$ from equilibrium position. The new amplitude of the motion is

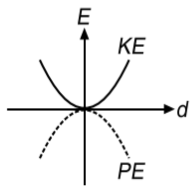
(A) $\frac{7A}{3}$ (B) $\frac{A}{3}\sqrt{41}$
(C) $3A$ (D) $A\sqrt{3}$

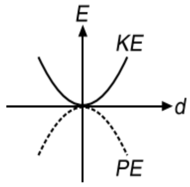
**28. [2015]**
A pendulum made of a uniform wire of cross-sectional area $A$ has time period $T$. When an additional mass $M$ is added to its bob, the time period changes to $T_M$. If the Young's modulus of the material of the wire is $Y$ then $\frac{1}{Y}$ is equal to ($g$ = gravitational acceleration)

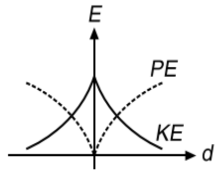
(A) $\left[\left(\frac{T_M}{T}\right)^2-1\right]\frac{A}{Mg}$ (B) $\left[\left(\frac{T_M}{T}\right)^2-1\right]\frac{Mg}{A}$
(C) $\left[1-\left(\frac{T_M}{T}\right)^2\right]\frac{A}{Mg}$ (D) $\left[1-\left(\frac{T}{T_M}\right)^2\right]\frac{A}{Mg}$

**29. [2015]**
For a simple pendulum, a graph is plotted between its kinetic energy $(KE)$ and potential energy $(PE)$ against its displacement $d$. Which one of the following represents these correctly? (graphs are schematic and not drawn to scale)

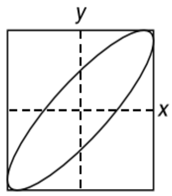
(A)


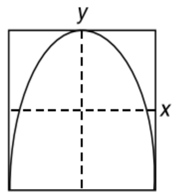
(B)


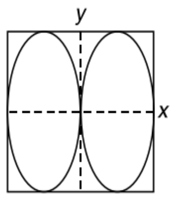
(C)


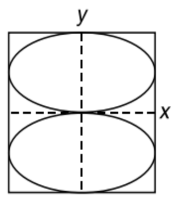
(D)



**30. [Online 2015]**
$x$ and $y$ displacements of a particle are given as $x(t)=a\sin\omega t$ and $y(t)=a\sin 2\omega t$. Its trajectory will look like

(A)


(B)


(C)


(D)



**31. [Online 2015]**
A simple harmonic oscillator of angular frequency $2\ rads^{-1}$ is acted upon by external force $F=(\sin t)$ N. If the oscillator is at rest in its equilibrium position at $t=0$, its position at later times is proportional to

(A) $\sin t+\frac{1}{2}\sin 2t$ (B) $\sin t+\frac{1}{2}\cos 2t$
(C) $\cos t-\frac{1}{2}\sin 2t$ (D) $\sin t-\frac{1}{2}\sin 2t$

**32. [Online 2015]**
A cylindrical block of wood (density = $650\ kgm^{-3}$), of base area $30\ cm^2$ and height 54 cm, floats in a liquid of density $900\ kgm^{-3}$. The block is depressed slightly and then released. The time period of the resulting oscillations of the block would be equal to that of a simple pendulum of length (nearly)

(A) 65 cm (B) 52 cm
(C) 39 cm (D) 26 cm

**33. [Online 2015]**
A pendulum with time period of 1 s is losing energy due to damping. At certain time its energy is 45 J. If after completing 15 oscillations, its energy has become 15 J, its damping constant (in $s^{-1}$) is

(A) $\frac{1}{30}\ln 3$ (B) $\frac{1}{15}\ln 3$
(C) 2 (D) $\frac{1}{2}$

**34. [2014]**
A particle moves with simple harmonic motion in a straight line. In first $\tau$ s, after starting from rest it travels a distance $a$ and in next $\tau$ s it travels $2a$, in same direction, then
(A) amplitude of motion is $3a$
(B) time period of oscillations is $8\tau$
(C) amplitude of motion is $4a$
(D) time period of oscillations is $6\tau$

**35. [2013]**
The amplitude of a damped oscillator decreases to 0.9 times its original magnitude in 5 s. In another 10 s it will decrease to $\alpha$ times its original magnitude where $\alpha$ equals
(A) 0.6 (B) 0.7
(C) 0.81 (D) 0.729

**36. [2013]**
An ideal gas enclosed in a vertical cylindrical container supports a freely moving piston of mass $M$. The piston and the cylinder have equal cross-sectional area $A$. When the piston is in equilibrium, the volume of the gas is $V_0$ and its pressure is $P_0$. The piston is slightly displaced from the equilibrium position and released. Assuming that the system is completely isolated from its surrounding, the piston executes a simple harmonic motion with frequency
(A) $\frac{1}{2\pi}\frac{A\gamma P_0}{V_0 M}$ (B) $\frac{1}{2\pi}\frac{V_0 M P_0}{A^2\gamma}$
(C) $\frac{1}{2\pi}\sqrt{\frac{A^2\gamma P_0}{MV_0}}$ (D) $\frac{1}{2\pi}\sqrt{\frac{MV_0}{A\gamma P_0}}$

**37. [2012]**
If a simple pendulum has significant amplitude (up to a factor of $\frac{1}{e}$ of original) only in the period between $t = 0$ s to $t = \tau$ s, then $\tau$ may be called the average life of the pendulum. When the spherical bob of the pendulum suffers a retardation (due to viscous drag) proportional to its velocity, with $b$ as the constant of proportionality, the average life time of the pendulum is (assuming damping is small) in seconds
(A) $b$ (B) $\frac{1}{b}$
(C) $\frac{2}{b}$ (D) $\frac{0.693}{b}$

