

EXERCISE

EXERCISE (S-1)

KINEMATICS OF SHM

HCV Worked out Examples(Chapter No. 12 - 1,2,3,4)

1. A body undergoing SHM about the origin has its equation is given by $x = 0.2 \cos 5\pi t$. Find its average speed from $t = 0$ to $t = 0.7$ sec.
2. Two particles A and B execute SHM along the same line with the same amplitude a , same frequency and same equilibrium position O. If the phase difference between them is $\phi = 2 \sin^{-1}(0.9)$, then find the maximum distance between the two.

HCV Exercises (Chapter No. 12 - 1,2,5,7)

ENERGY OF SHM

HCV Worked out Examples(Chapter No. 12 - 9,10)

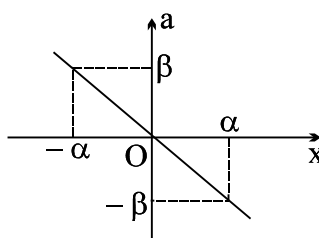
3. Potential Energy (U) of a body of unit mass moving in a one-dimension conservative force field is given by, $U = (x^2 - 4x + 3)$. All units are in S.I.
 - (i) Find the equilibrium position of the body.
 - (ii) Show that oscillations of the body about this equilibrium position is simple harmonic motion & find its time period.
 - (iii) Find the amplitude of oscillations if speed of the body at equilibrium position is $2\sqrt{6}$ m/s.
4. An object of mass 0.2 kg executes SHM along the x-axis with frequency of $(25/\pi)$ Hz. At the point $x = 0.04$ m the object has KE 0.5 J and PE 0.4 J. The amplitude of oscillation is _____.

HCV Exercises (Chapter No. 8 - 13,14,16,22)

TIME PERIOD

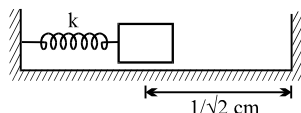
HCV Worked out Examples(Chapter No. 12 - 5,6,7)

5. The acceleration-displacement ($a - x$) graph of a particle executing simple harmonic motion is shown in the figure. Find the frequency of oscillation.

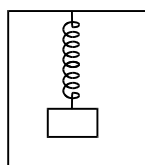
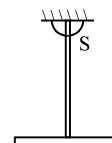


6. A body is in SHM with period T when oscillated from a freely suspended spring. If this spring is cut in two parts of length ratio 1 : 3 & again oscillated from the two parts separately, then the periods are T_1 & T_2 then find T_1/T_2 .

7. A block of mass 0.9 kg attached to a spring of force constant k is lying on a frictionless floor. The spring is compressed to $\sqrt{2}$ cm and the block is at a distance $1/\sqrt{2}$ cm from the wall as shown in the figure. When the block is released, it makes elastic collision with the wall and its period of motion is 0.2 sec. Find the approximate value of k .



8. A force $f = -10x + 2$ acts on a particle of mass 0.1 kg, where ' k ' is in m and F in newton. If it is released from rest at $x = -2$ m, find :
 (a) amplitude ; (b) time period ; (c) equation of motion.
9. Two identical rods each of mass m and length L , are rigidly joined and then suspended in a vertical plane so as to oscillate freely about an axis normal to the plane of paper passing through 'S' (point of suspension). Find the time period of such small oscillations.
10. (a) Find the time period of oscillations of a torsional pendulum, if the torsional constant of the wire is $K = 10\pi^2 \text{ J/rad}$. The moment of inertia of rigid body is 10 kg m^2 about the axis of rotation.
 (b) A simple pendulum of length $l = 0.5$ m is hanging from ceiling of a car. The car is kept on a horizontal plane. The car starts accelerating on the horizontal road with acceleration of 5 m/s^2 . Find the time period of oscillations of the pendulum for small amplitudes about the mean position.
11. A body of mass 1 kg is suspended from a weightless spring having force constant 600 N/m. Another body of mass 0.5 kg moving vertically upwards hits the suspended body with a velocity of 3.0 m/s and get embedded in it. Find the frequency of oscillations and amplitude of motion.
12. A spring mass system is hanging from the ceiling of an elevator in equilibrium. Elongation of spring is l . The elevator suddenly starts accelerating downwards with acceleration $g/3$ find



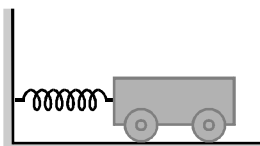
- (a) the frequency and (b) the amplitude of the resulting SHM.

HCV Exercises (Chapter No. 8 - 15,16,23,38,39,50,53)

COMPLEX SITUATIONS

HCV Worked out Examples (Chapter No. 12 - 8,11,12,13,14,15,16,17,18,19,20,21,22)

13. A cart consists of a body and four wheels on frictionless axles. The body has a mass m . The wheels are uniform disks of mass M and radius R . The cart rolls, without slipping, back and forth on a horizontal plane under the influence of a spring attached to one end of the cart (figure). The spring constant is k . Taking into account the moment of inertia of the wheels, find a formula for the frequency of the back and forth motion of the cart.



14. The motion of a simple pendulum is given by

$$\theta = A \cos \left(\sqrt{\frac{g}{\ell}} t \right) \text{ (symbols have their usual meaning)}$$

- (a) Find the tension in the string of this pendulum ; assume that $\theta \ll 1$.
 (b) The tension is a function of time. At what time is the tension maximum ? What is the value of this maximum tension ?
15. A physical pendulum has the shape of a disk of radius R . the pendulum swings about an axis perpendicular to the plane of the disk and at distance ℓ from the center of the disk.

$$\omega = \sqrt{\frac{g\ell}{\frac{1}{2}R^2 + \ell^2}}$$

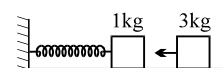
- (a) Show that the frequency of the oscillations of this pendulum is
 (b) For what value of ℓ is this frequency at a maximum ?

HCV Exercises (Chapter No. 8 - 17,18,19,21,25,26,27,28,29,30,31,57)

EXERCISE (S-2)

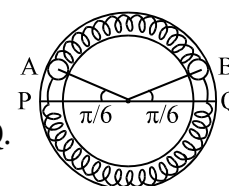
1. A point particle of mass 0.1kg is executing SHM with amplitude of 0.1m. When the particle passes through the mean position, its K.E. is 8×10^{-3} J. Obtain the equation of motion of this particle if the initial phase of oscillation is 45° .
2. One end of an ideal spring is fixed to a wall at origin O and the axis of spring is parallel to x-axis. A block of mass $m = 1$ kg is attached to free end of the spring and it is performing SHM. Equation of position of block in coordinate system shown is $x = 10 + 3\sin 10t$, t is in second and x in cm. Another block of mass $M = 3$ kg, moving towards the origin with velocity 30cm/s collides with the block performing SHM at $t = 0$ and gets struck to it, calculate :

- (i) new amplitude of oscillations.
- (ii) new equation for position of the combined body.
- (iii) loss of energy during collision. Neglect friction.



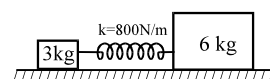
3. Two identical balls A and B each of mass 0.1 kg are attached to two identical massless springs. The spring mass system is constrained to move inside a rigid smooth pipe in the form of a circle as in fig. The pipe is fixed in a horizontal plane. The centres of the ball can move in a circle of radius 0.06m. Each spring has a natural length 0.06π m and force constant 0.1N/m. Initially both the balls are displaced by an angle of $\theta = \pi/6$ radian with respect to diameter PQ of the circle and released from rest

- (a) Calculate the frequency of oscillation of the ball B.
- (b) What is the total energy of the system.
- (c) Find the speed of the ball A when A and B are at the two ends of the diameter PQ.

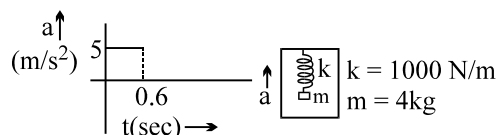


4. The system shown in the figure can move on a smooth surface. The spring is initially compressed by 6 cm and then released. Find

- (a) time period
- (b) amplitude of 3 kg block
- (c) maximum momentum of 6 kg block



5. A spring block (force constant $k = 1000$ N/m and mass $m = 4$ kg) system is suspended from the ceiling of an elevator such that block is initially at rest. The elevator begins to move upwards at $t = 0$. Acceleration time graph of the elevator is shown in the figure. Draw the displacement x (from its initial position taking upwards as positive) vs time graph of the block with respect to the elevator starting from $t = 0$ to $t = 1$ sec. Take $\pi^2 = 10$.

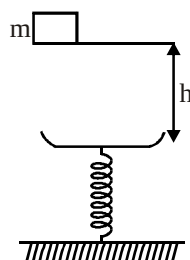


6. The resulting amplitude A' and the phase of the vibrations δ

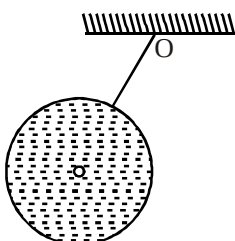
$$S = A \cos(\omega t) + \frac{A}{2} \cos\left(\omega t + \frac{\pi}{2}\right) + \frac{A}{4} \cos(\omega t + \pi) + \frac{A}{8} \cos\left(\omega t + \frac{3\pi}{2}\right) = A' \cos(\omega t + \delta)$$

are _____ and _____ respectively.

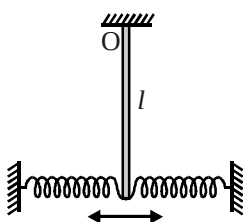
7. A mass m , which is attached to a spring with spring constant k , oscillates on a horizontal table, with amplitude A . At an instant when the spring is stretched by $\frac{\sqrt{3}A}{2}$, a second mass m is dropped vertically onto the original mass and immediately sticks to it. What is the amplitude of the resulting motion?
8. A body of mass m fell from a height h onto the pan of a spring balance. The masses of the pan and the spring are negligible, the stiffness of the latter is x . Having stuck to the pan, the body starts performing harmonic oscillations in the vertical direction. Find the amplitude and the energy of these oscillations.



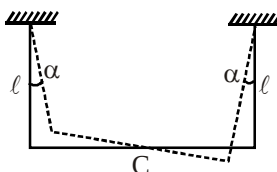
9. A pendulum is constructed as a light thin-walled sphere of radius R filled up with water and suspended at the point O from a light rigid rod. The distance between the point O and the centre of the sphere is equal to ℓ . How many times will the small oscillations of such a pendulum change after the water freezes? The viscosity of water and the change of its volume on freezing are to be neglected. moves translationwise, and the system behaves as a mathematical pendulum.



10. Find the frequency of small oscillations of a thin uniform vertical rod of mass m and length ℓ hinged at the point O . The combined stiffness of the springs is equal to x . The mass of the springs is negligible.



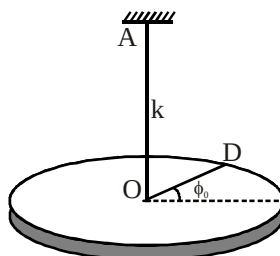
11. A uniform rod of mass $m = 1.5$ kg suspended by two identical threads $\ell = 90$ cm in length was turned through a small angle about the vertical axis passing through its middle point C . The threads deviated in the process through an angle $\alpha = 5.0^\circ$. Then the rod was released to start performing small oscillations.



