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Where Minds Pollinate

Class 12
Physics

Chapter 17

Printed Notes

National Book Foundation

FEDERAL BOARD OF INTERMEDIATE & SECONDARY EDUCATION

Class XII Physics — Domain D: Waves

Simple Harmonic Motion, Damping & Resonance

Total MCQs:	30	**Total Short Questions:**	20
Marks per MCQ:	1	**Marks per Short Q:**	3
Total Marks:	30 + 60 = 90	**SLOs Covered:**	P-12-D-01 to D-19

SECTION A: MULTIPLE CHOICE QUESTIONS (MCQs)

Each question carries 1 mark. Choose the best answer from the options given.

[P-12-D-01]

Q1. Which of the following is an example of free oscillation?

A) A pendulum swinging in vacuum
B) A forced vibration
C) Resonance
D) Damped oscillation

Answer: A) A pendulum swinging in vacuum

[P-12-D-02]

Q2. The time required to complete one full oscillation is called:

A) Frequency
B) Amplitude
C) Period
D) Angular frequency

Answer: C) Period

[P-12-D-02]

Q3. Phase difference between displacement and velocity in SHM is:

A) 0
B) π
C) $\pi/2$
D) 2π

Answer: C) $\pi/2$

[P-12-D-03]

Q4. The period of a simple pendulum of length L is given by:

A) $T = 2\pi\sqrt{(g/L)}$
B) $T = 2\pi\sqrt{(L/g)}$
C) $T = 2\pi\sqrt{(m/k)}$
D) $T = 2\pi\sqrt{(k/m)}$

Answer: B) $T = 2\pi\sqrt{(L/g)}$

[P-12-D-03]

Q5. Angular frequency ω is related to frequency f by:

A) $\omega = f/2\pi$
B) $\omega = 2\pi f$
C) $\omega = 2\pi/T^2$
D) $\omega = f^2$

Answer: B) $\omega = 2\pi f$

[P-12-D-04]

Q6. In SHM, acceleration is always directed:

A) Along the displacement
B) Opposite to displacement
C) Perpendicular to displacement
D) Along velocity

Answer: B) Opposite to displacement

[P-12-D-04]

Q7. Which equation best describes SHM?

A) $a = +\omega^2 x$
B) $a = -\omega^2 x$
C) $a = \omega^2 x^2$
D) $a = -\omega x$

Answer: B) $a = -\omega^2 x$

[P-12-D-05]

Q8. Using $a = -\omega^2 x$, if $\omega = 4$ rad/s and $x = 0.1$ m, what is the acceleration?

A) 0.4 m/s^2
B) –1.6 m/s^2
C) 1.6 m/s^2
D) –0.4 m/s^2

Answer: B) –1.6 m/s^2

[P-12-D-06]

Q9. The maximum velocity in SHM is given by:

A) $v = \omega x$■
B) $v = \omega A$
C) $v = \omega\sqrt{(A^2 - x^2)}$
D) $v = \omega^2 A$

Answer: B) $v = \omega A$

[P-12-D-06]

Q10. Velocity in SHM is zero when displacement x equals:

A) 0
B) A/2
C) A (amplitude)
D) 2A

Answer: C) A (amplitude)

[P-12-D-07]

Q11. In a displacement-time graph of SHM, the slope at any point represents:

A) Acceleration
B) Velocity
C) Displacement
D) Amplitude

Answer: B) Velocity

[P-12-D-07]

Q12. When displacement is maximum in SHM, the acceleration-time graph shows:

A) Zero
B) Maximum positive value
C) Maximum negative value
D) Minimum negative value

Answer: C) Maximum negative value

[P-12-D-08]

Q13. In SHM, when displacement is zero, kinetic energy is:

A) Zero
B) Maximum
C) Equal to potential energy
D) Half of total energy

Answer: B) Maximum

[P-12-D-08]

Q14. Total mechanical energy in SHM is:

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

Answer: A) $\frac{1}{2}m\omega^2A^2$

[P-12-D-09]