**38. [2011]**
Two particles are executing simple harmonic motion of the same amplitude $A$ and frequency $\omega$ along the $x$-axis. Their mean position is separated by distance $X_0\,(X_0 > A)$. If the maximum separation between them is $(X_0 + A)$, the phase difference between their motion is
(A) $\frac{\pi}{2}$ (B) $\frac{\pi}{3}$
(C) $\frac{\pi}{4}$ (D) $\frac{\pi}{6}$

**39. [2011]**
A mass $M$, attached to a horizontal spring, executes SHM with an amplitude $A_1$. When the mass $M$ passes through its mean position then a smaller mass $m$ is placed over it and both of them move together with amplitude $A_2$. The ratio of $\left(\frac{A_1}{A_2}\right)$ is
(A) $\frac{M}{M+m}$ (B) $\frac{M+m}{M}$
(C) $\left(\frac{M}{M+m}\right)^{\frac{1}{2}}$ (D) $\left(\frac{M+m}{M}\right)^{\frac{1}{2}}$

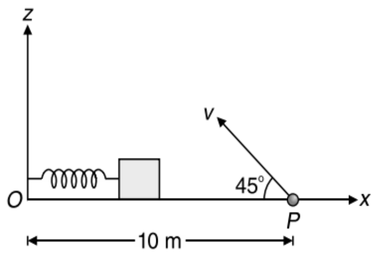
**40. [2009]**
If $x$, $v$ and $a$ denote the displacement, the velocity and the acceleration of a particle executing simple harmonic motion of time period $T$, then, which of the following does not change with time?
(A) $a^2T^2 + 4\pi^2v^2$ (B) $\frac{aT}{x}$
(C) $aT + 2\pi v$ (D) $\frac{aT}{v}$

## ARCHIVE: JEE ADVANCED

### Single Correct Choice Type Problems

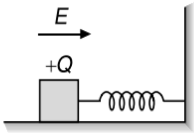
(In this section each question has four choices (A), (B), (C) and (D), out of which ONLY ONE is correct)

**1. [IIT-JEE 2012]**
A small block is connected to one end of a massless spring of un-stretched length 4.9 m. The other end of the spring (shown in Figure) is fixed. The system lies on a horizontal frictionless surface. The block is stretched by 0.2 m and released from rest at $t = 0$. It then executes simple harmonic motion with angular frequency $\omega = \frac{\pi}{3}$ rads$^{-1}$. Simultaneously at $t = 0$, a small pebble is projected with speed $v$ from point $P$ at an angle of 45° as shown in Figure. Point $P$ is at a horizontal distance of 10 m from $O$. If the pebble hits the block at $t = 1$ s, the value of $v$ is (Take $g = 10$ ms$^{-2}$)




(A) $\sqrt{50}$ ms$^{-1}$ (B) $\sqrt{51}$ ms$^{-1}$
(C) $\sqrt{52}$ ms$^{-1}$ (D) $\sqrt{53}$ ms$^{-1}$

2. **[IIT-JEE 2011]**
A wooden block performs SHM on a frictionless surface with frequency $\nu_0$. The block carries a charge $+Q$ on its surface. If now a uniform electric field $E$ is switched-on as shown, then the SHM of the block will be

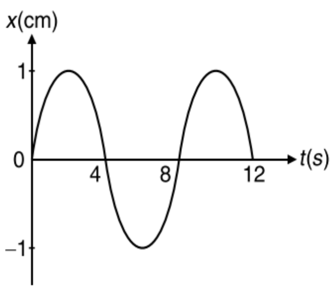



(A) of the same frequency and with shifted mean position
(B) of the same frequency and with the same mean position
(C) of changed frequency and with shifted mean position
(D) of charged frequency and with the same mean position

3. **[IIT-JEE 2011]**
A point mass is subjected to two simultaneous sinusoidal displacements in $x$-direction, $x_1(t) = A\sin(\omega t)$ and $x_2(t) = A\sin\left(\omega t + \frac{2\pi}{3}\right)$. Adding a third sinusoidal displacement $x_3(t) = B\sin(\omega t + \phi)$ brings the mass to a complete rest. The values of $B$ and $\phi$ are

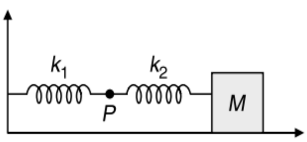
(A) $\sqrt{2}A, \frac{3\pi}{4}$  (B) $A, \frac{4\pi}{3}$
(C) $\sqrt{3}A, \frac{5\pi}{6}$  (D) $A, \frac{\pi}{3}$

4. **[IIT-JEE 2009]**
The $x$-$t$ graph of a particle undergoing simple harmonic motion is shown below. The acceleration of the particle at $t = \frac{4}{3}$ s is



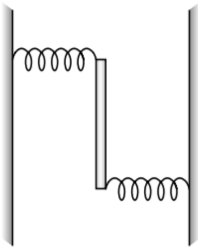

(A) $\frac{\sqrt{3}}{32}\pi^2$ cms$^{-2}$  (B) $-\frac{\pi^2}{32}$ cms$^{-2}$
(C) $\frac{\pi^2}{32}$ cms$^{-2}$  (D) $-\frac{\sqrt{3}}{32}\pi^2$ cms$^{-2}$

5. **[IIT-JEE 2009]**
The mass $M$ shown in Figure oscillates in simple harmonic motion with amplitude $A$. The amplitude of the point $P$ is



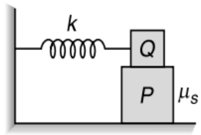

(A) $\frac{k_1 A}{k_2}$  (B) $\frac{k_2 A}{k_1}$
(C) $\frac{k_1 A}{k_1 + k_2}$  (D) $\frac{k_2 A}{k_1 + k_2}$

