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Comprehensive Master Notes: Chapter 07

Advanced Oscillations & Simple Harmonic Motion: Detailed Theoretical
Breakdown, Derivations, Energy Conservation & Board Numericals.

Chapter Outline & Core Objectives

01. Kinematics of SHM

Defining periodic motion, restoring forces, displacement, velocity, and acceleration relations.

02. Mechanical Systems

Detailed analysis of mass-spring systems, simple pendulums, and energy conservation proofs.

03. Damped & Resonance

Energy dissipation in damped oscillators, forced oscillations, and resonance phenomena.

Section 7.1: Principles of SHM

Restoring Force Law

Acceleration is directly proportional to displacement and always directed towards equilibrium: $a = -\omega^2 x$.

Phase & Amplitude (x_0)

Maximum displacement is amplitude; general displacement equation is $x(t) = x_0 \sin(\omega t + \phi)$.



Defining Characteristics

Isochronous oscillations where total mechanical energy remains conserved in absence of friction.

Section 7.2: Mass–Spring System Derivation

Mathematical Proof of Period for Elastic Spring

Step 1: Hooke's Law restoring force: $F = -kx$.

Step 2: Newton's Second Law: $F = ma = -kx \Rightarrow a = -\frac{k}{m}x$.

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Time period depends exclusively on oscillating mass (m) and spring constant (k).

Section 7.3: The Simple Pendulum

1 Restoring Force Component

Tangential component of gravitational weight provides restoring force: $F_t = -mg\sin\theta$.

2 Small Angle Approximation

For small angles ($\theta < 10^\circ$), $\sin\theta \approx \theta = x / l$, establishing true SHM.

3 Pendulum Formula

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

Section 7.4: Energy Conservation in SHM

Kinetic Energy (K)

Maximum at mean position ($x = 0$): $K_{\max} = \frac{1}{2}kx_0^2$.

Potential Energy (U)

Maximum at extreme positions ($x = \pm x_0$): $U_{\max} = \frac{1}{2}kx_0^2$.

Total Mechanical Energy

Sum of kinetic and potential energy remains constant throughout oscillation cycle.

$$E = K + U = \frac{1}{2}kx_0^2 = \text{constant}$$

Section 7.5: Numerical & Exam Review

Solved Numerical Example

Find the length of a simple pendulum having a period of 2.0 seconds at a location where $g = 9.8 \text{ m/s}^2$.

Solution: $T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow l = \frac{T^2 g}{4\pi^2}$

$$l = \frac{(2.0)^2 \times 9.8}{4 \times (3.14)^2}$$

Result: $l = 0.993 \text{ m}$

Top Board MCQs & Short Qs

- Define second's pendulum and state its period.
- Why is acceleration maximum at extreme positions in SHM?
- Total energy of SHM is proportional to square of amplitude (x_0^2).

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Chapter 07 Mastery Achieved

Review complete. Prepare your queries for the upcoming doubt-clearing session.

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