Q15. Total energy of a system in SHM equals:

A) $\frac{1}{2}m\omega^2x$■^{2}
B) $\frac{1}{2}mv^2$
C) $\frac{1}{2}kx^2$
D) Both KE and PE at mean position

Answer: A) $\frac{1}{2}m\omega^2x$■^{2}

[P-12-D-10]

Q16. A resistive force that opposes motion in an oscillating system is called:

A) Restoring force
B) Driving force
C) Damping force
D) Normal force

Answer: C) Damping force

[P-12-D-11]

Q17. In critical damping, the system:

A) Oscillates with decreasing amplitude
B) Returns to equilibrium without oscillating in minimum time
C) Oscillates forever
D) Overshoots equilibrium

Answer: B) Returns to equilibrium without oscillating in minimum time

[P-12-D-11]

Q18. Heavy damping means the system:

A) Returns quickly to equilibrium
B) Returns to equilibrium slowly without oscillating
C) Oscillates with constant amplitude
D) Resonates

Answer: B) Returns to equilibrium slowly without oscillating

[P-12-D-12]

Q19. In a displacement-time graph of light damping, the amplitude:

A) Remains constant
B) Increases with time
C) Decreases exponentially
D) Becomes negative

Answer: C) Decreases exponentially

[P-12-D-13]

Q20. Resonance occurs when the driving frequency equals:

A) Half the natural frequency
B) Twice the natural frequency
C) The natural frequency
D) Zero

Answer: C) The natural frequency

[P-12-D-13]

Q21. At resonance, the amplitude of oscillation is:

A) Zero
B) Minimum
C) Maximum
D) Equal to amplitude of driver

Answer: C) Maximum

[P-12-D-14]

Q22. A swing pushed at regular intervals is an example of:

A) Free oscillation
B) Damped oscillation
C) Forced oscillation
D) Critical damping

Answer: C) Forced oscillation

[P-12-D-15]

Q23. Car suspension systems use critical/heavy damping to:

A) Maximize oscillations
B) Minimize vibration for passenger comfort
C) Create resonance
D) Amplify road bumps

Answer: B) Minimize vibration for passenger comfort

[P-12-D-16]

Q24. The sharpness of resonance is determined by:

A) Mass only
B) Driving frequency
C) Amount of damping
D) Amplitude

Answer: C) Amount of damping

[P-12-D-16]

Q25. Less damping in a resonant system results in:

A) Broader resonance peak
B) Sharper resonance peak
C) No resonance
D) Lower natural frequency

Answer: B) Sharper resonance peak

[P-12-D-18]

Q26. Critical damping is important in car suspensions because:

A) It maximizes oscillations
B) It allows the system to return to equilibrium quickly without oscillating
C) It creates resonance
D) It reduces friction

Answer: B) It allows the system to return to equilibrium quickly without oscillating

[P-12-D-19]

Q27. Resonance is USEFUL in which of the following?

A) Airplane wings
B) Suspension bridges
C) Microwave ovens
D) Tall buildings in earthquakes

Answer: C) Microwave ovens

[P-12-D-19]

Q28. Resonance should be AVOIDED in:

A) Tuning a radio
B) MRI machines
C) Quartz clocks
D) Suspension bridges during wind

Answer: D) Suspension bridges during wind

[P-12-D-06]

Q29. The equation $v = \pm\omega\sqrt{(x\blacksquare^2 - x^2)}$ gives velocity at displacement x. When $x = 0$:

A) $v = 0$
B) $v = \pm\omega x\blacksquare$
C) $v = \omega x\blacksquare^2$
D) $v = \omega$

Answer: B) $v = \pm\omega x\blacksquare$

[P-12-D-04]

Q30. Which statement about SHM is correct?

A) Velocity is constant
B) Period depends on amplitude
C) Acceleration is proportional to displacement
D) Energy decreases with time

Answer: C) Acceleration is proportional to displacement

SECTION B: SHORT QUESTIONS

Each question carries 3 marks. Answer all questions briefly but completely.