6. **[IIT-JEE 2009]**
A uniform rod of length $L$ and mass $M$ is pivoted at the centre. Its two ends are attached to two springs of equal spring constants $k$. The springs are fixed to rigid supports as shown in Figure and the rod is free to oscillate in the horizontal plane. The rod is gently pushed through a small angle $\theta$ in one direction and released. The frequency of oscillation is



(A) $\frac{1}{2\pi}\sqrt{\frac{2k}{M}}$  (B) $\frac{1}{2\pi}\sqrt{\frac{k}{M}}$
(C) $\frac{1}{2\pi}\sqrt{\frac{6k}{M}}$  (D) $\frac{1}{2\pi}\sqrt{\frac{24k}{M}}$

7. **[IIT-JEE 2004]**
A block $P$ of mass $m$ is placed on a horizontal frictionless plane. A second block of same mass $m$ is placed on it and is connected to a spring of spring constant $k$, the two blocks are pulled by a distance $A$. Block $Q$ oscillates without slipping. What is the maximum value of frictional force between the two blocks?



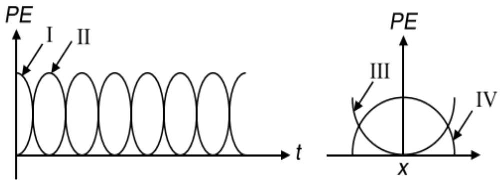

(A) $\frac{kA}{2}$  (B) $kA$
(C) $\mu_s mg$  (D) ZERO

8. **[IIT-JEE 2005]**
A simple pendulum has time period $T_1$. The point of suspension is now moved upward according to the relation $y = Kt^2$, $(K = 1\ \text{ms}^{-2})$ where $y$ is the vertical displacement. The time period now becomes $T_2$. The ratio of $\frac{T_1^2}{T_2^2}$ is $(g = 10\ \text{ms}^{-2})$

(A) $\frac{6}{5}$  (B) $\frac{5}{6}$
(C) 1  (D) $\frac{4}{5}$

**9. [IIT-JEE 2003]**

For a particle executing SHM the displacement $x$ given by $x = A\cos\omega t$. Identify the graph which represents the variation of potential energy $(PE)$ as a function of time $t$ and displacement $x$.




(A) I, III (B) II, IV
(C) II, III (D) I, IV

**10. [IIT-JEE 2001]**

A particle executes simple harmonic motion between $x = -A$ and $x = +A$. The time taken for it to go from 0 to $\frac{A}{2}$ is $T_1$ and to go from $\frac{A}{2}$ to $A$ is $T_2$, then

(A) $T_1 < T_2$ (B) $T_1 > T_2$
(C) $T_1 = T_2$ (D) $T_1 = 2T_2$

**11. [IIT-JEE 2000]**

The period of oscillation of simple pendulum of length $L$ suspended from the roof of the vehicle which moves without friction, down an inclined plane of inclination $\alpha$, is given by

(A) $2\pi\sqrt{\frac{L}{g\cos\alpha}}$ (B) $2\pi\sqrt{\frac{L}{g\sin\alpha}}$
(C) $2\pi\sqrt{\frac{L}{g}}$ (D) $2\pi\sqrt{\frac{L}{g\tan\alpha}}$

**12. [IIT-JEE 1999]**

A particle free to move along the $x$-axis has potential energy given by $U(x) = k\left[1-\exp(-x^2)\right]$ for $-\infty \le x \le +\infty$, where $k$ is a positive constant of appropriate dimensions. Then

(A) at points away from the origin, the particle is in unstable equilibrium
(B) for any finite non-zero value of $x$, there is a force directed away from the origin
(C) if its total mechanical energy is $\frac{k}{2}$, it has its minimum kinetic energy at the origin
(D) for small displacements from $x = 0$, the motion is simple harmonic

**13. [IIT-JEE 1999]**

A spring of force constant $k$ is cut into two pieces such that one piece is double the length of the other. Then the long piece will have a force constant of

(A) $\frac{2}{3}k$ (B) $\frac{3}{2}k$
(C) $3k$ (D) $6k$

**14. [IIT-JEE 1998]**

A particle of mass $m$ is executing oscillations about the origin on the $x$-axis. Its potential energy is $U(x) = k|x|^3$, where $k$ is a positive constant. If the amplitude of oscillation is $a$, then its time period $T$ is

(A) proportional to $\frac{1}{\sqrt{a}}$ (B) independent of $a$
(C) proportional to $\sqrt{a}$ (D) proportional to $a^{3/2}$

**15. [IIT-JEE 1993]**

One end of a long metallic wire of length $L$ is tied to the ceiling. The other end is tied to a massless spring of spring constant $K$. A mass $m$ hangs freely from the free end of the spring. The area of cross-section and the Young's modulus of the wire are $A$ and $Y$ respectively. If the mass is slightly pulled down and released, it will oscillate with a time period $T$ equal to

(A) $2\pi\left(\frac{m}{k}\right)^{1/2}$ (B) $2\pi\sqrt{\frac{m(YA+KL)}{YAK}}$
(C) $2\pi\left(\frac{mYA}{kL}\right)^{1/2}$ (D) $2\pi\left(\frac{mL}{YA}\right)^{1/2}$

**16. [IIT-JEE 1992]**

A highly rigid cubical block $A$ of small mass $M$ and side $L$ is fixed rigidly on to another cubical block $B$ of the same dimensions and of low modulus of rigidity $\eta$ such that the lower face of $A$ completely covers the upper face of $B$. The lower face of $B$ is rigidly held on a horizontal surface. A small force $F$ is applied perpendicular to one of the sides faces of $A$. After the force is withdrawn, block $A$ executes small oscillations, the time period of which is given by

