PHYSICS

NCERT - FULL MARKS PHYSICS(TAMIL)

OSCILLATIONS

Examples

1. On an average, a human heart is found to beat 75 times in a minute. Calculate its frequency and period.

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2. Which of the following functions of time represent periodic and non-periodic motion?

(a) $\sin \omega t + \cos \omega t$ (b) $e - \omega t$

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3. Which of the following functions of time represent (a) simple harmonic motion and (b) periodic but not simple harmonic? Give the period for each case.

(1) $\sin \omega t - \cos \omega t$

(2) $\sin^2 \omega t$

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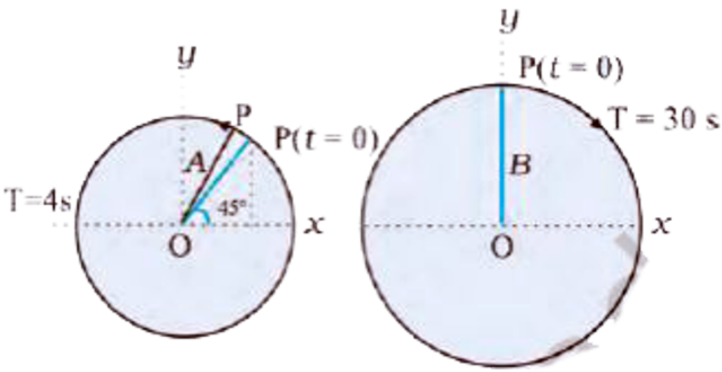
4. The figure given below depicts two circular motions. The radius of the circle, the period of revolution, the initial position and the sense of revolution are indicated in the figures. Obtain the simple harmonic motions of the x-projection of the radius vector of the rotating particle P in each case.



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5. A body oscillates with SHM according to the equation (in SI units),

$x = 5\cos[2\pi t + \pi/4]$.

At t = 1.5 s, calculate the (a) displacement, (b) speed and (c) acceleration of the body.

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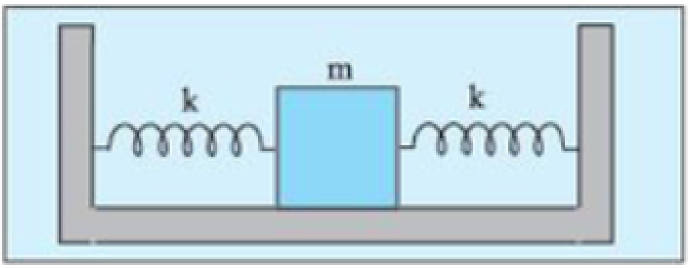
6. Two identical springs of spring constant k are attached to a block of mass m and to fixed supports as shown in Fig. 14.14. Show that when the mass is displaced from its equilibrium position on either side, it executes a simple harmonic motion. Find the period of oscillations.



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7. A block whose mass is 1 kg is fastened to a spring. The spring has a spring constant of $50Nm^{-1}$. The block is pulled to a distance x = 10 cm from its equilibrium position at x = 0 on a frictionless surface from rest at t = 0. Calculate the kinetic, potential and total energies of the block when it is 5 cm away from the mean position.

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8. A 5 kg collar is attached to a spring of spring constant 500 N m^{-1}. It slides without friction over a horizontal rod. The collar is displaced from its equilibrium position by 10.0 cm and released. Calculate

(a) the period of oscillation,

(b) the maximum speed and

(c) maximum acceleration of the collar.

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9. What is the length of a simple pendulum, which ticks seconds ?

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10. For the damped oscillator shown in Fig. 14.19, the mass m of the block is 200 g, k = 90 N m^{-1} and the damping constant b is 40 g s^{-1}. Calculate (a) the period of oscillation, (b) time taken for its amplitude of vibrations to drop to half of its initial value, and (c) the time taken for its mechanical energy to drop to half its initial value.

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Exercises

1. Which of the following examples represent periodic motion?

A. A swimmer completing one (return) trip from one bank of a river to the other and back.

B. A freely suspended bar magnet displaced from its N-S direction and released.

C. A hydrogen molecule rotating about its centre of mass.

D. An arrow released from a bow.

Answer:

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2. Which of the following examples represent (nearly) simple harmonic motion and which represent periodic but not simple harmonic motion?