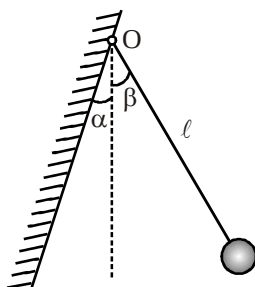
Find:

- (a) the oscillation period;
(b) the rod's oscillation energy.

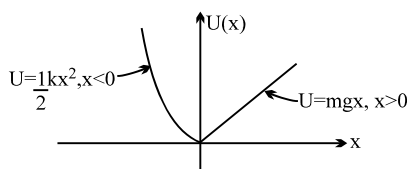
12. An arrangement illustrated in Fig. consists of a horizontal uniform disc D of mass m and radius R and a thin rod AO whose torsional coefficient is equal to k . Find the amplitude and the energy of small torsional oscillations if at the initial moment the disc was deviated through an angle ϕ_0 from the equilibrium position and then imparted an angular velocity ω_0 .



13. A ball is suspended by a thread of length ℓ at the point O on the wall, forming a small angle α with the vertical. Then the thread with the ball was deviated through a small angle β ($\beta > \alpha$) and set free. Assuming the collision of the ball against the wall to be perfectly elastic, find the oscillation period of such a pendulum.



14. A small body of mass m is fixed to the middle of a stretched string of length 2ℓ . In the equilibrium position the string tension is equal to T_0 . Find the angular frequency of small oscillations of the body in the transverse direction. The mass of the string is negligible, the gravitational field is absent.
15. Two physical pendulums perform small oscillations about the same horizontal axis with frequencies ω_1 and ω_2 . Their moments of inertia relative to the given axis are equal to I_1 and I_2 respectively. In a state of stable equilibrium the pendulums were fastened rigidly together. What will be the frequency of small oscillations of the compound pendulum?
16. A particle of mass m moves in the potential energy U shown above. Find the period of the motion when the particle has total energy E .

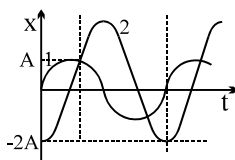


17. A particle of mass 4 kg moves between two points A and B on a smooth horizontal surface under the action of two forces such that when it is at a point P, the forces are $2PA$ N and $2PB$ N. If the particle is released from rest at A, find the time it takes to travel a quarter of the way from A to B.

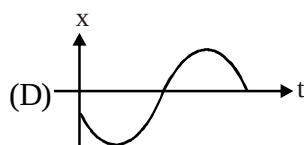
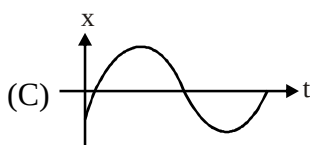
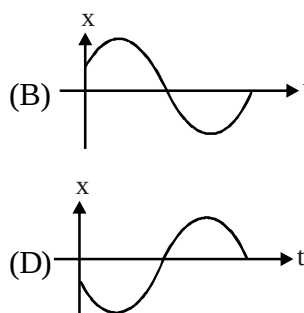
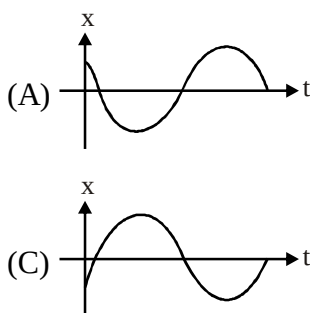
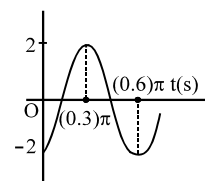
EXERCISE (O-1)

KINEMATICS OF SHM

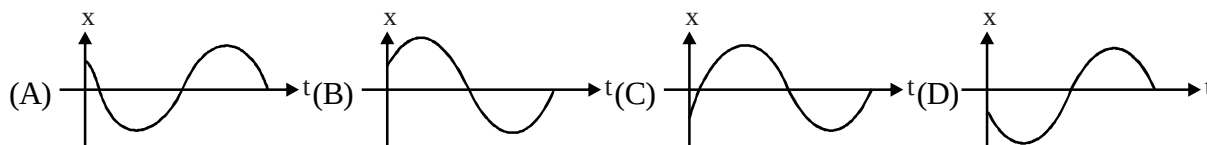
- Motion of a ball bearing inside a smooth curved bowl, when released from a point slightly above the lower point is
(A) simple harmonic motion. (B) non-periodic motion.
(C) periodic motion. (D) periodic but not S.H.M.
- The displacement of a particle varies with time according to the relation $y = a \sin \omega t + b \cos \omega t$.
(A) The motion is oscillatory but not S.H.M.
(B) The motion is S.H.M. with amplitude $a + b$
(C) The motion is S.H.M. with amplitude $a^2 + b^2$
(D) The motion is S.H.M. with amplitude $\sqrt{a^2 + b^2}$
- The oscillations represented by curve 1 in the graph are expressed by equation $x = A \sin \omega t$. The equation for the oscillations represented by curve 2 is expressed as:



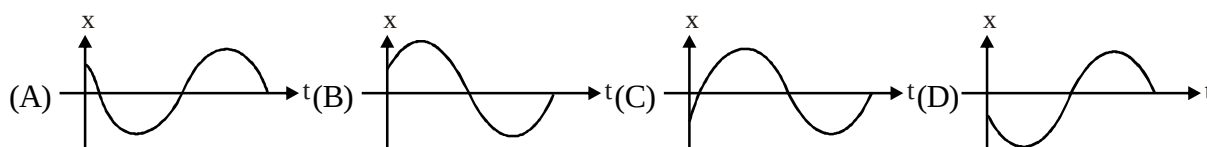
- (A) $x = 2A \sin (\omega t - \pi/2)$ (B) $x = 2A \sin (\omega t + \pi/2)$
(C) $x = -2A \sin (\omega t - \pi/2)$ (D) $x = A \sin (\omega t - \pi/2)$
- The equation of motion of a particle is $x = a \cos (\alpha t)^2$. The motion is
(A) periodic but not oscillatory. (B) periodic and oscillatory.
(C) oscillatory but not periodic. (D) neither periodic nor oscillatory.
- Part of a simple harmonic motion is graphed in the figure, where y is the displacement from the mean position. The correct equation describing this S.H.M is
(A) $y = 4 \cos (0.6t)$ (B) $y = 2 \sin \left(\frac{10}{3}t - \frac{\pi}{2} \right)$
(C) $y = 4 \sin \left(\frac{10}{3}t + \frac{\pi}{2} \right)$ (D) $y = 2 \cos \left(\frac{10}{3}t + \frac{\pi}{2} \right)$
- A particle performing S.H.M. about mean position $x = 0$ and at $t = 0$ it is at position $x = \frac{A}{\sqrt{2}}$ and moving towards the origin. Then which of the following is its possible graph between position (x) and time (t)



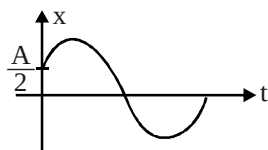
7. A particle is performing S.H.M. and at $t = 0$, is at position $= \frac{A}{\sqrt{2}}$ and moving towards the origin. Equilibrium position of the particle is at $x = 0$. Now after $t = \frac{T}{2}$, what will be the graph of the particle's S.H.M.



8. A particle is performing S.H.M. and at $t = \frac{3T}{4}$, is at position $= \frac{A}{\sqrt{2}}$ and moving towards the origin. Equilibrium position of the particle is at $x = 0$. After $t = \frac{3T}{2}$ what will be the graph of the particle according to person B.



9. Following graph shows a particle performing S.H.M. about mean position $x = 0$. The equation of particle if $t = \frac{T}{4}$ is taken as starting time is (Notations have usual meanings)



- (A) $A \sin\left(\omega t + \frac{2\pi}{3}\right)$ (B) $A \sin\left(\omega t + \frac{\pi}{3}\right)$ (C) $A \sin\left(\omega t + \frac{\pi}{6}\right)$ (D) $A \cos\left(\omega t + \frac{2\pi}{3}\right)$
10. A particle is performing S.H.M. and at $t = \frac{3T}{4}$, is at position $\frac{\sqrt{3}A}{2}$ and moving towards the origin. Equilibrium position of the particle is at $x = 0$. Then what was the position and direction of particle at $t = 0$?
- (A) $-\frac{A}{2}$, away from mean position (B) $\frac{A}{2}$, away from mean position
(C) $\frac{A}{2}$, towards mean position (D) $-\frac{A}{2}$, towards mean position
11. A particle is performing S.H.M. and at $t = \frac{3T}{4}$, is at position $\frac{\sqrt{3}A}{2}$ and moving towards the origin. Equilibrium position of the particle is at $x = 0$. Then what was the position and direction of particle at $t = \frac{3T}{2}$?
- (A) $-\frac{A}{2}$, away from mean position (B) $\frac{A}{2}$, away from mean position
(C) $\frac{A}{2}$, towards mean position (D) $-\frac{A}{2}$, towards mean position

12. The phase difference between two SHMs $Y_1 = 10\sin(10\pi t + \pi/3)$ and $Y_2 = 12\sin(8\pi t + \pi/4)$ at $t = 0.5s$ is.....
 (A) 195° (B) 200° (C) 180° (D) 170°
13. A bob is attached to a long, light string. The string is deflected by 3° initially with respect to vertical. The length of the string is 1 m. The value of q at any time t after the bob released can be approximately written as (Use $g = \pi^2$)
 (A) $3^\circ \cos \pi t$ (B) $3^\circ \sin \pi t$ (C) $3^\circ \sin \left(\pi t + \frac{\pi}{6} \right)$ (D) $3^\circ \cos \left(\pi t + \frac{\pi}{6} \right)$
14. A simple harmonic motion having an amplitude A and time period T is represented by the equation :
 $y = 5 \sin \pi(t + 4)$ m
 Then the values of A (in m) and T (in sec) are :
 (A) $A = 5$; $T = 2$ (B) $A = 10$; $T = 1$ (C) $A = 5$; $T = 1$ (D) $A = 10$; $T = 2$
15. 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 is doubled while amplitude remains constant
16. A stone is swinging in a horizontal circle 0.8 m in diameter at 30 rev / min. A distant horizontal light beam causes a shadow of the stone to be formed on a nearly vertical wall. The amplitude and period of the simple harmonic motion for the shadow of the stone are
 (A) 0.4 m, 4 s (B) 0.2 m, 2 s (C) 0.4 m, 2 s (D) 0.8 m, 2 s
17. A small mass executes linear SHM about O with amplitude a and period T . Its displacement from O at time $T/8$ after passing through O is:
 (A) $\frac{a}{8}$ (B) $\frac{a}{2\sqrt{2}}$ (C) $\frac{a}{2}$ (D) $\frac{a}{\sqrt{2}}$
18. The displacement of a body executing SHM is given by $x = A \sin (2\pi t + \pi/3)$. The first time from $t = 0$ when the velocity is maximum is
 (A) 0.33 sec (B) 0.16 sec (C) 0.25 sec (D) 0.5 sec
19. A particle performing SHM is found at its equilibrium at $t = 1$ sec. and it is found to have a speed of 0.25 m/s at $t = 2$ sec. If the period of oscillation is 6 sec. Calculate amplitude of oscillation
 (A) $\frac{3}{2\pi}$ m (B) $\frac{3}{4\pi}$ m (C) $\frac{6}{\pi}$ m (D) $\frac{3}{8\pi}$
20. The angular frequency of motion whose equation is $4 \frac{d^2y}{dt^2} + 9y = 0$ is (y = displacement and t = time)
 (A) $\frac{9}{4}$ (B) $\frac{4}{9}$ (C) $\frac{3}{2}$ (D) $\frac{2}{3}$
21. A particle performs SHM with a period T and amplitude a . The mean velocity of the particle over the time interval during which it travels a distance $a/2$ from the extreme position is
 (A) a/T (B) $2a/T$ (C) $3a/T$ (D) $a/2T$