(A) $2\pi\sqrt{M\eta L}$ (B) $2\pi\sqrt{\frac{M\eta}{L}}$
(C) $2\pi\sqrt{\frac{ML}{\eta}}$ (D) $2\pi\sqrt{\frac{M}{\eta L}}$

**17. [IIT-JEE 1990]**

A uniform cylinder of length $L$ and mass $M$ having cross-sectional area $A$ is suspended, with its length vertical, from a fixed point by a massless spring, such that it is half-submerged in a liquid of density $\rho$ at equilibrium position. When the cylinder is given a small downward push and released it starts oscillating vertically with a small amplitude. If the force constant of the spring is $k$, the frequency of oscillation of the cylinder is

(A) $\frac{1}{2\pi}\left(\frac{k-A\rho g}{M}\right)^{1/2}$ (B) $\frac{1}{2\pi}\left(\frac{k+A\rho g}{M}\right)^{1/2}$
(C) $\frac{1}{2\pi}\left(\frac{k+\rho g L^2}{M}\right)^{1/2}$ (D) $\frac{1}{2\pi}\left(\frac{k+A\rho g}{A\rho g}\right)^{1/2}$

**18. [IIT-JEE 1988]**

The bodies $A$ and $B$ of equal masses are suspended from two separate massless springs of constants $K_1$ and $K_2$, respectively. If the two oscillate vertically such that their maximum velocities are equal. The ratio of amplitude $A$ to that of $B$ is

(A) $\frac{K_1}{K_2}$ (B) $\frac{K_2}{K_1}$
(C) $\sqrt{\frac{K_1}{K_2}}$ (D) $\sqrt{\frac{K_2}{K_1}}$

**19. [IIT-JEE 1987]**
A particle executes S.H.M. with frequency $f$. The frequency with which its kinetic energy oscillates is

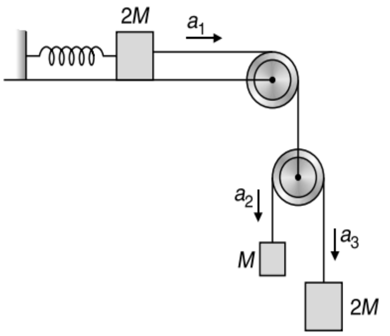
(A) $\frac{f}{2}$ (B) $f$

(C) $2f$ (D) $4f$

## Multiple Correct Choice Type Problems

(In this section each question has four choices (A), (B), (C) and (D), out of which ONE OR MORE is/are correct)

**1. [JEE (Advanced) 2019]**
A block of mass $2M$ is attached to a massless spring with spring-constant $k$. This block is connected to two other blocks of masses $M$ and $2M$ using two massless pulleys and strings. The accelerations of the blocks are $a_1$, $a_2$ and $a_3$ as shown in Figure. The system is released from rest with the spring in its unstretched state. The maximum extension of the spring is $x_0$. Which of the following option(s) is/are correct? ($g$ is the acceleration due to gravity. Neglect friction)




(A) At an extension of $\frac{x_0}{4}$ of the spring, the magnitude of acceleration of the block connected to the spring is $\frac{3g}{10}$

(B) $x_0 = \frac{4Mg}{k}$

(C) $a_2 - a_1 = a_1 - a_3$

(D) When spring achieves an extension of $\frac{x_0}{2}$ for the first time, the speed of the block connected to the spring is $3g\sqrt{\frac{M}{5k}}$

**2. [JEE (Advanced) 2016]**
A block with mass $M$ is connected by a massless spring with stiffness constant $k$ to a rigid wall and moves without friction on a horizontal surface. The block oscillates with small amplitude $A$ about an equilibrium position $x_0$. Consider two cases: (1) when the block is at $x_0$ and (2) when the block is at $x = x_0 + A$. If both the cases, a particle with mass $m(< M)$ is softly placed on the block after which they stick to each other. Which of the following statement(s) is (are) true about the motion after the mass $m$ is placed on the mass $M$?

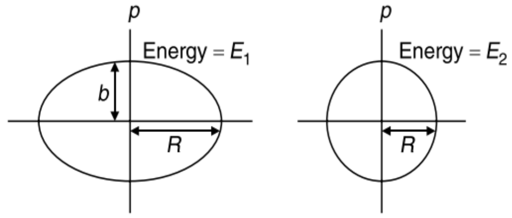
(A) The amplitude of oscillation in the first case changes by a factor of $\sqrt{\frac{M}{m+M}}$, whereas in the second case it remains unchanged

(B) The final time period of oscillation in both the cases is same

(C) The total energy decreases in both the cases

(D) The instantaneous speed at $x_0$ of the combined masses

**3. [JEE (Advanced) 2015]**
Two independent harmonic oscillators of equal masses are oscillating about the origin with angular frequencies $\omega_1$ and $\omega_2$ and have total energies $E_1$ and $E_2$, respectively. The variations of their momenta $p$ with positions $x$ are shown in Figures.




If $\frac{a}{b} = n^2$ and $\frac{a}{R} = n$, then the correct equations is/are

(A) $E_1\omega_1 = E_2\omega_2$ (B) $\frac{\omega_2}{\omega_1} = n^2$

(C) $\omega_1\omega_2 = n^2$ (D) $\frac{E_1}{\omega_1} = \frac{E_2}{\omega_2}$

**4. [JEE (Advanced) 2013]**
A particle of mass $m$ is attached to one end of a mass-less spring of force constant $k$, lying on a frictionless horizontal plane. The other end of the spring is fixed. The particle starts moving horizontally from its equilibrium position at time $t = 0$ with an initial velocity $u_0$. When the speed of the particle is $0.5u_0$, it collides elastically with a rigid wall. After this collision,

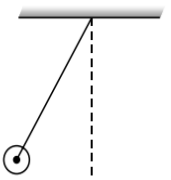
(A) The speed of the particle when it returns to its equilibrium position is $u_0$