A. a) the rotation of earth about its axis.

B. b) motion of an oscillating mercury column in a U-tube.

C. c) motion of a ball bearing inside a smooth curved bowl, when released from a point slightly above the lower most point.

D. d) general vibrations of a polyatomic molecule about its equilibrium position.

Answer:

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3. Fig. 14.23 depicts four x-t plots for linear motion of a particle. Which of the plots represent periodic motion? What is the period of motion (in case of periodic motion) ?

A.

B.

C.

D.

Answer:

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4. Which of the following functions of time represent (a) simple harmonic, (b) periodic but not simple harmonic, and (c) non-periodic motion? Give period for each case of periodic motion (ω is any positive constant):

(a) $\sin \omega t - \cos \omega t$

(b) $\sin^3 \omega t$

(c) $3 \cos(\pi / 4 - 2\omega t)$

(d) $\cos \omega t + \cos 3\omega t + \cos 5\omega t$

(e) $\exp(-\omega^2 t^2)$

(f) $1 + \omega t + \omega^2 t^2$

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5. A particle is in linear simple harmonic motion between two points, A and B, 10 cm apart. Take the direction from A to B as the positive direction and give the signs of velocity, acceleration and force on the particle when it is

at the end A.

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6. A particle is in linear simple harmonic motion between two points, A and B, 10 cm apart. Take the direction from A to B as the positive direction and give the signs of velocity, acceleration and force on the particle when it is

at the end B.

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7. A particle is in linear simple harmonic motion between two points, A and B, 10 cm apart. Take the direction from A to B as the positive direction and give the signs of velocity, acceleration and force on the particle when it is

at the mid-point of AB going towards A.

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8. A particle is in linear simple harmonic motion between two points, A and B, 10 cm apart. Take the direction from A to B as the positive direction and give the signs of velocity, acceleration and force on the particle when it is

at 2 cm away from B going towards A.

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9. A particle is in linear simple harmonic motion between two points, A and B, 10 cm apart. Take the direction from A to B as the positive direction and give the signs of velocity, acceleration and force on the particle when it is

at 3 cm away from A going towards B.

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10. A particle is in linear simple harmonic motion between two points, A and B, 10 cm apart. Take the direction from A to B as the positive direction and give the signs of velocity, acceleration and force on the particle when it is

at 4 cm away from B going towards A.

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11. Which of the following relationship between the acceleration a and the displacement x of a particle involve simple harmonic motion ?

A. $a = 0.7x$

B. $a = -200x^2$

C. $a = -10x^2$

D. $a = 100x^3$

Answer:

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12. The motion of a particle executing simple harmonic motion is described by the displacement function,

$x(t) = A\cos(\omega t + \phi)$.

If the initial (t = 0) position of the particle is 1 cm and its initial velocity is ω cm/s, what are its amplitude and initial phase angle ? The angular frequency of the particle is πs^{-1}. If instead of the cosine function, we choose the sine function to describe the SHM : $x = B\sin(\omega t + \alpha)$, what are the amplitude and initial phase of the particle with the above initial conditions.

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13. A spring balance has a scale that reads from 0 to 50kg the length of the scale is 20 cm . A body suspended from this balance, when displaced and released, oscillates with a period of 0.6s. Then the weight of the body will be

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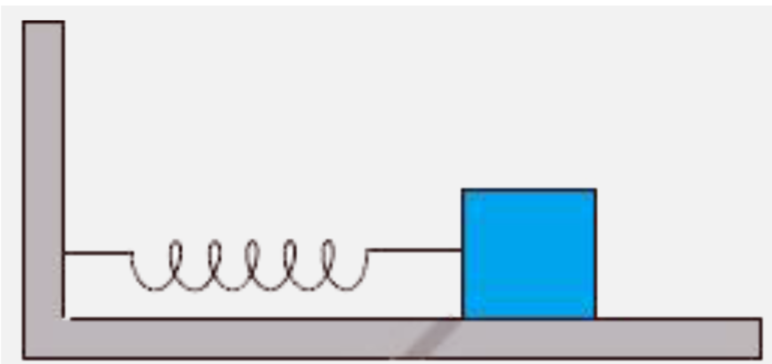
14. A spring having with a spring constant $1200 Nm^{-1}$ is mounted on a horizontal table as shown in Fig. 14.24. A mass of 3 kg is attached to the free end of the spring. The mass is then pulled sideways to a distance of 2.0 cm and released.



