CHAPTER-13: OSCILLATIONS

Part–1: Simple Harmonic Motion (SHM) – Basic Formulae

1. Periodic Motion

A motion which repeats itself after equal intervals of time is called **Periodic Motion**.

---

2. Oscillatory Motion

A body moving to and fro about its mean position repeatedly is said to perform **Oscillatory Motion**.

---

3. Simple Harmonic Motion (SHM)

A motion in which the restoring force (or acceleration) is directly proportional to the displacement from the mean position and always directed towards the mean position. Mathematically,

$$\boxed{F \propto -x}$$

Or

$$\boxed{F = -kx}$$

---

4. Restoring Force

According to Hooke's Law,

$$\boxed{F = -kx}$$

Where

- k = Force Constant
- x = Displacement

---

5. Acceleration in SHM

Using Newton's Second Law,

$$\boxed{a = -\omega^2 x}$$

This is the **fundamental equation of SHM**.

---

6. Displacement Equation

$$\boxed{x = A\sin(\omega t + \phi)}$$

Or

$$\boxed{x = A\cos(\omega t + \phi)}$$

Where

- A = Amplitude
- ω = Angular Frequency
- ϕ = Initial Phase

---

7. Amplitude
Maximum displacement from the mean position.
Symbol: A

8. Angular Frequency

$$\boxed{\omega = \frac{2\pi}{T}}$$

Also,

$$\boxed{\omega = 2\pi f}$$

Unit: rad/s

9. Time Period
Time taken for one complete oscillation.

$$\boxed{T = \frac{2\pi}{\omega}}$$

Unit: second

10. Frequency
Number of oscillations per second.

$$\boxed{f = \frac{1}{T}}$$

Unit: Hertz(Hz)

11. Phase
Phase at any instant

$$\boxed{\theta = \omega t + \phi}$$

12. Relation between Frequency and Angular Frequency

$$\boxed{\omega = 2\pi f}$$

Part–2 : Velocity • Energy • Spring–Mass System • Simple Pendulum

13. Velocity in SHM
Velocity is the rate of change of displacement.

$$\boxed{v = \omega\sqrt{A^2 - x^2}}$$

Also,

$$\boxed{v = \pm\omega\sqrt{A^2 - x^2}}$$

14. Maximum Velocity

At Mean Position (x = 0)

$$\boxed{v_{max} = A\omega}$$

15. Acceleration in SHM

$$\boxed{a = -\omega^2 x}$$

16. Maximum Acceleration

At Extreme Position

$$\boxed{a_{max} = A\omega^2}$$

17. Kinetic Energy in SHM

$$\boxed{KE = \frac{1}{2}m\omega^2(A^2 - x^2)}$$

18. Potential Energy in SHM

$$\boxed{PE = \frac{1}{2}m\omega^2 x^2}$$

19. Total Energy

Total Mechanical Energy remains constant.

$$\boxed{E = \frac{1}{2}m\omega^2 A^2}$$

Also,

$$\boxed{E = KE + PE}$$

20. Spring–Mass System

Time Period

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

Angular Frequency

$$\boxed{\omega = \sqrt{\frac{k}{m}}}$$

Frequency

$$\boxed{f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}}$$

---

21. Simple Pendulum

Time Period

$$\boxed{T = 2\pi\sqrt{\frac{L}{g}}}$$

Frequency

$$\boxed{f = \frac{1}{2\pi}\sqrt{\frac{g}{L}}}$$

---

22. Conditions for Simple Pendulum Formula

The formula $T = 2\pi\sqrt{\frac{L}{g}}$

is valid only if

- Oscillations are small.
- String is massless.
- Bob is treated as a point mass.
- Air resistance is neglected.

---

23. Energy Variation

At Mean Position

- Velocity = Maximum
- Kinetic Energy = Maximum
- Potential Energy = Zero

At Extreme Position

- Velocity = Zero
- Potential Energy = Maximum
- Kinetic Energy = Zero

Exam Tips

□ SHM Important Formula

$$\boxed{a = -\omega^2 x}$$

□ Negative Sign→Acceleration Towrads Mean Position

□ If Time Period given, then find ω

□ Total Energy→ **Constant**

□ Mean Position→**Speed greatest**

□ Extreme Position →**Acceleration greatest**

□ Simple Pendulum→Time Period depends on **Mass**
