Class 11 Physics · Chapter 13: Oscillations

Answer key and marking scheme · 20 marks · about 40 minutes · based on NCERT

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1. The amplitude of oscillation of a block on a spring is doubled, the spring and block being unchanged. The period of oscillation [1]

(a) doubles (b) halves
(c) becomes √2 times (d) stays the same

Answer: (d) $T = 2\pi\sqrt{(m/k)}$ contains neither the amplitude nor the energy; the period of SHM does not depend on the amplitude.

2. The length of the string of a simple pendulum is increased by 21%. Its period of small oscillations increases by [1]

(a) 10% (b) 21%
(c) 4.4% (d) 42%

Answer: (a) $T \propto \sqrt{L}$, so $T'/T = \sqrt{1.21} = 1.1$: an increase of 10%. 21% treats T as proportional to L; 42% doubles the change instead of halving it.

3. A particle in simple harmonic motion has a period of 0.2 s. Its angular frequency is about [1]

(a) 5 rad s^{-1} (b) 1.26 rad s^{-1}
(c) 15.7 rad s^{-1} (d) 31.4 rad s^{-1}

Answer: (d) $\omega = 2\pi/T = 2\pi/0.2 = 10\pi \approx 31.4$ rad s^{-1}. 5 rad s^{-1} is the frequency 1/T, not ω; 15.7 rad s^{-1} uses π/T; 1.26 rad s^{-1} multiplies 2π by T.

4. In simple harmonic motion, the phase difference between the displacement and the acceleration of the particle is [1]

(a) π (b) π/2
(c) zero (d) π/4

Answer: (a) With $x = A\cos\omega t$, $a = -\omega^2 A\cos\omega t = \omega^2 A\cos(\omega t + \pi)$; the acceleration plot differs in phase from the displacement plot by π. π/2 is the phase difference between displacement and velocity.

5. The amplitude of oscillation of a block on a spring is doubled, the spring and block being unchanged. The total mechanical energy of the oscillator [1]

(a) doubles (b) becomes four times
(c) stays the same (d) halves

Answer: (b) $E = \frac{1}{2}kA^2$. With k unchanged, doubling A multiplies E by $2^2 = 4$.

6. The diaphragm of a loudspeaker vibrates with an angular frequency of 1000π rad s^{-1}. Find its frequency in hertz and the time it takes to complete 50 vibrations. [2]

$\nu = \omega/2\pi = 1000\pi/2\pi = 500$ Hz. $T = 1/\nu = 0.002$ s, so 50 vibrations take $50 \times 0.002 = 0.1$ s.

- $\nu = \omega/2\pi = 500$ Hz (1)
- T = 0.002 s; 50 vibrations in 0.1 s (1)

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7. A ball tied to a string is whirled in a horizontal circle of radius 30 cm at 2 revolutions per second. Parallel light from a distant lamp, travelling in the plane of the circle, falls normally on a vertical wall and throws the shadow of the ball on it. Describe the motion of the shadow, giving its amplitude and period. [2]

The shadow is the projection of the uniform circular motion on a diameter of the circle, so it executes simple harmonic motion along a horizontal line, about the point opposite the centre. Its amplitude is the radius, 30 cm, and its period is the time for one revolution, 1/2 s = 0.5 s.

- projection of uniform circular motion: SHM (1)
- amplitude 30 cm, period 0.5 s (1)

8. A child on a swing is given a single push and then left alone. Why does the swinging eventually stop, and how can the swing be kept going at the same amplitude? [2]

The swinging dies out because of damping: friction at the support and air resistance take energy out of the motion, until the swing comes to rest at its equilibrium position. It can be kept going by an external periodic agency, for example a push given once in every swing, which supplies the energy lost.

- damping by friction and air resistance removes energy; comes to rest at equilibrium (1)
- an external periodic push maintains the oscillation (1)

9. Name the forces on the bob of a simple pendulum displaced through an angle θ, resolve them along and perpendicular to the string, and state the role of each component. At which point of the swing is the tension in the string greatest, and why? [3]

Two forces act: the tension T along the string towards the support, and the weight mg vertically down, which resolves into mg cos θ along the string (away from the support) and mg sin θ perpendicular to it. T − mg cos θ provides the radial (centripetal) acceleration and has no torque about the support; mg sin θ gives the tangential acceleration and the restoring torque. $T = mg\cos\theta + mv^2/L$ is greatest at the mean position, where cos θ = 1 and the speed is greatest.

- tension and weight; mg cos θ along, mg sin θ perpendicular (1)
- T − mg cos θ radial; mg sin θ tangential, restoring torque (1)
- tension greatest at the mean position: cos θ largest and speed largest (1)

10. A block of mass 0.5 kg on a smooth horizontal floor is attached to a spring of constant 200 N m^{-1}. It passes through its mean position with a speed of 2 m s^{-1}. Find (a) the amplitude, (b) the total energy and (c) the distance from the mean position at which its speed is 1 m s^{-1}. [3]

$\omega = \sqrt{(k/m)} = \sqrt{(200/0.5)} = 20$ rad s^{-1}. (a) $v_m = \omega A$ gives $A = 2/20 = 0.1$ m. (b) $E = \tfrac{1}{2}mv_m^2 = \tfrac{1}{2} \times 0.5 \times 4 = 1.0$ J (check: $\tfrac{1}{2}kA^2 = \tfrac{1}{2} \times 200 \times 0.01 = 1$ J). (c) $v = \omega\sqrt{(A^2 - x^2)}$: $1 = 20\sqrt{(0.01 - x^2)}$, so $x^2 = 0.01 - 0.0025 = 0.0075$ and $x \approx 0.0866$ m, about 8.7 cm.

- ω = 20 rad s^{-1}, A = 0.1 m (1)
- E = 1.0 J (1)
- x ≈ 0.0866 m (1)

11. The displacement of a particle is $x(t) = A\cos(\omega t + \phi)$. Obtain its velocity and acceleration by differentiation, and state the phase of each relative to the displacement. [3]

$v = dx/dt = -\omega A\sin(\omega t + \phi) = \omega A\cos(\omega t + \phi + \pi/2)$. $a = dv/dt = -\omega^2 A\cos(\omega t + \phi) = -\omega^2 x$. So the velocity leads the displacement in phase by π/2, with amplitude ωA, and the acceleration differs from it in phase by π, with amplitude $\omega^2 A$.

- $v = -\omega A\sin(\omega t + \phi)$ (1)
- $a = -\omega^2 A\cos(\omega t + \phi) = -\omega^2 x$ (1)
- phase differences π/2 and π (1)

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