Determine (i) the frequency of oscillations, (ii) maximum acceleration of the mass, and (iii) the maximum speed of the mass.

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15. Let us take the position of mass when the spring is unstreched as x = 0, and the direction from left to right as the positive direction of x-axis. Give x as a function of time t for the oscillating mass if at the moment we start the stopwatch (t = 0), the mass of the object is 3 kg, spring constant is 1200 N/m and the amplitude is 2 cm.

(a) at the mean position,

(b) at the maximum stretched position, and

(c) at the maximum compressed position.

In what way do these functions for SHM differ from each other, in frequency, in amplitude or the initial phase?

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16. Figures 14.25 correspond to two circular motions. The radius of the circle, the period of revolution, the initial position, and the sense of revolution (i.e. clockwise or anti-clockwise) are indicated on each figure.

Obtain the corresponding simple harmonic motions of the x-projection of the radius vector of the revolving particle P, in each case.

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17. Plot the corresponding reference circle for each of the following simple harmonic motions. Indicate the initial (t =0) position of the particle, the radius of the circle, and the angular speed of the rotating particle. For simplicity, the sense of rotation may be fixed to be anticlockwise in every case: (x is in cm and t is in s).

A. a) $x = -2\sin(3t + \pi/3)$

B. b) $x = \cos(\pi/6 - t)$

C. c) $x = 3\sin(2\pi t + \pi/4)$

D. d)$x = 2\cos \pi t$

Answer:

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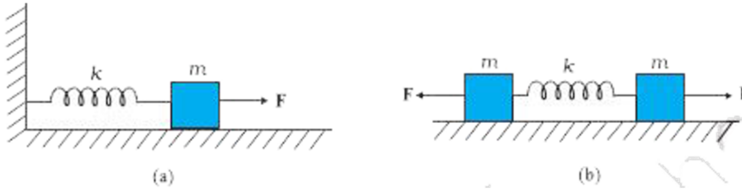
18. Figure 14.26 (a) shows a spring of force constant k clamped rigidly at one end and a mass m attached to its free end. A force F applied at the free end stretches the spring. Figure 14.26 (b) shows the same spring with both ends free and attached to a mass m at either end. Each end of the spring in Fig. 14.26(b) is stretched by the same force F.



What is the maximum extension of the spring in the two cases ?

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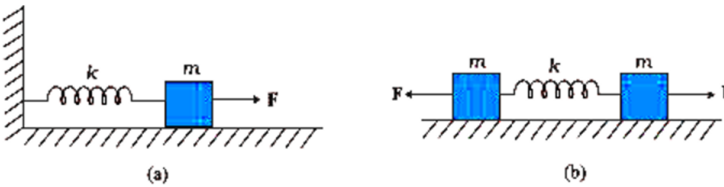
19. Figure 14.26 (a) shows a spring of force constant k clamped rigidly at one end and a mass m attached to its free end. A force F applied at the free end stretches the spring. Figure 14.26 (b) shows the same spring with both ends free and attached to a mass m at either end. Each end of the spring in Fig. 14.26(b) is stretched by the same force F.



If the mass in Fig. (a) and the two masses in Fig. (b) are released, what is the period of oscillation in each case ?

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20. The piston in the cylinder head of a locomotive has a stroke (twice the amplitude) of 1.0 m. If the piston moves with simple harmonic motion with an angular frequency of 200 rad/min, what is its maximum speed ?

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21. The acceleration dula to gravity on the surface of moon is $1.7ms^{-2}$. What is the time period of a simple pendulum on the surface of moon if its time period on the surface of earth is 3.5s ?

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22. Answer the following question :

Time period of a particle in SHM depends on the force constant k and mass m of the particle:

$T = 2\pi\sqrt{\frac{m}{k}}$. A simple pendulum executes SHM approximately. Why then is the time period of a pendulum independent of the mass of the pendulum?

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23. Answer the following question :

The motion of a simple pendulum is approximately simple harmonic for small angle oscillations. For larger angles of oscillation, a more involved analysis shows that T is greater than $2\pi\sqrt{\frac{l}{g}}$, Think of a qualitative argument to appreciate this result.