22. Two particles execute SHM of same amplitude of 20 cm with same period along the same line about the same equilibrium position. The maximum distance between the two is 20 cm. Their phase difference in radians is
(A) $\frac{2\pi}{3}$ (B) $\frac{\pi}{2}$ (C) $\frac{\pi}{3}$ (D) $\frac{\pi}{4}$
23. Two particles are in SHM on same straight line with amplitude A and 2A and with same angular frequency ω . It is observed that when first particle is at a distance $A/\sqrt{2}$ from origin and going toward mean position, other particle is at extreme position on other side of mean position. Find phase difference between the two particles
(A) 45° (B) 90° (C) 135° (D) 180°
24. **Statement 1 :** Displacement–time equation of a particle moving along x–axis is $x=4 + 6 \sin \omega t$. Under this situation, motion of particle is not simple harmonic.
and
Statement 2: $\frac{d^2x}{dt^2}$ for the given equation is not proportional to $-x$.
(A) Statement–1 is True, Statement–2 is True ; Statement–2 is a correct explanation for Statement–1.
(B) Statement–1 is True, Statement–2 is True ; Statement–2 is not a correct explanation for Statement–1.
(C) Statement–1 is True, Statement–2 is False.
(D) Statement–1 is False, Statement–2 is True.
25. 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 $v^2 = 108 - 9x^2$ (all quantities in S.I. unit). Then
(A) The motion is uniformly accelerated along the straight line
(B) The magnitude of the acceleration at a distance 3 cm from the fixed point is 0.27 m/s^2 .
(C) The motion is simple harmonic about $x = \sqrt{12} \text{ m}$.
(D) The maximum displacement from the fixed point is 4 cm.

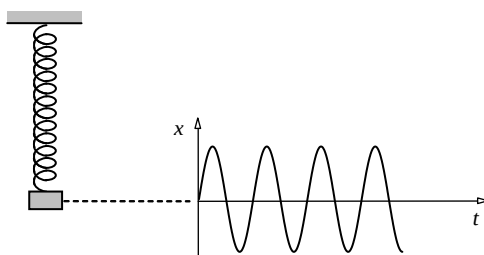
MULTIPLE CORRECT TYPE QUESTIONS

26. The rotation of earth about its axis is
(A) periodic motion. (B) simple harmonic motion.
(C) periodic but not simple harmonic motion. (D) non-periodic motion.
27. Two particles are in SHM with same amplitude A and same angular frequency ω . At time $t=0$, one is at $x = +\frac{A}{2}$ and other is at $x = -\frac{A}{2}$. Both are moving in same direction.
(A) Phase difference between the two particle is $\frac{\pi}{3}$
(B) Phase difference between the two particle is $\frac{2\pi}{3}$
(C) They will collide after time $t = \frac{\pi}{2\omega}$ (D) They will collide after time $t = \frac{3\pi}{\omega}$
28. A particle moves in x-y plane according to equation $\vec{S} = (2\hat{i} + \hat{j}) \cos \omega t$. The motion of particle is
(A) On straight line (B) On ellipse (C) Periodic (D) SHM

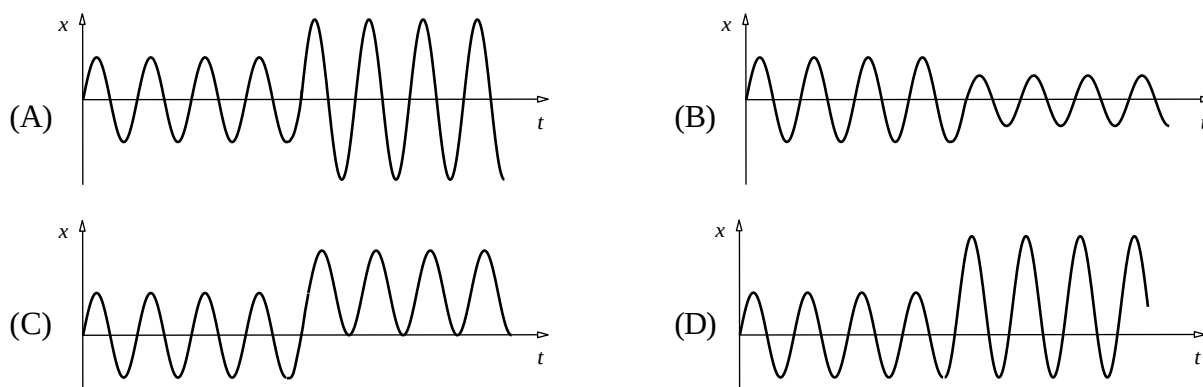
29. A particle is executing SHM with amplitude A , time period T , maximum acceleration a_0 and maximum velocity v_0 . It starts from mean position at $t=0$ and at time t , it has the displacement $A/2$, acceleration a and velocity v then
 (A) $t = T/12$ (B) $a = a_0/2$ (C) $v = v_0/2$ (D) $t = T/8$

ENERGY OF SHM

30. In the figure is shown a spring-mass system oscillating in uniform gravity. If we neglect all dissipative forces, it will keep on oscillating endlessly with constant amplitude and frequency. Accompanying graph shows how displacement x of the block from the equilibrium position varies with time t .



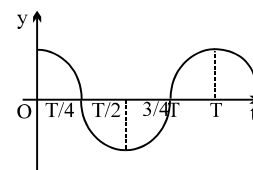
Now at a certain instant $t = t_0$ when the block reaches its lowest position, gravity is switched off by some unknown mechanism. Which of the following graphs would correctly describes the changes taking place due to switching off the gravity?



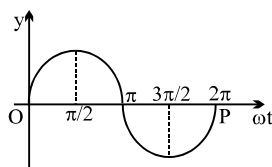
31. Potential energy of a particle is given as $U(x) = 2x^3 - 9x^2 + 12x$. If the motion of a particle is S.H.M. & potential energy in joule and x (in m). Then find the approx potential energy of the particle :
 (A) -36 J (B) 4 J (C) 5 J (D) None of these
32. If the potential energy of a harmonic oscillator of mass 2 kg on its equilibrium position is 5 joules and the total energy is 9 joules when the amplitude is one meter the period of the oscillator (in sec) is:
 (A) 1.5 (B) 3.14 (C) 6.28 (D) 4.67
33. A plank with a small block on top of it is under going vertical SHM. Its period is 2 sec. The minimum amplitude at which the block will separate from plank is :
 (A) $\frac{10}{\pi^2}$ (B) $\frac{\pi^2}{10}$ (C) $\frac{20}{\pi^2}$ (D) $\frac{\pi}{10}$
34. Two bodies P & Q of equal mass are suspended from two separate massless springs of force constants k_1 and k_2 respectively. If the maximum velocity of them are equal during their motion, the ratio of amplitude of P to Q is:
 (A) $\frac{k_1}{k_2}$ (B) $\sqrt{\frac{k_2}{k_1}}$ (C) $\frac{k_2}{k_1}$ (D) $\sqrt{\frac{k_1}{k_2}}$

35. The displacement-time graph of a particle executing SHM is shown. Which of the following statements is/are true?

- (A) The velocity is maximum at $t = T/2$
(B) The acceleration is maximum at $t = T$
(C) The force is zero at $t = 3T/4$
(D) The potential energy equals the oscillation energy at $t = T/2$.



36. The graph plotted between phase angle (ϕ) and displacement of a particle from equilibrium position (y) is a sinusoidal curve as shown below. Then the best matching is



Column A

- (A) K.E. versus phase angle curve
(B) P.E. versus phase angle curve
(C) T.E. versus phase angle curve
(D) Velocity versus phase angle curve

Column B

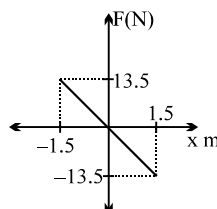
- (P)
- (Q)
- (C)
- (D)

TIME PERIOD

37. The time taken by a particle performing SHM to pass from point A to B where its velocities are same is 2 seconds. After another 2 seconds it returns to B. The time period of oscillation is (in seconds)

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

38. A particle of mass 1 kg is undergoing S.H.M., for which graph between force and displacement (from mean position) as shown. Its time period, in seconds, is:

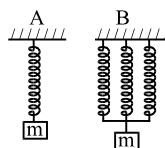


- (A) $\pi/3$ (B) $2\pi/3$ (C) $\pi/6$ (D) $3/\pi$

39. Two pendulums have time periods T and $5T/4$. They start SHM at the same time from the mean position. After how many oscillations of the smaller pendulum they will be again in the same phase:

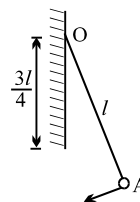
- (A) 5 (B) 4 (C) 11 (D) 9

40. The springs in fig. A and B are identical but length in A is three times each of that in B. The ratio of period T_A/T_B is



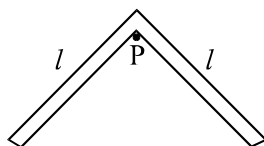
- (A) $\sqrt{3}$ (B) $1/3$ (C) 3 (D) $1/\sqrt{3}$

41. A small bob attached to a light inextensible thread of length l has a periodic time T when allowed to vibrate as a simple pendulum. The thread is now suspended from a fixed end O of a vertical rigid rod of length $\frac{3l}{4}$ (as in figure). If now the pendulum performs periodic oscillations in this arrangement, the periodic time will be



- (A) $\frac{3T}{4}$ (B) $\frac{T}{2}$ (C) T (D) $2T$

42. A system of two identical rods (L-shaped) of mass m and length l are resting on a peg P as shown in the figure. If the system is displaced in its plane by a small angle θ , find the period of oscillations:

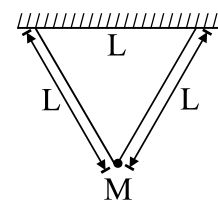


- (A) $2\pi\sqrt{\frac{\sqrt{2}l}{3g}}$ (B) $2\pi\sqrt{\frac{2\sqrt{2}l}{3g}}$ (C) $2\pi\sqrt{\frac{2l}{3g}}$ (D) $3\pi\sqrt{\frac{l}{3g}}$

43. A ring of diameter $2m$ oscillates as a compound pendulum about a horizontal axis passing through a point at its rim. It oscillates such that its centre move in a plane which is perpendicular to the plane of the ring. The equivalent length of the simple pendulum is

- (A) $2m$ (B) $4m$ (C) $1.5m$ (D) $3m$

44. A man is swinging on a swing made of 2 ropes of equal length L and in direction perpendicular to the plane of paper. The time period of the small oscillations about the mean position is



- (A) $2\pi\sqrt{\frac{L}{2g}}$ (B) $2\pi\sqrt{\frac{\sqrt{3}L}{2g}}$
(C) $2\pi\sqrt{\frac{L}{2\sqrt{3}g}}$ (D) $\pi\sqrt{\frac{L}{g}}$

45. A rod whose ends are A & B of length 25 cm is hanged in vertical plane. When hanged from point A and point B the time periods calculated are 3 sec & 4 sec respectively. Given the moment of inertia of rod about axis perpendicular to the rod is in ratio 9 : 4 at points A and B. Find the distance of the centre of mass from point A.