(B) The time at which the particle passes through the equilibrium position for the first time is $t = \pi\sqrt{\frac{m}{k}}$

(C) The time at which the maximum compression of the spring occurs is $t = \frac{4\pi}{3}\sqrt{\frac{m}{k}}$

(D) The time at which the particle passes through the equilibrium position for the second time is $t = \frac{5\pi}{3}\sqrt{\frac{m}{k}}$

**5. [IIT-JEE 2011]**
A metal rod of length $L$ and mass $m$ is pivoted at one end. A thin disc of mass $M$ and radius $R(< L)$ is attached at its centre to the free end of the rod. Consider two ways the disc is attached.
Case A: The disc is not free to rotate about its centre and
Case B: The disc is free to rotate about its centre.
The rod-disc system performs SHM in vertical plane after being released from the same displaced position. Which of the following statement(s) is/are true?



(A) Restoring torque in case $A$ equals restoring torque in case $B$
(B) Restoring torque in case $A$ is less than restoring torque in case $B$
(C) Angular frequency for case $A$ is more than angular frequency for case $B$
(D) Angular frequency for case $A$ is less than angular frequency for case $B$

**6. [IIT-JEE 2006]**
The function $x = A\sin^2\omega t + B\cos^2\omega t + C\sin\omega t\cos\omega t$ represents SHM
(A) for any value of $A$, $B$ and $C$ (except $C = 0$)
(B) if $A = -B$, $C = 2B$, amplitude $= |B\sqrt{2}|$
(C) if $A = B$; $C = 0$
(D) if $A = B$; $C = 2B$, amplitude $= |B|$

**7. [IIT-JEE 1999]**
Three simple harmonic motions in the same direction having the same amplitude and same period are superposed. If each differ in phase from the next by 45°, then
(A) the resultant amplitude is $(1+\sqrt{2})$
(B) the phase of the resultant motion relative to the first is 90°
(C) the energy associated with the resulting motion is $(3+2\sqrt{2})$ times the energy associated with any single motion
(D) the resulting motion is not simple harmonic

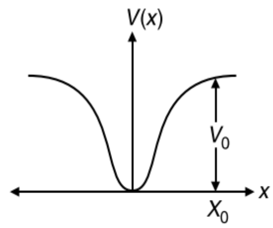
**8. [IIT-JEE 1989]**
A linear harmonic oscillator of force constant $2\times10^6$ Nm$^{-1}$ and amplitude 0.01 m has a total mechanical energy of 160 J. Its
(A) maximum potential energy is 100 J
(B) maximum kinetic energy is 100 J
(C) maximum potential energy is 160 J
(D) maximum potential energy is zero

## Linked Comprehension Type Questions

This section contains Linked Comprehension Type Questions or Paragraph based Questions. Each set consists of a Paragraph followed by questions. Each question has four choices (A), (B), (C) and (D), out of which only one is correct. (For the sake of competitiveness there may be a few questions that may have more than one correct options)

### *Comprehension I*

When a particle of mass $m$ moves on the $x$-axis in a potential of the form $V(x) = kx^2$, it performs simple harmonic motion. The corresponding time period is proportional to $\sqrt{\frac{m}{k}}$, as can be seen easily using dimensional analysis. However, the motion of a particle can be periodic even when its potential energy increases on both sides of $x = 0$ in a way different from $kx^2$ and its total energy is such that the particle does not escape to infinity. Consider a particle of mass $m$ moving on the $x$-axis. Its potential energy is $V(x) = \alpha x^4\ (\alpha > 0)$ for $|x|$ near the origin and becomes a constant equal to $V_0$ for $|x| \geq X_0$ (shown in Figure).




Based on the above facts, answer the following questions.

**1. [IIT-JEE 2010]**
If the total energy of the particle is $E$, it will perform periodic motion only if
(A) $E < 0$ (B) $E > 0$
(C) $V_0 > E > 0$ (D) $E > V_0$

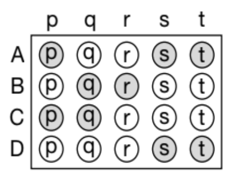
**2. [IIT-JEE 2010]**
For periodic motion of small amplitude $A$, the time period $T$ of this particle is proportional to
(A) $A\sqrt{\frac{m}{\alpha}}$ (B) $\frac{1}{A}\sqrt{\frac{m}{\alpha}}$
(C) $A\sqrt{\frac{\alpha}{m}}$ (D) $\frac{1}{A}\sqrt{\frac{\alpha}{m}}$

**3. [IIT-JEE 2010]**
The acceleration of this particle for $|x| > X_0$ is
(A) proportional to $V_0$ (B) proportional to $\frac{V_0}{mX_0}$
(C) proportional to $\sqrt{\frac{V_0}{mX_0}}$ (D) ZERO

## Matrix Match/Column Match Type Questions

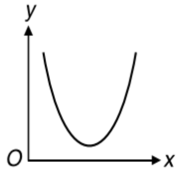
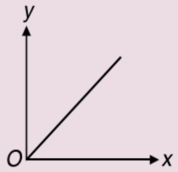
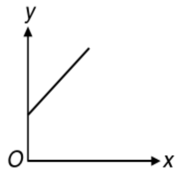
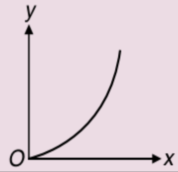
Each question in this section contains statements given in two columns, which have to be matched. The statements in **COLUMN-I** are labelled A, B, C and D, while the statements in **COLUMN-II** are labelled p, q, r, s (and t). Any given statement in **COLUMN-I** can have correct matching with **ONE OR MORE** statement(s) in **COLUMN-II**. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following examples:

If the correct matches are A → p, s and t; B → q and r; C → p and q; and D → s and t; then the correct darkening of bubbles will look like the following:



**1.** **[IIT-JEE 2008]**

**COLUMN-I** gives a list of possible set of parameters measured in some experiments. The variations of the parameters in the form of graphs are shown in **COLUMN-II**. Match the set of parameters given in **COLUMN-I** with the graphs given in **COLUMN-II**. Indicate your answer by darkening the appropriate bubbles of the $4 \times 4$ matrix given in the ORS.

| COLUMN-I | COLUMN-II |
|---|---|
| (A) Potential energy of a simple pendulum ($y$-axis) as a function of displacement ($x$-axis) | (p)  |
| (B) Displacement ($y$-axis) as a function of time ($x$-axis) for a one dimensional motion at zero or constant acceleration when the body is moving along the positive $x$-direction | (q)  |
| (C) Range of a projectile ($y$-axis) as a function of its velocity ($x$-axis) when projected at a fixed angle | (r)  |
| (D) The square of the time period ($y$-axis) of a simple pendulum as a function of its length ($x$-axis) | (s)  |

**2.** **[IIT-JEE 2007]**

**COLUMN I** describes some situations in which a small object moves. **COLUMN II** describes some characteristics of these motions. Match the situations in **COLUMN I** with the characteristics in **COLUMN II**.

| COLUMN-I | COLUMN-II |
|---|---|
| (A) The object moves on the $x$-axis under a conservative force in such a way that its speed and position satisfy $v = c_1\sqrt{c_2 - x^2}$, where $c_1$ and $c_2$ are positive constants. | (p) The object executes a simple harmonic motion. |
| (B) The object moves on the $x$-axis in such a way that its velocity and its displacement from the origin satisfy $v = -kx$, where $k$ is a positive constant. | (q) The object does not change its direction. |
| (C) The object is attached to one end of a mass-less spring of a given spring constant. The other end of the spring is attached to the ceiling of an elevator. Initially everything is at rest. The elevator starts going upwards with a constant acceleration $a$. The motion of the object is observed from the elevator during the period it maintains this acceleration. | (r) The kinetic energy of the object keeps on decreasing |
| (D) The object is projected from the earth's surface vertically upwards with a speed $2\sqrt{\frac{GM_e}{R_e}}$, where $M_e$ is the mass of the earth and $R_e$ is the radius of the earth. Neglect forces from object other than the earth. | (s) The object can change its direction only once. |

*(Continued)*

## Integer/Numerical Answer Type Questions

In this section, the answer to each question is a numerical value obtained after series of calculations based on the data provided in the question(s).

**1.** **[IIT-JEE 2010]**

A 0.1 kg mass is suspended from a wire of negligible mass. The length of the wire is 1 m and its cross-sectional area is $4.9 \times 10^{-7}$ m$^2$. If the mass is pulled a little in the vertically downward direction and released, it performs simple harmonic motion of angular frequency 140 rad s$^{-1}$. If the Young's modulus of the material of the wire is $n \times 10^9$ Nm$^{-2}$, the value of $n$ is

# ANSWER KEYS–TEST YOUR CONCEPTS AND PRACTICE EXERCISES

## Test Your Concepts-I (Based on SHM Properties)

1. (a) 8 cm (b) 1.57 $rads^{-1}$
   (c) 1.97 $Nm^{-1}$ (d) zero
   (e) 0.197 $ms^{-2}$
2. No Solution required
3. (a) Oscillatory but not harmonic
   (b) Rectilinear along negative $x$ direction
   (c) SHM about $x = 2$
4. $6\cos(\pi t), -6\pi\sin(\pi t), -6\pi^2\cos(\pi t)$
5. $\frac{2}{\pi}, \frac{2}{\pi}$
6. (a) $3.14\times10^{-2}$ s
   (b) 1.571 s
7. 2 $ms^{-1}$, $2\sin^{-1}\left(\frac{4}{5}\right)$
8. $5A$
9. (a) 1.4 s (b) 0.0964 m
   (c) 0.207
10. $\frac{2\pi}{3}$
11. No Answer
12. (a) $\frac{\pi}{4}$ s (b) 8 $ms^{-1}$
    (c) 0
13. $\pi - \sin^{-1}\left(\frac{1}{6}\right) - \sin^{-1}\left(\frac{1}{3}\right)$
14. (a) 0.35 $ms^{-1}$ (b) 0.61 $ms^{-2}$
    (c) 0.3 s (d) 0.80 m
15. (a) 150 J (b) 50 J (c) 200 J
16. $0.1\sin\left(4t + \frac{\pi}{4}\right)$ metre
17. $2\pi\sqrt{\frac{m}{b^2U_0}}$
18. 0.806
19. 7.2 cm
20. (a) $2A, 2A, 1$ (b) $A, A, 1$
    (c) $\frac{A}{\sqrt{2}}, A\left(1-\frac{1}{\sqrt{2}}\right), 2.4$
21. $\frac{3}{4}, \frac{A}{\sqrt{2}}$
22. (a) $m\left(g + a\omega^2\cos\omega t\right)$ (b) 8.01 cm
23. (a) 2.5 Hz, 0.4 s (b) 3 m (c) −3 m, 0