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24. A man with a writs on his hands fall from te top of a tower. Does the watch give correct time ?

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25. Answer the following question :

What is the frequency of oscillation of a simple pendulum mounted in a cabin that is freely falling under gravity ?

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26. A simple pendulum of length l and having a bob of mass M is suspended in a car. The car is moving on a circular track of radius R with a uniform speed v. If the pendulum makes small oscillations in a radial direction about its equilibrium position, what will be its time period ?

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27. A cylindrical piece of cork of density of base area A and height h floats in a liquid of density p_l. The cork is depressed slightly and then released. Show that the cork oscillates up and down simple harmonically with a period

$$T = 2\pi\sqrt{\frac{hp}{p_1 g}}$$

where p is the density of cork. (Ignore damping due to viscosity of the liquid).

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28. One end of a U-tube containing mercury is connected to a suction pump and the other end to atmosphere. A small pressure difference is maintained between the two columns. Show that, when the suction pump is removed, the column of mercury in the U-tube executes simple harmonic motion.

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Additional Exercises

1. An air chamber of volume V has a neck area of cross section a into which a ball of mass m just fits and can move up and down without any friction (Fig.14.27). Show that when the ball is pressed down a little and released , it executes SHM. Obtain an expression for the time period of oscillations assuming pressure-volume variations of air to be isothermal [see Fig. 14.27].

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2. You are riding in an automobile of mass 3000 kg. Assuming that you are examining the oscillation characteristics of its suspension system. The suspension sags 15 cm when the entire automobile is placed on it. Also, the amplitude of oscillation decreases by 50% during one complete oscillation. Estimate the values of (a) the spring constant k and (b) the damping constant b for the spring and shock absorber system of one wheel, assuming that each wheel supports 750 kg.

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3. Show that for a particle executing simple harmonic motion the average value of kinetic energy is equal to the average value of potential energy.

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4. A circular disc of mass 10 kg is suspended by a wire attached to its centre. The wire is twisted by rotating the disc and released. The period of torsional oscillations is found to be

1.5 s. The radius of the disc is 15 cm. Determine the torsional spring constant of the wire. (Torsional spring constant a is defined by the relation $J = -\alpha\theta$, where J is the restoring couple and q the angle of twist).

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5. A body describes simple harmonic motion with an amplitude of 5 cm and a period of 0.2 s. Find the acceleration and velocity of the body when the displacement is (a) 5 cm (b) 3 cm (c) 0 cm.

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6. A mass attached to a spring is free to oscillate, with angular velocity ω, in a horizontal plane without friction or damping. It is pulled to a distance x_0 and pushed towards the centre with a velocity v_0 at time t = 0. Determine the amplitude of the resulting oscillations in terms of the parameters ω, x_0

and v_0. [Hint : Start with the equation $x = a\cos(\omega t + \theta)$ and note that the initial velocity is negative.]

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Example

1. Classify the following motion as periodic and non-periodic motion?

Motion of Halley's comet.

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2. Classify the following motion as periodic and non-periodic motion?

Motion of clouds.

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3. Classify the following motion as periodic and non-periodic motion?

Moon revolving around the Earth.

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4. Which of the following functions of time represent periodic and non-periodic motion?

a. sin ωt + cos ωt

b. ln ωt

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5. Which of the following represent simple harmonic motion?

(i) x = A sin ωt + B cos ωt

(ii) x = A sin ωt + B cos $2\omega t$

(iii) x = A $e^{i\omega t}$

(iv) x A ln ωt

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6. Consider a particle undergoing simple harmonic motion. The velocity of the particle at position x_1 is v_1 and velocity of the particle at position x_2 is v_2. Show that the ratio of time period and amplitude is

$$\frac{T}{A} = 2\pi\sqrt{\frac{x_2^2 - x_1^2}{v_1^2 x_2^2 - v_2^2 x_1^2}}$$

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7. A nurse measured the average heart beats of a patient and reported to the doctor in terms of time period as 0.8 s. Express the heart beat of the patient in terms of number of beats measured per minute.