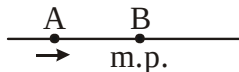
- (A) 9 cm (B) 5 cm (C) 25 cm (D) 20 cm

COMPLEX SITUATIONS

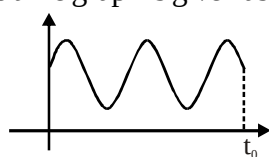
46. The amplitude of the vibrating particle due to superposition of two SHMs,
 $y_1 = \sin\left(\omega t + \frac{\pi}{3}\right)$ and $y_2 = \sin \omega t$ is
 (A) 1 (B) $\sqrt{2}$ (C) $\sqrt{3}$ (D) 2
47. Two simple harmonic motions $y_1 = A \sin \omega t$ and $y_2 = A \cos \omega t$ are superimposed on a particle of mass m . The total mechanical energy of the particle is:
 (A) $\frac{1}{2} m\omega^2 A^2$ (B) $m\omega^2 A^2$ (C) $\frac{1}{4} m\omega^2 A^2$ (D) zero
48. Equations $y = 2A \cos^2 \omega t$ and $y = A(\sin \omega t + \sqrt{3} \cos \omega t)$ represent the motion of two particles.
 (A) Only one of these is S.H.M. (B) Ratio of maximum speeds is 2 : 1
 (C) Ratio of maximum speeds is 1 : 1 (D) Ratio of maximum accelerations is 1 : 4

EXERCISE (O-2)

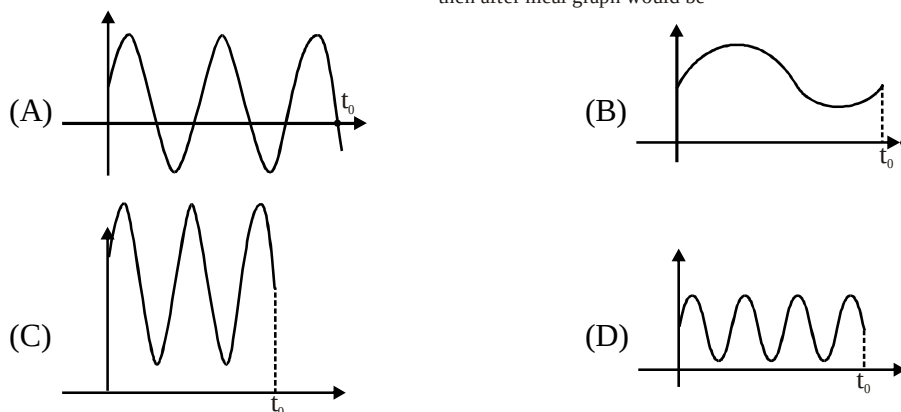
1. A particle is oscillating simple harmonically with angular frequency ω and amplitude A . It is at a point (A) at certain instant (shown in figure). At this instant it is moving towards mean position (B). It takes time t to reach mean position (B). If time period of oscillation is T , the average speed between A and B is



- (A) $\frac{A \sin \omega t}{t}$ (B) $\frac{A \cos \omega t}{t}$ (C) $\frac{A \sin \omega t}{T}$ (D) $\frac{A \cos \omega t}{T}$
2. The insulin concentration in blood increases after meals and gradually returns to basal levels during the next 1–2 hours. However, the basal insulin level is not stable. It oscillates with a regular period of 3–6 min. After meal the amplitude of these oscillations increases but the periodicity remains constant. If before meal insulin concentration vs time graph is given as shown



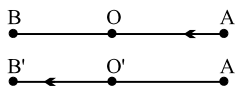
then after meal graph would be



3. The time taken by a particle performing SHM to pass from point A to B where its velocities are same is 2 seconds. After another 2 seconds it returns to B. The time period of oscillation is (in seconds)
(A) 2 (B) 8 (C) 6 (D) 4
4. Time period of a particle executing SHM is 8 sec. At $t = 0$ it is at the mean position. The ratio of the distance 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) $\sqrt{2}+1$
5. A particle executes SHM on a straight line path. The amplitude of oscillation is 2 cm. When the displacement of the particle from the mean position is 1 cm, the numerical value of magnitude of acceleration is equal to the numerical value of magnitude of velocity. The frequency of SHM (in second^{-1}) is:
(A) $2\pi\sqrt{3}$ (B) $2\pi/\sqrt{3}$ (C) $\sqrt{3}/(2\pi)$ (D) $1/(2\pi\sqrt{3})$
6. A particle executes SHM with time period T and amplitude A . The maximum possible average velocity in time $\frac{T}{4}$ is
(A) $\frac{2A}{T}$ (B) $\frac{4A}{T}$ (C) $\frac{8A}{T}$ (D) $\frac{4\sqrt{2}A}{T}$

7. A particle moves along the x-axis according to : $x = A.[1 + \sin \omega t]$. What distance does it travel between $t = 0$ and $t = 2.5\pi/\omega$?
- (A) 4A (B) 6A (C) 5A (D) None

8. Two particles undergo SHM along parallel lines with the same time period (T) and equal amplitudes. At a particular instant, one particle is at its extreme position while the other is at its mean position. They move in the same direction. They will cross each other after a further time



- (A) T/8 (B) 3T/8 (C) T/6 (D) 4T/3
9. Two particles are in SHM in a straight line about same equilibrium position. Amplitude A and time period T of both the particles are equal. At time $t=0$, one particle is at displacement $y_1 = +A$ and the other at $y_2 = -A/2$, and they are approaching towards each other. After what time they cross each other ?
- (A) T/3 (B) T/4 (C) 5T/6 (D) T/6
10. Two particles A and B perform SHM along the same straight line with the same amplitude 'a', same frequency 'f' and same equilibrium position 'O'. The greatest distance between them is found to be $3a/2$. At some instant of time they have the same displacement from mean position. What is the displacement?

- (A) $a/2$ (B) $a\sqrt{7}/4$ (C) $\sqrt{3}a/2$ (D) $3a/4$

11. Potential energy of a particle having mass 'm' is given as function of position x is U

$(x) = U_0 \left[e^{\frac{2(x-x_0)}{b}} - 2e^{\frac{(x-x_0)}{b}} \right]$. In the vicinity of equilibrium position $x = x_0$, for small displacement, then find the time period of particle.

- (A) $2\pi b \sqrt{\frac{6m}{u_0}}$ (B) $2\pi \sqrt{\frac{b \times m}{u_0}}$ (C) $2\pi b \sqrt{\frac{m}{6u_0}}$ (D) $2\pi \sqrt{\frac{b}{u_0}}$

12. A particle of mass m is executing oscillations about the origin on the x-axis. Its potential energy is $V(x) = k|x|^3$ where k is a positive constant. If the amplitude of oscillations is a, then its time period T is

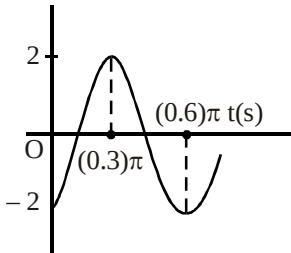
- (A) proportional to $1/\sqrt{a}$ (B) independent of a
(C) proportional to $\sqrt{a}$ (D) proportional to $a^{3/2}$

13. A wire frame in the shape of an equilateral triangle is hinged at one vertex so that it can swing freely in a vertical plane, with the plane of the Δ always remaining vertical. The side of the frame is $1/\sqrt{3}$ m. The time period in seconds of small oscillations of the frame will be

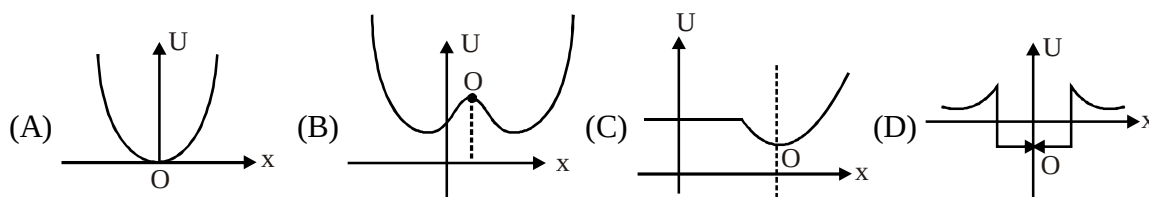
- (A) $\frac{\pi}{\sqrt{2}}$ (B) $\pi\sqrt{2}$ (C) $\frac{\pi}{\sqrt{6}}$ (D) $\frac{\pi}{\sqrt{5}}$

14. A circular disc has a tiny hole in it, at a distance z from its center. Its mass is M and radius R ($R > z$). A horizontal shaft is passed through the hole and held fixed so that the disc can freely swing in the vertical plane. For small disturbance, the disc performs SHM whose time period is minimum for z =

- (A) R/2 (B) R/3 (C) $R/\sqrt{2}$ (D) $R/\sqrt{3}$

15. 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 ω for which the mass just breaks off the plank and the moment it occurs first after $t = 0$ are given by: (y is 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) $\sqrt{2g}, \sqrt{\frac{2\pi}{3g}}$
16. For a particle acceleration is defined as $\vec{a} = \frac{-5x\hat{i}}{|x|}$ for $x \neq 0$ and $\vec{a} = 0$ for $x = 0$. If the particle is initially at rest (a, 0) what is period of motion of the particle.
- (A) $4\sqrt{2a/5}$ sec. (B) $8\sqrt{2a/5}$ sec. (C) $2\sqrt{2a/5}$ sec. (D) cannot be determined
17. Part of a simple harmonic motion is graphed in the figure, where y is the displacement from the mean position. The correct equation describing this S.H.M is
- (A) $y = 4 \cos(0.6t)$ (B) $y = 2 \sin\left(\frac{10}{3}t - \frac{\pi}{2}\right)$ (C) $y = 4 \sin\left(\frac{10}{3}t + \frac{\pi}{2}\right)$ (D) $y = 2 \cos\left(\frac{10}{3}t + \frac{\pi}{2}\right)$
- 
18. The angular frequency of a spring block system is ω_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 downwards as a positive direction, choose the wrong statement:
- (A) The amplitude of the block is $\frac{v_0}{\omega_0}$ (B) The initial phase of the block is π .
(C) The equation of motion for the block is $\frac{v_0}{\omega_0} \sin \omega_0 t$
(D) The maximum speed of the block is v_0
19. Two particles are in SHM with same angular frequency and amplitudes A and 2A respectively along same straight line with same mean position. They cross each other at position A/2 distance from mean position in opposite direction. The phase between them is :
- (A) $\frac{5\pi}{6} - \sin^{-1}\left(\frac{1}{4}\right)$ (B) $\frac{\pi}{6} - \sin^{-1}\left(\frac{1}{4}\right)$ (C) $\frac{5\pi}{6} - \cos^{-1}\left(\frac{1}{4}\right)$ (D) $\frac{\pi}{6} - \cos^{-1}\left(\frac{1}{4}\right)$
20. A particle executing a simple harmonic motion of period 2s. When it is at its extreme displacement from its mean position, it receives an additional energy equal to what it had in its mean position. Due to this, in its subsequent motion,
- (A) its amplitude will change and become equal to $\sqrt{2}$ times its previous amplitude
(B) its periodic time will become doubled i.e. 4s
(C) its potential energy will be decreased
(D) it will continue to execute simple harmonic motion of the same amplitude and period as before receiving the additional energy.
21. A particle is executing SHM of amplitude A, about the mean position $x = 0$. Which of the following cannot be a possible phase difference between the positions of the particle at $x = +A/2$ and $x = -A/\sqrt{2}$
- (A) 75° (B) 165° (C) 135° (D) 195°

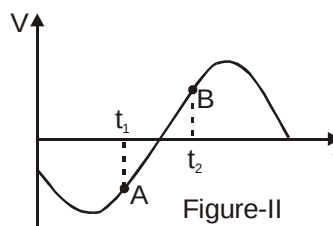
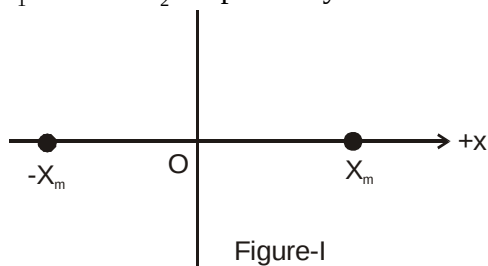
22. Potential energy vs displacement graph is given for different–different situation then for any displacement about position 'O' in which of the following motion is periodic



23. A particle free to move along the x-axis has potential energy given by $U(x) = k[1 - \exp(-x^2)]$ for $-\infty < x < +\infty$, where k is a positive constant of appropriate dimensions. Then
- (A) at point 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 $k/2$, it has its minimum kinetic energy at the origin.
 - (D) for small displacements from $x=0$, the motion is simple harmonic.