[P-12-D-01]

SQ1. Define free oscillations and give two examples.

Model Answer: Free oscillations occur when a body oscillates without any external driving force after being displaced from equilibrium. Examples: (1) A simple pendulum swinging in vacuum, (2) A mass-spring system oscillating freely after initial displacement.

[P-12-D-02]

SQ2. Define the terms: amplitude, period, frequency, and phase difference.

Model Answer: Amplitude (A): maximum displacement from the mean position. Period (T): time for one complete oscillation. Frequency (f): number of oscillations per second ($f = 1/T$). Phase difference: the difference in phase angle between two oscillating quantities — for example, velocity leads displacement by $\pi/2$ in SHM.

[P-12-D-03]

SQ3. Write the formula for the period of SHM in terms of angular frequency.

Model Answer: $T = 2\pi/\omega$, where ω is the angular frequency. For a spring-mass system: $T = 2\pi\sqrt{(m/k)}$. For a simple pendulum: $T = 2\pi\sqrt{(L/g)}$. Both show that period is independent of amplitude.

[P-12-D-04]

SQ4. Explain why acceleration is in the opposite direction to displacement in SHM.

Model Answer: In SHM, the restoring force always acts toward the equilibrium position. Since $F = -kx$ (Hooke's Law), and $F = ma$, we get $a = -\omega^2 x$. The negative sign shows acceleration always opposes displacement, always pointing back toward the equilibrium position.

[P-12-D-05]

SQ5. Using $a = -\omega^2 x$, calculate acceleration of an object with $\omega = 5$ rad/s at $x = 0.2$ m.

Model Answer: $a = -\omega^2 x = -(5)^2 \times (0.2) = -25 \times 0.2 = -5\ m/s^2$. The magnitude is $5\ m/s^2$ and the negative sign indicates the acceleration is directed toward the equilibrium position (opposite to displacement).

[P-12-D-06]

SQ6. State the equation for velocity in SHM and explain when velocity is maximum and zero.

Model Answer: $v = \pm\omega\sqrt{(x\blacksquare^2 - x^2)}$. Velocity is maximum ($v = \pm\omega x\blacksquare$) when $x = 0$, i.e., at the mean/equilibrium position. Velocity is zero when $x = x\blacksquare$, i.e., at the extreme positions (turning points).

[P-12-D-07]

SQ7. Describe how displacement, velocity, and acceleration vary graphically in SHM.

Model Answer: All three are sinusoidal curves. Displacement: $x = x\blacksquare\sin(\omega t)$. Velocity leads displacement by 90°: $v = x\blacksquare\omega\cos(\omega t)$. Acceleration is 180° out of phase with displacement: $a = -x\blacksquare\omega^2\sin(\omega t)$. When displacement is maximum, velocity is zero and acceleration is maximum in the opposite direction.

[P-12-D-08]

SQ8. State the law of conservation of energy as applied to SHM.

Model Answer: Total mechanical energy $E = KE + PE = \frac{1}{2}m\omega^2 x\blacksquare^2$ = constant throughout motion. At mean position: all energy is kinetic (KE = max, PE = 0). At extreme positions: all energy is potential (PE = max, KE = 0). Energy continuously interconverts between kinetic and potential forms.

[P-12-D-09]

SQ9. Write the formula for total energy of a system undergoing SHM.

Model Answer: $E = \frac{1}{2}m\omega^2 x\blacksquare^2$, where m is mass, ω is angular frequency, and $x\blacksquare$ is amplitude. For a spring system, since $\omega^2 = k/m$, this becomes $E = \frac{1}{2}kx\blacksquare^2$. Total energy is proportional to the square of amplitude.

[P-12-D-10]

SQ10. Explain how a resistive force causes damping in an oscillating system.

Model Answer: A damping (resistive) force acts opposite to the direction of motion (e.g., air resistance, viscous drag). It removes energy from the system continuously, causing amplitude to decrease over time. Eventually the oscillator comes to rest at the equilibrium position.

