PHYSICS

NCERT - NCERT PHYSICS(TELUGU)

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 (a) periodic and (b) non-periodic motion? Give the period for each case of periodic motion [ω is any positive constant].

(i) $\sin \omega t + \cos \omega t$

(ii) $\sin \omega t + \cos 2\omega t + \sin 4\omega t$

(iii) $e^{-\omega t}$

(iv) $\log(\omega t)$

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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. the rotation of earth about its axis.

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

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

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) $\exp\left(-\omega^2 t^2\right)$

(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 B.

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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 mid-point of AB going towards A.

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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 2 cm away from B 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 4 cm away from B going towards A.

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9. Which of the following relationships 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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10. 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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11. 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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12. In Exercise 14.9, 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 is

(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?

13. 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.

14. 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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15. 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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16. 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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17. 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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18. 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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19. Answer the following question :

A man with a wristwatch on his hand falls from the top of a tower. Does the watch give correct time during the free fall ?

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20. Answer the following question :

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

21. 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 ?

22. 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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23. 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].

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 in linear SHM the average kinetic energy over a period of oscillation equals the average potential energy over the same period.

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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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