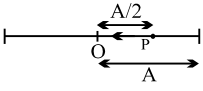
MULTIPLE CORRECT TYPE QUESTIONS

24. A necessary and sufficient condition for SHM is
- (A) constant period.
 - (B) constant acceleration.
 - (C) proportionality between acceleration and displacement from equilibrium position.
 - (D) proportionality between the restoring force and displacement from equilibrium position.
25. For a SHM with given angular frequency, two arbitrary initial conditions are necessary and sufficient to determine the motion completely. These initial conditions may be-
- (A) Amplitude and initial phase
 - (B) Amplitude and total energy of oscillation
 - (C) Initial phase and total energy of oscillation
 - (D) Initial position and initial velocity
26. A particle is executing SHM between points $-X_m$ and X_m , as shown in figure-I. The velocity $V(t)$ of the particle is partially graphed and shown in figure-II. Two points A and B corresponding to time t_1 and time t_2 respectively are marked on the $V(t)$ curve.



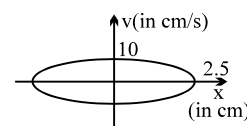
- (A) At time t_1 , it is going towards X_m .
 - (B) At time t_1 , its speed is decreasing.
 - (C) At time t_2 , its position lies in between $-X_m$ and O.
 - (D) The phase difference $\Delta\phi$ between points A and B must be expressed as $90^\circ < \Delta\phi < 180^\circ$.
27. For a body executing SHM with amplitudes A, time period T, max velocity $v_{\max}$ and phase constant zero, which of the following statements are correct?
- (A) At $y = (A/2)$, $v > (v_{\max}/2)$
 - (B) $v = (v_{\max}/2)$ for $y > (A/2)$
 - (C) For $t = (T/8)$, $y > (A/2)$
 - (D) For $y = (A/2)$, $t < (T/8)$

28. The amplitude of a particle executing SHM about O is 10 cm. Then:
 (A) When the K.E. is 0.64 of its max. K.E. its displacement is 6cm from O.
 (B) When the displacement is 5 cm from O its K.E. is 0.75 of its max. P.E.
 (C) Its total energy at any point is equal to its maximum K.E.
 (D) Its velocity is half the maximum velocity when its displacement is half the maximum displacement.
29. The position vector of a particle that is moving in three dimensions is given by

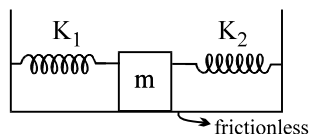
$$\vec{r} = (1 + 2 \cos 2\omega t)\hat{i} + (3 \sin^2 \omega t)\hat{j} + (3)\hat{k}$$
 in the ground frame. All units are in SI. Choose the correct statement (s) :
 (A) The particle executes SHM in the ground frame about the mean position $\left(1, \frac{3}{2}, 3\right)$
 (B) The particle executes SHM in a frame moving along the z-axis with a velocity of 3 m/s.
 (C) The amplitude of the SHM of the particle is $\frac{5}{2}$ m.
 (D) The direction of the SHM of the particle is given by the vector $\left(\frac{4}{5}\hat{i} - \frac{3}{5}\hat{j}\right)$
30. A particle starts from a point P at a distance of A/2 from the mean position O & travels towards left as shown in the figure. If the time period of SHM, executed about O is T and amplitude A then the equation of motion of particle is :
 (A) $x = A \sin \left(\frac{2\pi}{T} t + \frac{\pi}{6} \right)$ (B) $x = A \sin \left(\frac{2\pi}{T} t + \frac{5\pi}{6} \right)$ 
 (C) $x = A \cos \left(\frac{2\pi}{T} t + \frac{\pi}{6} \right)$ (D) $x = A \cos \left(\frac{2\pi}{T} t + \frac{\pi}{3} \right)$
31. A particle of mass m performs SHM along a straight line with frequency f and amplitude A.
 (A) The average kinetic energy of the particle is zero.
 (B) The average potential energy is $m \pi^2 f^2 A^2$.
 (C) The frequency of oscillation of kinetic energy is 2f.
 (D) Velocity function leads acceleration by $\pi/2$.
32. A system is oscillating with undamped simple harmonic motion. Then the
 (A) average total energy per cycle of the motion is its maximum kinetic energy.
 (B) average total energy per cycle of the motion is $\frac{1}{\sqrt{2}}$ times its maximum kinetic energy.
 (C) root mean square velocity is $\frac{1}{\sqrt{2}}$ times its maximum velocity
 (D) mean velocity is 1/2 of maximum velocity.
33. Two particles execute SHM with amplitude A and 2A and angular frequency ω and 2ω respectively. At $t = 0$ they start with some initial phase difference. At $t = \frac{2\pi}{3\omega}$ they are in same phase. Their initial phase difference is :
 (A) $\frac{\pi}{3}$ (B) $\frac{2\pi}{3}$ (C) $\frac{4\pi}{3}$ (D) π

34. A spring has natural length 40 cm and spring constant 500 N/m. A block of mass 1 kg is attached at one end of the spring and other end of the spring is attached to ceiling. The block released from the position, where the spring has length 45 cm.
- (A) the block will perform SHM of amplitude 5 cm.
 (B) the block will have maximum velocity $30\sqrt{5}$ cm/sec.
 (C) the block will have maximum acceleration 15 m/s^2
 (D) the minimum potential energy of the spring will be zero.

35. The figure shows a graph between velocity and displacement (from mean position) of a particle performing SHM:

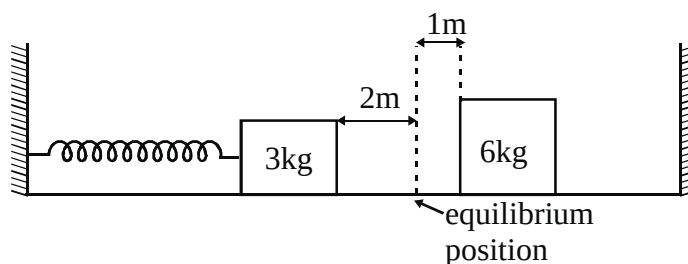


- (A) the time period of the particle is 1.57s
 (B) the maximum acceleration will be 40 cm/s^2
 (C) the velocity of particle is $2\sqrt{21}$ cm/s when it is at a distance 1 cm from the mean position.
 (D) none of these
36. Two springs with negligible masses and force constant of $K_1 = 200 \text{ Nm}^{-1}$ and $K_2 = 160 \text{ Nm}^{-1}$ are attached to the block of mass $m = 10 \text{ kg}$ as shown in the figure. Initially the block is at rest, at the equilibrium position in which both springs are neither stretched nor compressed. At time $t = 0$, a sharp impulse of 50 Ns is given to the block with a hammer.

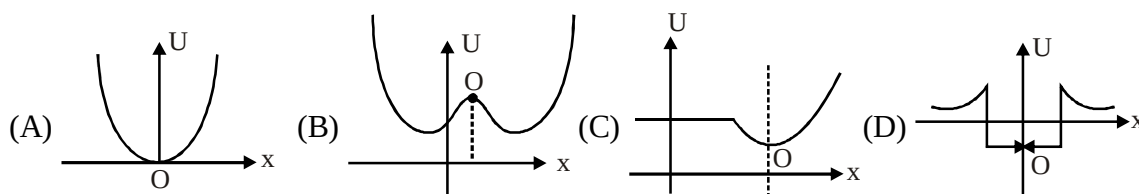


- (A) Period of oscillations for the mass m is $\frac{\pi}{3}$ s.
 (B) Maximum velocity of the mass m during its oscillation is 5 ms^{-1} .
 (C) Data are insufficient to determine maximum velocity.
 (D) Amplitude of oscillation is 0.42 m.
37. A mass of 0.2kg is attached to the lower end of a massless spring of force-constant 200 N/m, the upper end of which is fixed to a rigid support. Which of the following statements is/are true?
- (A) In equilibrium, the spring will be stretched by 1cm.
 (B) If the mass is raised till the spring is unstretched state and then released, it will go down by 2cm before moving upwards.
 (C) The frequency of oscillation will be nearly 5 Hz.
 (D) If the system is taken to the moon, the frequency of oscillation will be the same as on the earth.
38. The potential energy of a particle of mass 0.1kg, moving along x-axis, is given by $U = 5x(x-4)$ J where x is in metres. It can be concluded that
- (A) the particle is acted upon by a constant force.
 (B) the speed of the particle is maximum at $x = 2 \text{ m}$
 (C) the particle executes simple harmonic motion
 (D) the period of oscillation of the particle is $\pi/5$ s.

39. Two blocks of masses 3 kg and 6 kg rest on a horizontal smooth surface. The 3 kg block is detached to a spring with a force constant $k = 900 \text{ Nm}^{-1}$ which is compressed 2 m from beyond the equilibrium position. The 6 kg mass is at rest 1 m strikes the 6 kg mass and the two stick together.



- (A) velocity of the combined masses immediately after the collision is 10 ms^{-1}
 (B) velocity of the combined masses immediately after the collision is 5 ms^{-1}
 (C) Amplitude of the resulting oscillation is $\sqrt{2} \text{ m}$
 (D) Amplitude of the resulting oscillation is $\sqrt{5/2} \text{ m}$.
40. The equation of motion for an oscillating particle is given by $x = 3\sin(4\pi t) + 4\cos(4\pi t)$, where x is in mm and t is in second
 (A) The motion is simple harmonic
 (B) The period of oscillation is 0.5 s
 (C) The amplitude of oscillation is 5 mm
 (D) The particle starts its motion from the equilibrium
41. Potential energy vs displacement graph is given for different–different situation then for a small displacement about position 'O' in which of the following motion is S.H.M.



COMPREHENSION TYPE QUESTIONS

Paragraph for Question 42 to 44

The time–period of a simple pendulum performing simple harmonic motion, having length ℓ is given

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

This formula holds good if following conditions are satisfied.