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8. Calculate the amplitude, angular frequency, frequency, time period and initial phase for the simple harmonic oscillation given below

$y = 0.3 \sin(40\pi t + 1.1)$

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9. Calculate the amplitude, angular frequency, frequency, time period and initial phase for the simple harmonic oscillation given below

$y = 2 \cos(\pi t)$

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10. Calculate the amplitude, angular frequency, frequency, time period and initial phase for the simple harmonic oscillation given below

$y = 3\sin(2\pi t - 1.5)$

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11. Show that for a simple harmonic motion, the phase difference between displacement and velocity is $\frac{\pi}{2}$ radian or 90°.

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12. Show that for a simple harmonic motion, the phase difference between velocity and acceleration is $\frac{\pi}{2}$ radian or 90°.

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13. Show that for a simple harmonic motion, the phase difference between displacement and acceleration is π radian or 180°.

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14. A spring balance has a scale which ranges from 0 to 25 kg and the length of the scale is 0.25m. It is taken to an unknown planet X where the acceleration due to gravity is 11.5 ms^{-1}. Suppose a body of mass M kg is suspended in this spring and made to oscillate with a period of 0.50 s. Compute the gravitational force acting on the body.

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15. Consider two springs whose force constants are 1 N m^{-1} and 2 N m^{-1} which are connected in series. Calculate the effective spring constant (k_s) and comment on k_s.

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16. Consider two springs with force constants 1 N m^{-1} and 2 N m^{-1} connected in parallel. Calculate the effective spring constant (k_p) and comment on k_p.

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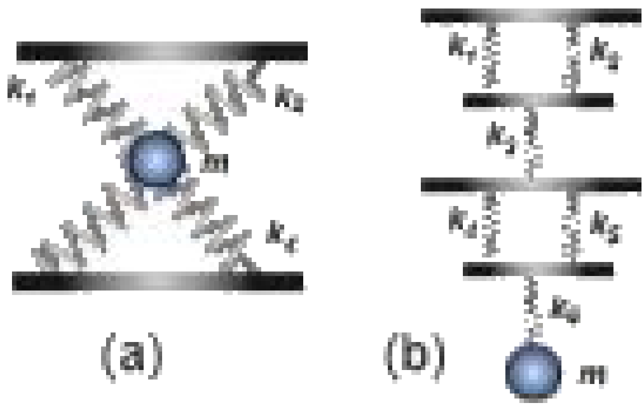
17. Calculate the equivalent spring constant for the following systems and also compute if all the spring constants are equal:



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18. A mass m moves with a speed v on a horizontal smooth surface and collides with a nearly massless spring whose spring constant is k. If the mass stops after collision, compute the maximum compression of the spring.

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19. In simple pendulum experiment, we have used small angle approximation. Discuss the small angle approximation.

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20. If the length of the simple pendulum is increased by 44% from its original length, calculate the percentage increase in time period of the pendulum.

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21. Write down the kinetic energy and total energy expressions in terms of linear momentum, For one-dimensional case.

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22. Compute the position of an oscillating particle when its kinetic energy and potential energy are equal.

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Evaluation I Multiple Choice Questions

1. In a simple harmonic oscillation, the acceleration against displacement for one complete oscillation will be

A. an ellipse

B. a circle

C. a parabola

D. a straight line

Answer: D

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2. A particle executing SHM crosses points A and B with the same velocity. Having taken 3 s in passing from A to B, it returns to B after another 3 s. The time period is

A. 15 s

B. 6 s

C. 12 s

D. 9 s

Answer: C

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3. The length of a second's pendulum on the surface of the Earth is 0.9 m. The length of the same pendulum on surface of planet X such that the acceleration of the planet X is n times greater than the Earth is

A. 0.9n

B. $\frac{0.9}{n}m$

C. $0.9n^2m$

D. $\frac{0.9}{n^2}$

Answer: A

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4. A simple pendulum is suspended from the roof of a school bus which moves in a horizontal direction with an acceleration a, then the time period is

A. $T \propto \dfrac{1}{g^2 + a^2}$

B. $T \propto \dfrac{1}{\sqrt{g^2 + a^2}}$

C. $T \propto \sqrt{g^2 + a^2}$

D. $T \propto (g^2 + a^2)$

Answer: B

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5. Two bodies A and B whose masses are in the ratio 1:2 are suspended from two separate massless springs of force constants k_A and k_B respectively. If the two bodies oscillate vertically such that their maximum velocities are in the ratio 1:2, the ratio of the amplitude