[P-12-D-11]

SQ11. Distinguish between light, critical, and heavy damping.

Model Answer: Light damping: system oscillates with gradually and exponentially decreasing amplitude — takes long to stop. Critical damping: system returns to equilibrium in minimum time without oscillating — used in instrument pointers and door closers. Heavy (over) damping: system returns very slowly to equilibrium without oscillating — slower than critical damping.

[P-12-D-12]

SQ12. Describe displacement-time graphs for light, critical, and heavy damping.

Model Answer: Light damping: sinusoidal oscillation with exponentially decreasing amplitude envelope. Critical damping: smooth exponential decay to equilibrium in minimum time — no oscillations. Heavy damping: very slow exponential return to equilibrium, taking longer than critical damping, with no oscillations.

[P-12-D-13]

SQ13. Define resonance and state the condition for it to occur.

Model Answer: Resonance is the phenomenon in which the amplitude of an oscillating system becomes maximum when it is driven at its natural frequency. Condition: the driving frequency must equal the natural frequency of the oscillating system. At resonance, energy transfer from driver to oscillator is maximum.

[P-12-D-14]

SQ14. Give two examples each of free and forced oscillations.

Model Answer: Free oscillations: (1) Simple pendulum swinging after initial displacement, (2) Tuning fork vibrating after being struck. Forced oscillations: (1) A child's swing pushed periodically by an adult, (2) Vibration of a building structure under periodic wind force.

[P-12-D-15]

SQ15. Explain the importance of damping in a car suspension system.

Model Answer: Car suspension must be critically or heavily damped to prevent continuous bouncing after hitting a bump. Without sufficient damping, resonance could cause dangerously large vibrations. Critical damping returns the suspension to equilibrium quickly, ensuring tyre contact with the road, good handling, and passenger comfort.

[P-12-D-16]

SQ16. Explain how damping affects the sharpness of resonance.

Model Answer: Greater damping produces a broader, flatter resonance peak with lower maximum amplitude. Less damping produces a sharper, taller, narrower peak. A lightly damped system is very frequency-selective (used in radio tuners), while a heavily damped system responds over a wider frequency range.

[P-12-D-17]

SQ17. What are standing waves? Give one application involving resonance (knowledge of wave harmonic modes not required).

Model Answer: Standing waves form when two identical waves travel in opposite directions and superpose. They have fixed nodes (points of zero displacement) and antinodes (points of maximum displacement). Application: Chladni plates — sand sprinkled on a vibrating plate collects at nodes, forming beautiful geometric patterns that reveal vibration modes of the surface.

[P-12-D-18]

SQ18. Justify the importance of critical damping in a car suspension system.

Model Answer: Critical damping is optimal for car suspensions because it allows the system to return to its rest position in the shortest possible time without overshooting or oscillating. This maintains tyre contact with the road at all times, prevents dangerous resonance build-up over rough roads, and provides the most comfortable and safe ride for passengers.

[P-12-D-19]

SQ19. Give two circumstances where resonance is useful and two where it should be avoided.

Model Answer: Useful: (1) Microwave ovens — microwaves at the natural frequency of water molecules cause efficient heating of food. (2) Radio/TV tuning — LC circuits resonate at specific frequencies to select stations. Must be avoided: (1) Suspension bridges — Tacoma Narrows Bridge (1940) collapsed due to wind-induced resonance. (2) Airplane wings — aerodynamic flutter at resonance frequency can cause structural failure.

[P-12-D-13]

SQ20. A mass-spring system has a natural frequency of 5 Hz. At what driving frequency will resonance occur, and what happens to amplitude?

Model Answer: Resonance will occur at a driving frequency of 5 Hz (equal to the natural frequency). At this frequency, energy transfer from the driver to the oscillator is most efficient. The amplitude becomes maximum — theoretically infinite in the absence of damping, but in practice limited to a large finite value by damping present in the system.

All questions are aligned to FBISE SLOs for Domain D: Waves (Simple Harmonic Motion, Damping & Resonance) — Class XII Physics