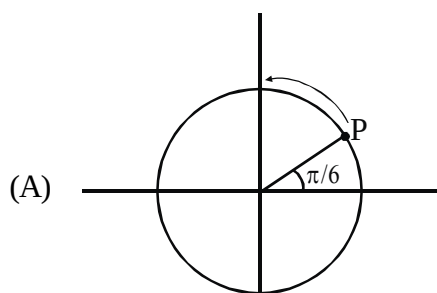
- (i) String is massless and extensible. (ii) Bob is a point mass.
 (iii) Angular displacement about mean position is very small, and
 (iv) Length of string is very small as compared to the radius of earth (R_e).

42. If the bob is a solid sphere of radius R and length of string is L , then equivalent length of pendulum will be
 (A) $\frac{2}{5} \frac{R^2}{(L+R)} + (R+L)$ (B) $\frac{2}{5} \frac{R^2}{L} + L$ (C) $R+L$ (D) L
43. If the bob is a hollow spherical shell of radius R and length string is L . The time period of pendulum is T_1 . Now bob is filled with water completely and now its time period become T_2 then T_1/T_2 is
 (A) $= 1$ (B) < 1 (C) > 1 (D) None of these

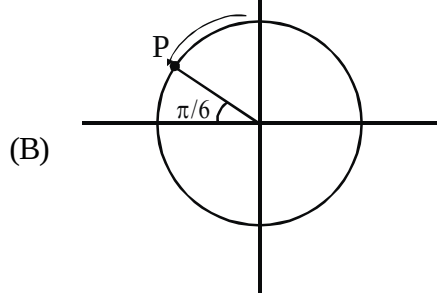
44. Now the water of bob is completely freezes into ice and this phenomena does not produce any change in L . The new time period becomes T_3 then T_2/T_3 is
 (A) = 1 (B) < 1 (C) 1 (D) None of these
45. All the phasor diagrams in column I are representing SHM, which has same time period, same amplitude and same angular frequency. The phasor moves in anticlockwise direction and projections on vertical diameter of reference circle represent SHM.

Column I

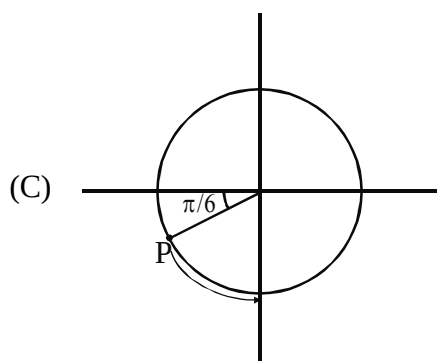
Column II



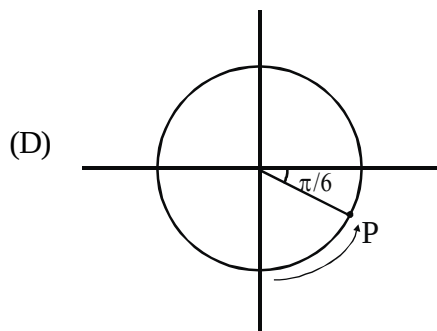
(P) Equilibrium position is reached earliest.



(Q) Acceleration is towards mean position.



(R) Speed is increasing.

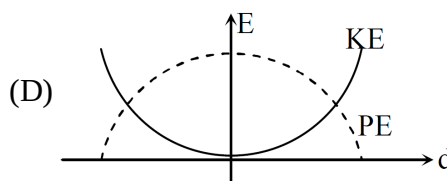
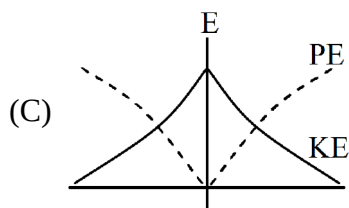
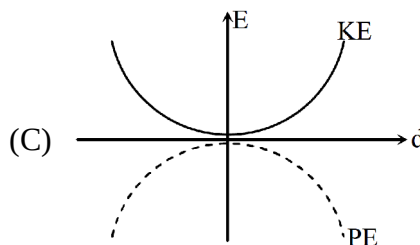
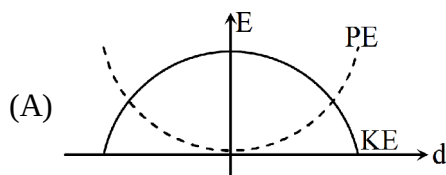


(S) Velocity will reversed its direction in $T/4$ time

(T) It crosses mean position in $T/6$ time.

EXERCISE (JM)

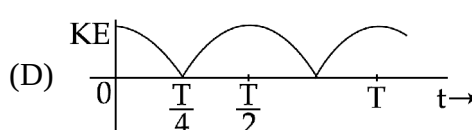
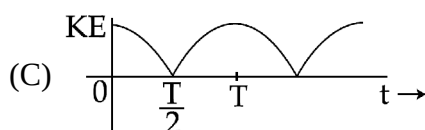
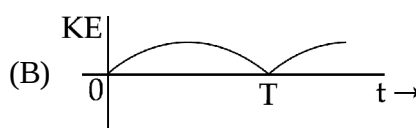
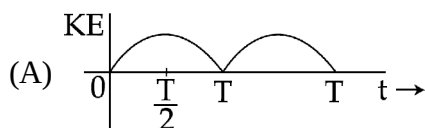
1. A particle of mass m executes simple harmonic motion with amplitude a and frequency ν . The average kinetic energy during its motion from the position of equilibrium to the end is : **[AIEEE 2007]**
 (A) $\pi^2 ma^2\nu^2$ (B) $\frac{1}{4} ma^2\nu^2$ (C) $4\pi^2 ma^2\nu^2$ (D) $2\pi^2 ma^2\nu^2$
2. 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? **[AIEEE 2009]**
 (A) $\frac{aT}{x}$ (B) $aT + 2\pi v$ (C) $\frac{aT}{v}$ (D) $a^2T^2 + 4\pi^2 v^2$
3. A mass M , attached to a horizontal spring, executes SHM with a 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 : **[AIEEE-2011]**
 (A) $\frac{M}{M+m}$ (B) $\frac{M+m}{M}$ (C) $\left(\frac{M}{M+m}\right)^{1/2}$ (D) $\left(\frac{M+m}{M}\right)^{1/2}$
4. Two particles are executing simple harmonic motion of the same amplitude A and frequency ω 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 : **[AIEEE-2011]**
 (A) $\frac{\pi}{2}$ (B) $\frac{\pi}{3}$ (C) $\frac{\pi}{4}$ (D) $\frac{\pi}{6}$
5. A particle moves with simple harmonic motion in a straight line. In first τ s, after starting from rest it travels a distance a , and in next τ s it travels $2a$, in same direction, then : **[JEE MAIN 2014]**
 (A) amplitude of motion is $3a$ (B) time period of oscillations is 8τ
 (C) amplitude of motion is $4a$ (D) time period of oscillations is 6τ
6. 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 ? **[JEE MAIN 2015]**
(Graphs are schematic and not drawn to scale)



7. 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 : **[JEE MAIN 2016]**

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

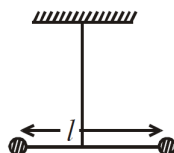
8. A particle is executing simple harmonic motion with a time period T . At time $t = 0$, it is at its position of equilibrium. The kinetic energy - time graph of the particle will look like : **[JEE MAIN 2017]**



9. A silver atom in a solid oscillates in simple harmonic motion in some direction with a frequency of 10^{12} /sec. What is the force constant of the bonds connecting one atom with the other? (Mol. wt. of silver = 108 and avogadro number = 6.02×10^{23} gm mole $^{-1}$) **[JEE MAIN 2018]**

(A) 5.5 N/m (B) 6.4 N/m (C) 7.1 N/m (D) 2.2 N/m

10. 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 θ . If the rod is rotated by θ_0 and released, the tension in it when it passes through its mean position will be: **[JEE Main-2019]**



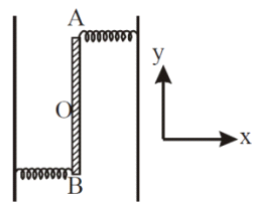
(1) $\frac{3k\theta_0^2}{l}$ (2) $\frac{k\theta_0^2}{2l}$ (3) $\frac{2k\theta_0^2}{l}$ (4) $\frac{k\theta_0^2}{l}$

11. 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 ' $L/2$ ' from its centre on both sides, it reduces the oscillation frequency by 20%. The value of ratio m/M is close to: **[JEE Main-2019]**

(1) 0.17 (2) 0.77 (3) 0.57 (4) 0.37

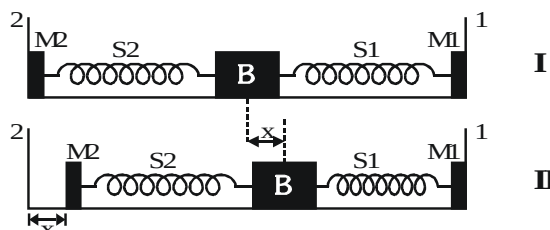
12. A particle is executing simple harmonic motion (SHM) of amplitude A , along the x -axis, about $x = 0$. When its potential Energy (PE) equals kinetic energy (KE), the position of the particle will be: **[JEE Main-2019]**

(1) $\frac{A}{2\sqrt{2}}$ (2) A (3) $\frac{A}{2}$ (4) $\frac{A}{\sqrt{2}}$

13. 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 ω . If the radius of the bottle is 2.5 cm then ω close to :
(density of water = 10^3 kg/m^3) [JEE Main-2019]
(1) 2.50 rad s^{-1} (2) 1.25 rad s^{-1} (3) 3.75 rad s^{-1} (4) 5.00 rad s^{-1}
14. 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 : [JEE Main-2019]
(1) $\frac{4\pi}{3}$ (2) $\frac{8\pi}{3}$ (3) $\frac{7}{3}\pi$ (4) $\frac{3}{8}\pi$
15. A particle undergoing simple harmonic motion has time dependent displacement given by $x(t) = A \sin \frac{\pi t}{90}$. The ratio of kinetic to potential energy of this particle at $t = 210 \text{ s}$ will be : [JEE Main-2019]
(1) 1 (2) $\frac{1}{9}$ (3) 3 (4) 2
16. A pendulum is executing simple harmonic motion and its maximum kinetic energy is K_1 . If the length of the pendulum is doubled and it performs simple harmonic motion with the same amplitude as in the first case, its maximum kinetic energy is K_2 . Then :- [JEE Main-2019]
(1) $K_2 = \frac{K_1}{4}$ (2) $K_2 = 2K_1$ (3) $K_2 = \frac{K_1}{2}$ (4) $K_2 = K_1$
17. A simple pendulum of length 1 m is oscillating with an angular frequency 10 rad/s . The support of the pendulum starts oscillating up and down with a small angular frequency of 1 rad/s and an amplitude of 10^{-2} m . The relative change in the angular frequency of the pendulum is best given by :- [JEE Main-2019]
(1) 10^{-5} rad/s (2) 1 rad/s (3) 10^{-1} rad/s (4) 10^{-3} rad/s
18. Two light identical springs of spring constant k are attached horizontally at the two ends of a uniform horizontal rod AB of length l 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: [JEE Main-2019]
(1) $\frac{1}{2\pi} \sqrt{\frac{2k}{m}}$ (2) $\frac{1}{2\pi} \sqrt{\frac{k}{m}}$ (3) $\frac{1}{2\pi} \sqrt{\frac{6k}{m}}$ (4) $\frac{1}{2\pi} \sqrt{\frac{3k}{m}}$
- 
19. A simple harmonic motion is represented by:
 $y = 5(\sin 3\pi t + \sqrt{3} \cos 3\pi t) \text{ cm}$
The amplitude and time period of the motion are: [JEE Main-2019]
(1) $5 \text{ cm}, \frac{3}{2} \text{ s}$ (2) $10 \text{ cm}, \frac{2}{3} \text{ s}$ (3) $10 \text{ cm}, \frac{3}{2} \text{ s}$ (4) $5 \text{ cm}, \frac{2}{3} \text{ s}$
20. A simple pendulum is being used to determine the value of gravitational acceleration g at a certain place. The length of the pendulum is 25.0 cm and a stop watch with 1 s resolution measures the time taken for 40 oscillations to be 50 s . The accuracy in g is : [JEE Main-2020]
(1) 4.40% (2) 5.40% (3) 3.40% (4) 2.40%