A to that of B is

A. $\sqrt{\frac{k_B}{2k_A}}$

B. $\sqrt{\frac{k_B}{8k_A}}$

C. $\sqrt{\frac{2k_B}{k_A}}$

D. $\sqrt{\frac{8k_B}{2k_A}}$

Answer: B

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6. A spring is connected to a mass m suspended from it and its time period for vertical oscillation is T. The spring is now cut into two equal halves and the same mass is suspended from one of the halves. The period of vertical oscillation is

A. $T' = \sqrt{2}T$

B. $T' = \frac{T}{\sqrt{2}}$

C. $T' = \sqrt{2T}$

D. $T' = \sqrt{\frac{T}{2}}$

Answer: B

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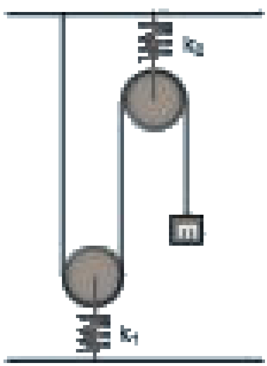
7. The time period for small vertical oscillations of block of mass m when the masses of the pulleys are negligible and spring constant k_1 and k_2 is



A. $T = 4\pi\sqrt{m\left(\frac{1}{k_1} + \frac{1}{k_2}\right)}$

B. $T = 2\pi\sqrt{m\left(\frac{1}{k_1} + \frac{1}{k_2}\right)}$

C. $T = 4\pi\sqrt{m(k_1 + k_2)}$

D. $T = 2\pi\sqrt{m(k_1 + k_2)}$

Answer: A

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8. A simple pendulum has a time period T_1. When its point of suspension is moved vertically upwards according as $y = kt^2$ where y is vertical distance covered and $k = 1 ms^{-2}$, its time period becomes T_1. Then, $\frac{T_1^2}{T_2^2}$ is (g= 10 m s^{-2})

A. $\frac{5}{6}$

B. $\frac{11}{10}$

C. $\frac{6}{5}$

D. $\frac{5}{4}$

Answer: C

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9. An ideal spring of spring constant k, is suspended from the ceiling of a room and a block of mass M is fastened to its lower end. If the block is released when the spring is un-stretched, then the maximum extension in the spring is

A. $4\frac{Mg}{k}$

B. $\frac{Mg}{k}$

C. $2\frac{Mg}{k}$

D. $\frac{Mg}{2k}$

Answer: C

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10. A pendulum is hung in a very high building oscillates to and fro motion freely like a simple harmonic oscillator. If the acceleration of the bob is 16 ms^{-2} at a distance of 4 m from the mean position, then the time period is

A. 2 s

B. 1 s

C. $2\pi s$

D. πs

Answer: D

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11. A hollow sphere is filled with water. It is hung by a long thread. As the water flows out of a hole at the bottom, the period of oscillation will

A. first increase and then decrease

B. first decrease and then increase

C. increase continuously

D. decrease continuously

Answer: A

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12. The damping force on an oscillator is directly proportional to the velocity. The units of the constant of proportionality are

A. kg m s^{-1}

B. kg m s^{-2}

C. kg s^{-1}

D. kg s

Answer: C

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13. When a damped harmonic oscillator completes 100 oscillations, its amplitude is reduced to $\frac{1}{3}$ of its initial value. What will be its amplitude when it completes 200 oscillations?

A. $\frac{1}{5}$

B. $\frac{2}{3}$

C. $\frac{1}{6}$

D. $\frac{1}{9}$

Answer: D

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14. Which of the following differential equations represents damped a harmonic oscillator?