## Test Your Concepts-II (Based on Spring Mass Systems)

1. (a) $A_1\sqrt{\frac{M}{M+m}}, 2\pi\sqrt{\frac{M+m}{k}}$ (b) $A_1, 2\pi\sqrt{\frac{M+m}{k}}$
2. (a) $\frac{1}{2\pi}\sqrt{\frac{k_1+k_2}{m_1+m_2}}$ (b) $\frac{k_1}{k_2} < \frac{m_1}{m_2}$
   (c) $\frac{\mu(m_1+m_2)m_2 g}{m_1k_2 - m_2k_1}$
3. 1.6 kg
4. $2\pi\sqrt{\frac{mM}{k(M+m)}}$
5. (a) 0.35 $ms^{-1}$ (b) 0.61 $ms^{-2}$
   (c) 0.3 s (d) 0.80 m
6. 7.2 cm
7. (a) $\frac{kA}{(m_1+m_2)g}$
   (b) $A$ and $E$ remain unchanged, $\omega_f = \left(\sqrt{\frac{m_1}{m_1+m_2}}\right)\omega_i$
   (c) $T$ increases, $T_f = \left(\sqrt{\frac{m_1+m_2}{m_1}}\right)T_i$
8. $\sqrt{\frac{k_1k_2}{4m(k_1+k_2)}}$
9. (a) 1.5 kg (b) 0.82 cm
   (c) $x = 2.5\cos(34.6t)$ cm, $v = -86.5\sin(34.6t)$ $cms^{-1}$
   $a = -29.9\cos(34.6t)$ $ms^{-2}$
10. $2\pi\sqrt{\frac{m(k_1+4k_2)}{k_1k_2}}$
11. (a) $\frac{1}{2\pi}\sqrt{\frac{k}{m}}$ (b) $\frac{ma}{k}$
12. (a) 13 cm (b) 6.5 cm
    (c) 0.51 s (d) 0.32 J
    (e) 0.8 $ms^{-1}$, 0.13 s (f) 0.12 s, 1.13 $ms^{-1}$
13. 4.3 kg
14. $\frac{\pi}{2}\sqrt{\frac{k}{2m}}$
15. $2\pi\sqrt{\frac{(k_1+k_2)m}{4k_1k_2}}$

## Test Your Concepts-III (Based on Rotational SHM)

1. $2\pi\sqrt{\left|\frac{\theta}{\alpha'}\right|} = 2\pi\sqrt{\frac{28R}{5g}}$

2. $0.4\cos(16.16t)$
3. $\dfrac{2\pi a}{b}\sqrt{\dfrac{m}{k}}$
4. 0.963 s
5. $2\pi\sqrt{\dfrac{ml^2}{mgl+2kb^2}}$
6. $2\pi\sqrt{\dfrac{3M}{16k}}$
7. $2\pi\sqrt{\dfrac{M+\dfrac{I}{R^2}}{4k}}$
8. $2\pi\sqrt{\dfrac{9M}{4k}}$

## Test Your Concepts-IV (Based on Pendulum Systems)

1. $\dfrac{T_0}{\sqrt{\cos\alpha}}$
2. 0.816
3. 1.1 s
4. 12.8 s
5. $T=\sqrt{\dfrac{l}{g}}\left[\pi+2\sin^{-1}\left(\dfrac{\alpha}{\beta}\right)\right]$
6. $2\pi\sqrt{\dfrac{\ell}{g\cos\theta}}$
7. $\dfrac{4}{9}$
8. $\dfrac{\left(m+\dfrac{M}{2}\right)R}{m}$
9. (a) 0.25 m, (b) $-0.123\ \text{ms}^{-1}$
10. $\sqrt{\dfrac{g}{2r}}$

## Test Your Concepts-V (Based on SHM in Other Physical Systems, Composition of SHM, Damped Oscillations, Forced Oscillations & Resonance)

1. $2\pi\sqrt{\dfrac{\ell}{g-\dfrac{qE}{m}}}$
2. $2\pi\sqrt{\dfrac{r\cos\alpha}{g\left(1+\cos^2\alpha\right)^{1/2}}}$
3. 0.2 s
4. $\dfrac{1}{2\pi}\sqrt{\dfrac{YA}{ml}}$
5. $\pi\sqrt{\dfrac{R^3}{GM}}$
6. $2\pi\sqrt{\dfrac{MV_0}{\gamma A(P_0A+Mg)}}$
7. $11.25\sin(\omega t+\phi)$, $\phi=40.4^\circ$
8. 1.25 cm
9. 1.25 kg
10. 8

## Single Correct Choice Type Questions

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1. B | 2. B | 3. B | 4. A | 5. D | 6. C | 7. C | 8. C | 9. D | 10. C |
| 11. C | 12. C | 13. C | 14. B | 15. B | 16. B | 17. A | 18. D | 19. A | 20. C |
| 21. C | 22. B | 23. D | 24. A | 25. C | 26. B | 27. A | 28. B | 29. A | 30. C |
| 31. D | 32. A | 33. D | 34. B | 35. A | 36. B | 37. C | 38. A | 39. A | 40. C |
| 41. B | 42. B | 43. C | 44. D | 45. B | 46. B | 47. C | 48. B | 49. B | 50. C |
| 51. C | 52. B | 53. C | 54. A | 55. B | 56. B | 57. D | 58. A | 59. B | 60. D |
| 61. D | 62. B | 63. C | 64. C | 65. A | 66. A | 67. C | 68. B | 69. B | 70. C |
| 71. B | 72. B | 73. D | 74. B | 75. D | 76. C | 77. C | 78. B | 79. C | 80. D |
| 81. D | 82. B | 83. C | 84. D | 85. B | 86. A | 87. C | 88. B | 89. A | 90. D |
| 91. C | 92. D | 93. D | 94. B | 95. B | 96. B | 97. A | 98. A | 99. B | 100. D |
| 101. A | 102. C | 103. A | 104. D | 105. A | 106. B | 107. C | 108. D | 109. D | 110. B |
| 111. D | 112. D | 113. C | 114. C | 115. C | 116. A | 117. D | 118. B | 119. B | 120. B |
| 121. B | 122. A | 123. C | 124. B | 125. C | 126. C | 127. B | 128. B | 129. A | 130. A |
| 131. D | 132. A | 133. C | 134. D | 135. D | 136. C | 137. B | 138. A | 139. D | 140. B |
| 141. C | 142. C | 143. D | 144. D | 145. A | 146. D | 147. C | 14. A | 149. D | 150. D |
| 151. C | 152. A | 153. A | | | | | | | |