EXERCISE (JA)

1. A block (B) is attached to two unstretched springs S_1 and S_2 with spring constants k and $4k$, respectively (see figure I). The other ends are attached to identical supports M_1 and M_2 not attached to the walls. The springs and supports have negligible mass. There is no friction anywhere. The block B is displaced towards wall 1 by a small distance x (figure II) and released. [IIT-JEE 2008]

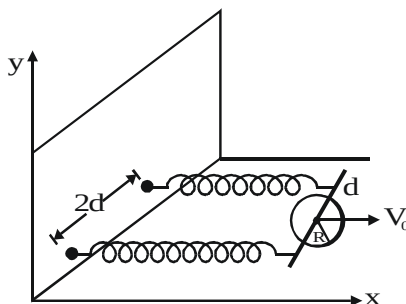


The block returns and moves a maximum distance y towards wall 2. displacements x and y are measured with respect to the equilibrium position of the block B. The ratio $\frac{y}{x}$ is

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

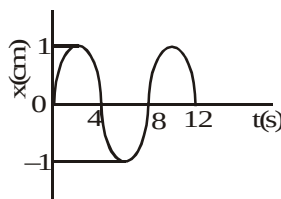
Paragraph for Q.2 to Q.4

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 μ . [IIT-JEE 2008]

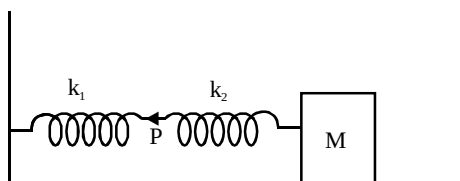


2. The net external force acting on the disk when its centre of mass is at displacement x with respect to its equilibrium position is
- (A) $-kx$ (B) $-2kx$ (C) $-\frac{2kx}{3}$ (D) $-\frac{4kx}{3}$
3. The centre of mass of the disk undergoes simple harmonic motion with angular frequency ω equal to
- (A) $\sqrt{\frac{k}{M}}$ (B) $\sqrt{\frac{2k}{M}}$ (C) $\sqrt{\frac{2k}{3M}}$ (D) $\sqrt{\frac{4k}{3M}}$
4. The maximum value of V_0 for which the disk will roll without slipping is
- (A) $\mu g \sqrt{\frac{M}{k}}$ (B) $\mu g \sqrt{\frac{M}{2k}}$ (C) $\mu g \sqrt{\frac{3M}{k}}$ (D) $\mu g \sqrt{\frac{5M}{2k}}$

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

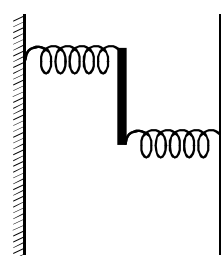


- (A) $\frac{\sqrt{3}}{32} \pi^2 \text{ cm/s}^2$ (B) $-\frac{\pi^2}{32} \text{ cm/s}^2$ (C) $\frac{\pi^2}{32} \text{ cm/s}^2$ (D) $-\frac{\sqrt{3}}{32} \pi^2 \text{ cm/s}^2$
6. The mass M shown in the figure oscillates in simple harmonic motion with amplitude A. The amplitude of the point P is : [IIT-JEE 2009]



- (A) $\frac{k_1 A}{k_2}$ (B) $\frac{k_2 A}{k_1}$ (C) $\frac{k_1 A}{k_1 + k_2}$ (D) $\frac{k_2 A}{k_1 + k_2}$
7. 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 constant k. The springs are fixed to rigid supports as shown in the figure, and the rod is free to oscillate in the horizontal plane. The rod is gently pushed through a small angle θ in one direction and released. The frequency of oscillation is : [IIT-JEE 2009]

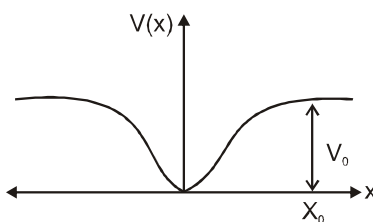
- (A) $\frac{1}{2\pi} \sqrt{\frac{2k}{M}}$ (B) $\frac{1}{2\pi} \sqrt{\frac{k}{M}}$
(C) $\frac{1}{2\pi} \sqrt{\frac{6k}{M}}$ (D) $\frac{1}{2\pi} \sqrt{\frac{24k}{M}}$



Paragraph for Q.8 to Q.10

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 $|x| \geq X_0$ (see figure) [IIT-JEE 2010]

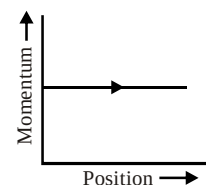


8. If the total energy of the particle is E , it will perform periodic motion only if :
 (A) $E < 0$ (B) $E > 0$ (C) $V_0 > E > 0$ (D) $E > V_0$
9. For periodic motion of small amplitude A , the time period T of this particle is proportional to :
 (A) $A\sqrt{\frac{m}{\alpha}}$ (B) $\frac{1}{A}\sqrt{\frac{m}{\alpha}}$ (C) $A\sqrt{\frac{\alpha}{m}}$ (D) $\frac{1}{A}\sqrt{\frac{\alpha}{m}}$
10. 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
11. A 0.1 kg mass is suspended from a wire of negligible mass. The length of the wire is 1m and its cross-sectional area is $4.9 \times 10^{-7} \text{ m}^2$. 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 $n \times 10^9 \text{ Nm}^{-2}$, the value of n is [IIT-JEE 2010]

COMPREHENSION TYPE QUESTIONS

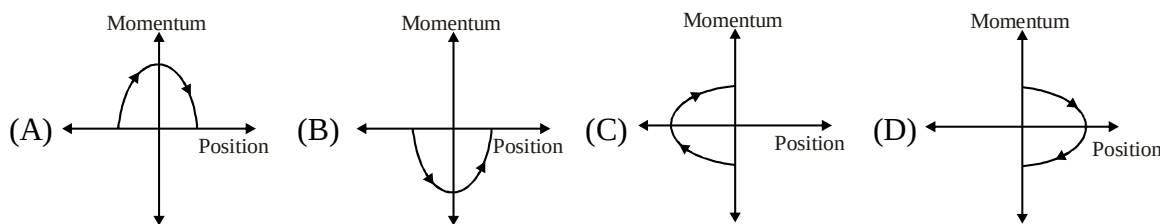
Paragraph for Q.12 to Q.14

Phase space diagrams are useful tools in analyzing 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.



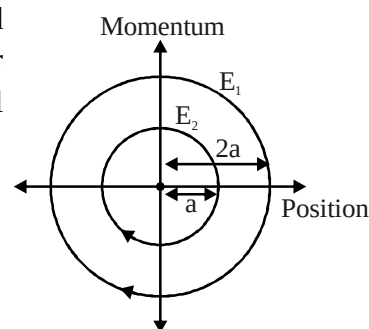
[IIT-JEE 2011]

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

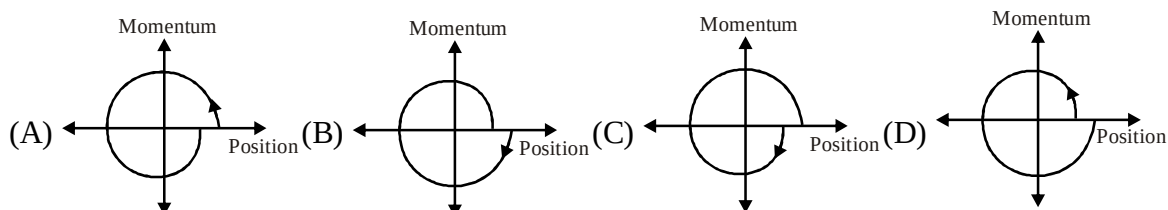
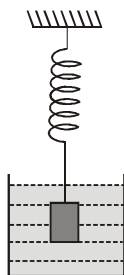


13. The phase space diagram for simple harmonic motion is a circle centered at the origin. In the figure, the two circles represent the same oscillator but for different initial conditions, and E_1 and E_2 are the total mechanical energies respectively. Then

- (A) $E_1 = \sqrt{2} E_2$
 (B) $E_1 = 2E_2$
 (C) $E_1 = 4E_2$
 (D) $E_1 = 16E_2$



14. 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 :



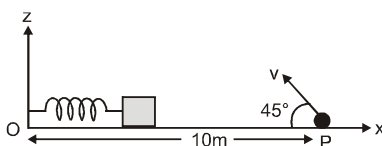
15. A point mass is subjected to two simultaneous sinusoidal displacements in x-direction, $x_1(t) = A \sin \omega t$ and $x_2(t) = A \sin \left(\omega t + \frac{2\pi}{3} \right)$. Adding a third sinusoidal displacement $x_3(t) = B \sin (\omega t + \phi)$ brings the mass to a complete rest. The values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

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

16. A metal rod of length 'L' and mass 'm' is pivoted at one end. A thin disk of mass 'M' and radius 'R' ($< L$) is attached at its center 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 center and (case B) the disc is free to rotate about its center. The rod-disk system performs SHM in vertical plane after being released from the same displaced position. Which of the following statement(s) is(are) true? [IIT-JEE 2011]

- (A) Restoring torque in case A = Restoring torque in case B
(B) Restoring torque in case A < Restoring torque in case B
(C) Angular frequency for case A > Angular frequency for case B
(D) Angular frequency for case A < Angular frequency for case B

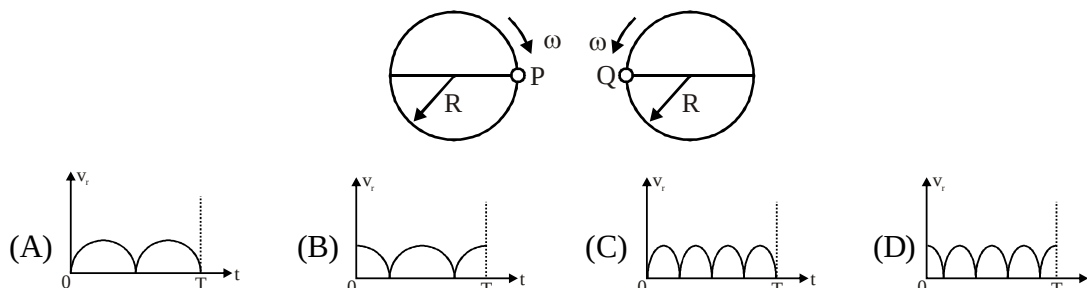
17. A small block is connected to one end of a massless spring of un-stretched length 4.9 m. The other end of the spring (see the figure) is fixed. The system lies on a horizontal frictionless surface. The block is stretched by 0.2 m and released from rest at $t = 0$. It then executes simple harmonic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



- (A) $\sqrt{50} \text{ m/s}$ (B) $\sqrt{51} \text{ m/s}$ (C) $\sqrt{52} \text{ m/s}$ (D) $\sqrt{53} \text{ m/s}$

18. Two identical discs of same radius R are rotating about their axes in opposite directions with the same constant angular speed ω . The discs are in the same horizontal plane. At time $t = 0$, the points P and Q are facing each other as shown in the figure. The relative speed between the two points P and Q is v_r . In one time period (T) of rotation of the discs, v_r as a function of time is best represented by

[IIT-JEE-2012]



19. 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 $0.5 u_0$, it collides elastically with a rigid wall. After this collision :

[IIT-JEE 2013]

(A) the speed of the particle when it returns to its equilibrium position is u_0 .