A. $\frac{d^2y}{dt^2} + y = 0$

B. $\frac{d^2y}{dt^2} + \gamma\frac{dy}{dt} + y = 0$

C. $\frac{d^2y}{dt^2} + ky^2 = 0$

D. $\frac{dy}{dt} + y = 0$

Answer: B

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15. If the inertial mass and gravitational mass of the simple pendulum of length l are not equal, then the time period of the simple pendulum is

A. $T = 2\pi\sqrt{\frac{m_i l}{m_g g}}$

B. $T = 2\pi\sqrt{\frac{m_g l}{m_i g}}$

C. $T = 2\pi\frac{m_g}{m_i}\sqrt{\frac{l}{g}}$

D. $T = 2\pi\frac{m_i}{m_g}\sqrt{\frac{l}{g}}$

Answer: A

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Evaluation Iv Numerical Problems

1. Calculate the time period of the oscillation of a particle of mass m moving in the potential defined as $U_x = \begin{cases} \frac{1}{2}kx^2, x < 0 \\ mgx, x > 0 \end{cases}$

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2. Consider two simple harmonic motion along x and y-axis having same frequencies but different amplitudes as $x = A\sin(\omega t + \varphi)$ (along x axis) and $y = B\sin\omega t$ (along y axis). Then show that $\frac{x^2}{A^2} + \frac{y^2}{B^2} - \frac{2xy}{AB}\cos\varphi = \sin^2\varphi$ and also discuss the special cases when

a. $\varphi = 0$ b. $\varphi = \pi$ c. $\varphi = \frac{\pi}{2}$ d. $\varphi = \frac{\pi}{2}$ and A=B (e) $\varphi = \frac{\pi}{4}$

Note: when a particle is subjected to two simple harmonic motion at right angle to each other the particle may move along different paths. Such paths are called Lissajous figures.

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3. Show that for a particle executing simple harmonic motion

a. the average value of kinetic energy is equal to the average value of potential energy.

b. average potential energy = average kinetic energy = $\frac{1}{2}$ (total energy)

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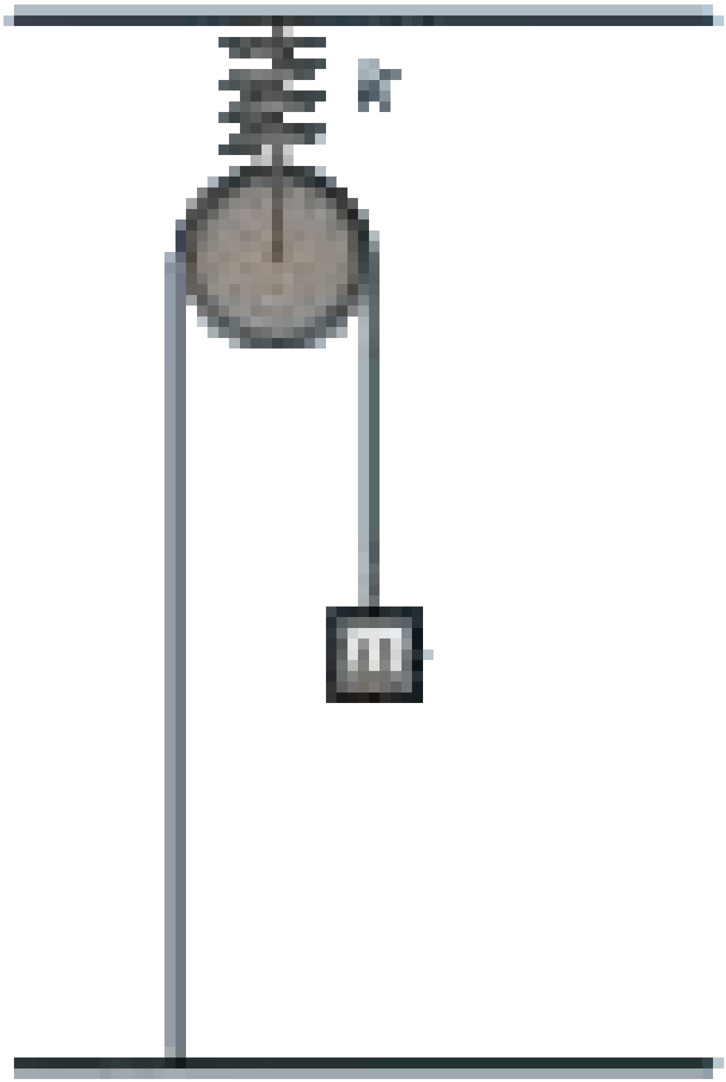
4. Compute the time period for the following system if the block of mass m is slightly displaced vertically down from its equilibrium position and then released. Assume that the pulley is light and smooth, strings and springs are light.



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