## Multiple Correct Choice Type Questions

| | | | | |
|---|---|---|---|---|
| **1.** B, D | **2.** B, C, D | **3.** A, C | **4.** A, C | **5.** B, C |
| **6.** A, C | **7.** A, B, C | **8.** A, B, D | **9.** A, C | **10.** A, C |
| **11.** A, C, D | **12.** B, C, D | **13.** A, B, C, D | **14.** A, C, D | **15.** A, C |
| **16.** A, B, C | **17.** A, C, D | **18.** B, C | **19.** B, C | **20.** A, C |
| **21.** A, B, C, D | **22.** B, C | **23.** A, B, C | **24.** A, C | **25.** B, C, D |
| **26.** A, B, C | **27.** B, D | **28.** C, D | **29.** A, B, C | **30.** B, C, D |
| **31.** A, B | | | | |

## Reasoning Based Questions

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1.** B | **2.** B | **3.** B | **4.** B | **5.** D | **6.** A | **7.** A | **8.** D | **9.** D | **10.** B |
| **11.** B | **12.** D | **13.** A | **14.** C | **15.** A | **16.** D | **17.** D | **18.** A | **19.** C | **20.** A |

## Linked Comprehension Type Questions

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1.** C | **2.** B | **3.** C | **4.** D | **5.** B | **6.** B | **7.** C | **8.** D | **9.** D | **10.** B, C |
| **11.** D | **12.** C | **13.** B | **14.** C | **15.** A | **16.** D | **17.** B | **18.** D | **19.** D | **20.** D |
| **21.** C | **22.** D | **23.** A | **24.** D | **25.** D | **26.** C | **27.** D | **28.** B | **29.** A | **30.** C |
| **31.** A | **32.** D | **33.** C | **34.** A | **35.** B | **36.** C | **37.** A | **38.** C | **39.** B | **40.** C |
| **41.** B | **42.** C | **43.** A | **44.** A | **45.** D | **46.** B | **47.** A | **48.** A | **49.** A | **50.** C |
| **51.** A | **52.** B | **53.** A | **54.** A | **55.** B | **56.** C | **57.** C | | | |

## Matrix Match/Column Match Type Questions

| | | | |
|---|---|---|---|
| **1.** A → (q) | B → (r) | C → (s) | D → (t) |
| **2.** A → (r) | B → (p) | C → (q) | D → (s) |
| **3.** A → (r) | B → (q) | C → (p) | D → (q) |
| **4.** A → (r) | B → (r) | C → (s) | D → (s) |
| **5.** A → (q) | B → (p) | C → (s) | D → (q) |
| **6.** A → (q) | B → (s) | C → (p) | D → (r) |
| **7.** A → (q) | B → (s) | C → (p) | D → (r) |
| **8.** A → (q) | B → (r) | C → (q) | D → (q) |
| **9.** A → (r) | B → (p) | C → (s) | D → (p, q) |
| **10.** A → (q) | B → (s) | C → (s) | D → (s) |
| **11.** A → (q) | B → (t) | C → (p) | D → (t) |

## Integer/Numerical Answer Type Questions

| | | | | |
|---|---|---|---|---|
| **1.** 4 | 2. (a) 9 (b) 3 | **3.** 2 | **4.** 8 | 5. $x = 3, y = 5$ |
| **6.** 1 | **7.** 2 | **8.** 2 | **9.** 5 | **10.** 10 |
| **11.** 7 | **12.** (a) 147 (b) 7 | **13.** 9 | **14.** (a) 1600 (b) 80 (c) 20 | **15.** 10 |
| **16.** 2, 10 | **17.** 20 | **18.** 4 | **19.** 8 | **20.** (a) 54 (b) 108 |

## ARCHIVE: JEE MAIN

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1.** D | **2.** A | **3.** A | **4.** B | **5.** D | **6.** B | **7.** A | **8.** B | **9.** B | **10.** C |
| **11.** A | **12.** C | **13.** * | **14.** A | **15.** D | **16.** D | **17.** A | **18.** * | **19.** B | **20.** D |
| **21.** A | **22.** D | **23.** D | **24.** B | **25.** A | **26.** C | **27.** A | **28.** A | **29.** B | **30.** C |
| **31.** D | **32.** C | **33.** A | **34.** D | **35.** D | **36.** C | **37.** C | **38.** B | **39.** D | **40.** B |

* No given option is correct.

## ARCHIVE: JEE ADVANCED

### Single Correct Choice Type Problems

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **1.** A | **2.** A | **3.** B | **4.** D | **5.** D | **6.** C | **7.** A | **8.** A | **9.** A | **10.** A |
| **11.** A | **12.** D | **13.** B | **14.** A | **15.** B | **16.** D | **17.** B | **18.** D | **19.** C | |

### Multiple Correct Choice Type Problems

| | | | | |
|---|---|---|---|---|
| **1.** C | **2.** A, B, D | **3.** B, D | **4.** A, D | **5.** A, D |
| **6.** B, D | **7.** A, C | **8.** B, C | **9.** A, C | **10.** A, C |

### Linked Comprehension Type Questions

| | | |
|---|---|---|
| **1.** C | **2.** B | **3.** D |

### Matrix Match/Column Match Type Questions

| | | | |
|---|---|---|---|
| **1.** A → (p, s) | B → (q, r, s) | C → (s) | D → (q) |
| **2.** A → (p) | B → (q, r) | C → (p) | D → (q, r) |

### Integer/Numerical Answer Type Questions

| |
|---|
| **1.** 4 |