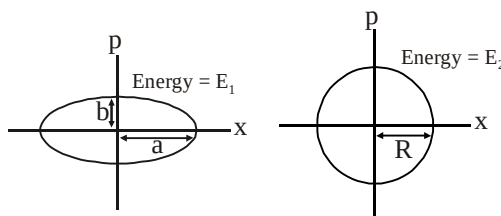
(B) the time at which the particle passes through the equilibrium position for the first time is $t = \pi \sqrt{\frac{m}{k}}$.

(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 $t = \frac{5\pi}{3} \sqrt{\frac{m}{k}}$.

20. Two independent harmonic oscillators of equal mass are oscillating about the origin with angular frequencies ω_1 and ω_2 and have total energies E_1 and E_2 , respectively. The variations of their momenta p with positions x are shown in the figures. If $\frac{a}{b} = n^2$ and $\frac{a}{R} = n$, then the correct equation (s) is (are)

[IIT-JEE -2015]



- (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) $\frac{E_1}{\omega_1} = \frac{E_2}{\omega_2}$

21. A particle of unit mass is moving along the x-axis under the influence of a force and its total energy is conserved. Four possible forms of the potential energy of the particle are given in column I (a and U_0 are constants). Match the potential energies in column I to the corresponding statement(s) in column II.

[IIT-JEE -2015]

Column I

(A) $U_1(x) = \frac{U_0}{2} \left[1 - \left(\frac{x}{a} \right)^2 \right]^2$

(B) $U_2(x) = \frac{U_0}{2} \left(\frac{x}{a} \right)^2$

(C) $U_3(x) = \frac{U_0}{2} \left(\frac{x}{a} \right)^2 \exp \left[- \left(\frac{x}{a} \right)^2 \right]$

(D) $U_4(x) = \frac{U_0}{2} \left[\frac{x}{a} - \frac{1}{3} \left(\frac{x}{a} \right)^3 \right]$

Column II

(P) The force acting on the particle is zero at $x = a$.

(Q) The force acting on the particle is zero at $x = 0$.

(R) The force acting on the particle is zero at $x = a$.

(S) The particle experiences an attractive force towards $x = 0$ in the region $|x| < a$.

(T) The particle with total energy $\frac{U_0}{4}$ can oscillate about the point $x = a$.

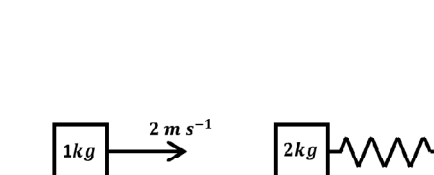
22. A block with mass M is connected by a massless spring with stiffness constant k to a rigid wall and moves without friction on a horizontal surface. The block oscillates with small amplitude A about an equilibrium position x_0 . Consider two cases: (i) when the block is at x_0 ; and (ii) when the block is at $x = x_0 + A$. In 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 ?

[IIT-JEE 2016]

- (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 decreases in both the cases

23. A spring-block system is resting on a frictionless floor as shown in the figure. The spring constant is 2.0 N m^{-1} and the mass of the block is 2.0 kg . Ignore the mass of the spring. Initially the spring is in an unstretched condition. Another block of mass 1.0 kg moving with a speed of 2.0 m s^{-1} collides elastically with the first block. The collision is such that the 2.0 kg block does not hit the wall. The distance, in metres, between the two blocks when the spring returns to its unstretched position for the first time after the collision is _____.

[JEE-Advance (P1) 2018]

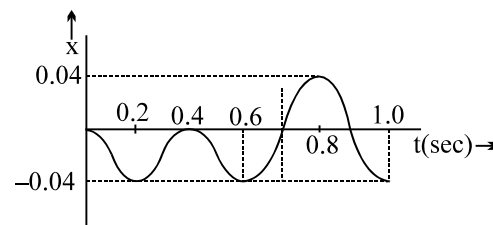


ANSWER KEY

EXERCISE (S-1)

1. 2 m/s 2. 1.8 a 3. (i) $x_0 = 2\text{m}$; (ii) $T = \sqrt{2} \text{ p sec.}$; (iii) $2\sqrt{3}$ 4. 0.06m
5. $\frac{1}{2\pi} \sqrt{\frac{\beta}{\alpha}}$ 6. $1/\sqrt{3}$ 7. 100 Nm^{-1}
8. (a) $\frac{11}{5} \text{ m}$, (b) $\frac{\pi}{5} \text{ sec.}$, (c) $x = 0.2 - \frac{11}{5} \cos \omega t$ 9. $2\pi \sqrt{\frac{17L}{18g}}$
10. (a) 2 sec, (b) $T = \frac{2}{5^{1/4}} \text{ sec}$ 11. $10/\pi \text{ Hz}$, $\frac{5\sqrt{37}}{6} \text{ cm}$
12. (a) $\frac{1}{T} = \frac{1}{2\pi} \sqrt{\frac{g}{L}}$, (b) $\frac{L}{3}$ 13. $\omega = \sqrt{\frac{k}{(m+6M)}}$
14. (a) $T = mg + mgA^2 \sin^2 \sqrt{\frac{g}{\ell}} t$; (b) $t = (2n+1) \frac{\pi}{2} \sqrt{\frac{\ell}{g}}$; $n \in \mathbb{I}$; $T_{\max} = mg + mgA^2$
15. $\frac{R}{\sqrt{2}}$

EXERCISE (S-2)

1. $y = 0.1 \sin(4t + \pi/4)$ 2. 3cm, $x = 10 - 3 \sin 5t$; $\Delta E = 0.135 \text{ J}$
3. $f = \frac{1}{\pi}$; $E = 4\pi^2 \times 10^{-5} \text{ J}$; $v = 2\pi \times 10^{-2} \text{ m/s}$ 4. (a) $\frac{\pi}{10} \text{ sec}$, (b) 4 cm, (c) 2.40 kg m/s.
5.  6. $\frac{3\sqrt{5} \text{ A}}{8}$, $\tan^{-1}\left(\frac{1}{2}\right)$
7. $\sqrt{\frac{7}{8}} \text{ A}$ 8. $a = (mg/x) \sqrt{1 + 2hx/mg}$, $\frac{1}{2} x \left(a + \frac{mg}{x} \right)^2$
9. Will increase $\sqrt{1 + \frac{2}{5} \left(\frac{R}{\ell} \right)^2}$ times. It is taken into account here that the water (when in liquid phase)
10. $\omega = \sqrt{\frac{3g}{2} \left(1 + \frac{2x\ell}{mg} \right)}$
11. (a) $T = 2\pi \sqrt{\frac{\ell}{3g}} = 1.1 \text{ s}$; (b) $E = \frac{1}{2} mg \ell \alpha^2 = 0.05 \text{ J}$
12. $\phi_m = \phi_0 \sqrt{1 + mR^2 \omega_0^2 / 2k\phi_0^2}$, $E = \frac{1}{2} mg \phi_m^2$ 13. 4.20 Ir , $T = 2\sqrt{(l/g) [\pi/2 + \sin^{-1}(\alpha/\beta)]}$
14. $\omega = \sqrt{\frac{2T_0}{m\ell}}$ 15. $\omega = \sqrt{(I_1 \omega_1^2 - I_2 \omega_2^2) / (I_1 + I_2)}$
16. $\pi \sqrt{m/k} + 2\sqrt{2E/mg^2}$ 17. $\frac{\pi}{3} \text{ s}$

EXERCISE (O-1)

- | | | | | | | |
|--------------------------------|-------|-------|-------|--------|--------|---------|
| 1. A | 2. D | 3. A | 4. D | 5. B | 6. C | 7. B |
| 8. B | 9. B | 10. A | 11. B | 12. A | 13. A | 14. A |
| 15. C | 16. C | 17. D | 18. A | 19. A | 20. C | 21. C |
| 22. C | 23. C | 24. D | 25. B | 26. AC | 27. AC | 28. ACD |
| 29. AB | 30. D | 31. B | 32. B | 33. A | 34. B | 35. BCD |
| 36. (A)→Q; (B)→P; (C)→R; (D)→S | 37. B | 38. B | 39. A | 40. C | | |
| 41. A | 42. B | 43. C | 44. B | 45. D | 46. C | 47. B |
| 48. C | | | | | | |

EXERCISE (O-2)

- | | | | | | | |
|--------|----------|--|---------|---------|---------|---------|
| 1. A | 2. C | 3. B | 4. D | 5. C | 6. D | 7. C |
| 8. B | 9. D | 10. B | 11. C | 12. A | 13. D | 14. C |
| 15. A | 16. A | 17. B | 18. B | 19. A | 20. A | 21. C |
| 22. AB | 23. D | 24. CD | 25. ACD | 26. BC | 27. ABC | 28. ABC |
| 29. AC | 30. BD | 31. BC | 32. AC | 33. BC | 34. BCD | 35. ABC |
| 36. AB | 37. ABCD | 38. BCD | 39. AC | 40. ABC | 41. ABC | 42. A |
| 43. C | 44. B | 45. (A)→QS; (B)→PQRT; (C)→QS; (D)→PQRT | | | | |

EXERCISE (JM)

- | | | | | | |
|---|-----------|--|---------|---------|---------|
| 1. (A) | 2. (A,D) | 3. (D) | 4. (B) | 5. (D) | 6. (A) |
| 7. (C) | 8. (D) | 9. (C) | 10. (4) | 11. (4) | 12. (4) |
| 13. (4) (after solving it is found $\omega = 8 \text{ rad s}^{-1}$ but JEE had given 5.00 rad s^{-1} which is closest to accurate answer. In this questions students may ask for Bonus) | | | | | |
| 14. (2) | 15. BONUS | 16. Correct Ans is (2) but JEE has given (3) | | | |
| 17. (4) | 18. (3) | 19. (2) | 20. (1) | | |

EXERCISE (JA)

- | | | | | | | |
|---|---------|----------|-------|--------|--------|-------|
| 1. C | 2. D | 3. D | 4. C | 5. D | 6. D | 7. C |
| 8. C | 9. B | 10. D | 11. 4 | 12. D | 13. C | 14. B |
| 15. B | 16. A | 17. D | 18. A | 19. AD | 20. BD | |
| 21. (A)→PQRT ; (B)→QS ; (C)→PQRS; (D)→PRT | 22. ABD | 23. 2.09 | | | | |

