FREE NOTES · NCERT + JEE/NEET LEVEL

Oscillations

Periodic motion, SHM ka equation, velocity, acceleration, phase, SHM ki energy, spring-mass system, simple pendulum aur damped/forced oscillations. Graphs aur solved numericals ke saath.

01 Periodic & oscillatory motion
02 Simple harmonic motion (SHM)
03 Displacement, velocity, acceleration
04 SHM aur uniform circular motion
05 Force law
06 Energy in SHM
07 Spring-mass system
08 Simple pendulum
09 Damped & forced oscillations
10 JEE Extra + Tricks
11 Solved numericals (g = 10 m/s², π² ≈ 10)
12 Common mistakes
13 Formula sheet
14 Practice questions
15 Quick revision: exam se pehle 5 minute

01 Periodic & oscillatory motion

- **Periodic:** ek fixed time ke baad khud ko dohrata hai (Earth ka ghoomna, ghadi ki suiyan).
- **Oscillatory:** periodic + ek **mean position** ke aage-peeche (jhoola, pendulum, guitar ki taar).

Har oscillatory motion periodic hai, par har periodic motion oscillatory nahi (Earth ka chakkar oscillation nahi).

Time period T: ek poore oscillation ka time (s)

Frequency $\nu = 1/T$ (Hz)

Angular frequency $\omega = 2\pi/T = 2\pi\nu$ (rad/s)

02 Simple harmonic motion (SHM)

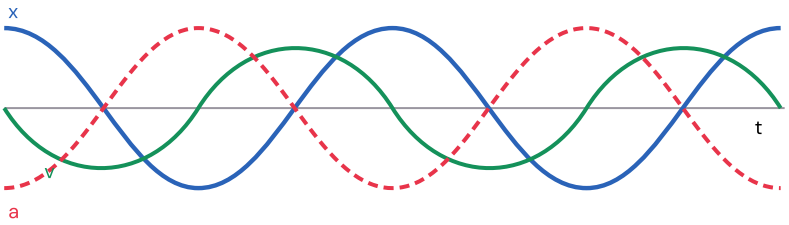
Sabse simple oscillation, jahan displacement time ke saath **sine ya cosine** ki tarah badalta hai.

$$x(t) = A\cos(\omega t + \varphi)$$

A = **amplitude** (max displacement), (ωt + φ) = **phase**, φ = phase constant (t = 0 pe kahan tha). Agar t = 0 pe mean position se shuru: x = A sin ωt.

03 Displacement, velocity, acceleration

Quantity	Formula	Mean position (x = 0)	Extreme (x = ±A)
Displacement	$x = A\cos(\omega t + \varphi)$	0	±A
Velocity	$v = -A\omega\sin(\omega t + \varphi) = \omega\sqrt{(A^2 - x^2)}$	Max = Aω	0
Acceleration	$a = -\omega^2 x$	0	Max = Aω²



x (neela), v (hara) x se π/2 aage, a (laal) x se π ulta

PHASE RELATIONS

Velocity displacement se **π/2** aage. Acceleration displacement se **π** (bilkul ulta). v–x graph **ellipse**, a–x graph seedhi line (negative slope).

04 SHM aur uniform circular motion

Ek particle circle (radius A) pe constant ω se ghoom raha hai. Uski **shadow (projection)** kisi diameter pe SHM karti hai, amplitude A aur angular frequency ω. Isliye SHM me ω ko "angular frequency" kehte hain.

05 Force law

SHM KI PEHCHAAN

F = -k x, a = -ω² x

Restoring force displacement ke proportional aur hamesha **mean position ki taraf**. Agar kisi sawaal me $a = -(\text{kuch constant}) \times x$ mile, toh SHM hai aur $\omega = \sqrt{(\text{constant})}$, $T = 2\pi\sqrt{(m/k)}$.

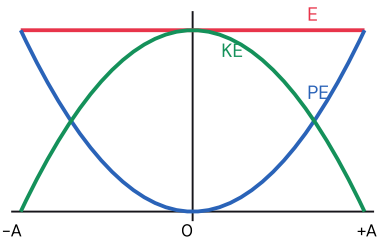
06 Energy in SHM

$KE = \frac{1}{2} k (A^2 - x^2)$

$PE = \frac{1}{2} k x^2$

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

Total energy constant. Mean pe sab KE, extreme pe sab PE. KE = PE jab $x = A/\sqrt{2}$.



KE aur PE parabola, total seedhi line

FREQUENCY KA TRAP

Displacement ki frequency ν hai, par KE aur PE ki frequency **2ν** (ek oscillation me do baar max hote hain).

07 Spring-mass system

$$T = 2\pi \sqrt{(m/k)}$$

Horizontal ho ya vertical, T same. Vertical me sirf mean position neeche khisakti (mg/k). g pe depend nahi, isliye Moon pe bhi same.

COMBINATIONS

Series: $1/k = 1/k_1 + 1/k_2$

Parallel: $k = k_1 + k_2$

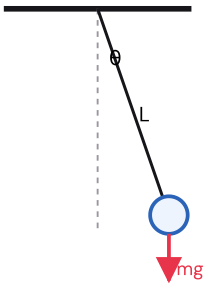
Spring ko n hisson me kaato: $k' = nk$

Do masses spring se jude (koi deewar nahi): $T = 2\pi\sqrt{(\mu/k)}$, $\mu = m_1m_2/(m_1 + m_2)$ (reduced mass).

08 Simple pendulum

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

Sirf chhote angle ($\theta \lesssim 15°$) pe, jab $\sin\theta \approx \theta$. **Mass aur amplitude pe depend nahi**. L = suspension point se bob ke centre tak.



Restoring force = mg sin θ

- **Seconds pendulum:** T = 2 s, L ≈ 1 m (99.3 cm).
- Lift upar accelerate (a): $g_{eff} = g + a$, T kam.
  Neeche: g - a. Free fall: T = ∞.
- Moon pe g/6 ⇒ T √6 guna.
- Garmi me L badhta ⇒ T badhta ⇒ ghadi **slow**.

09 Damped & forced oscillations

Type	Kya hota hai
Free oscillation	Apni natural frequency pe, koi rukawat nahi
Damped	Friction / hawa se energy ghatti, amplitude exponentially kam: $A\ e^{\wedge}(-bt/2m)$
Forced	Bahar ka periodic force apni frequency pe hilaata
Resonance	Bahar ki frequency = natural frequency ⇒ amplitude **sabse zyada**

RESONANCE KE EXAMPLES

Jhoole ko sahi waqt pe dhakka dena; soldiers pul pe kadam milaake nahi chalte (pul toot sakta); radio tuning; ek tuning fork doosre ko hila deta.

10 JEE Extra + Tricks

JEE LEVEL

- Springs: series $1/k = 1/k_1 + 1/k_2$; parallel $k = k_1 + k_2$. Vertical spring–mass ka T bhi $2\pi\sqrt{(m/k)}$.
- a se upar jaati lift me pendulum: $T = 2\pi\sqrt{(L/(g + a))}$; neeche: $g - a$; free fall: oscillation nahi.
- Physical pendulum: $T = 2\pi\sqrt{(I/(mgd))}$; Earth ke radius jitni lambai wala pendulum ⇒ $T \approx 84.6$ min.
- SHM me energy: $KE = \frac{1}{2}k(A^2 - x^2)$, $PE = \frac{1}{2}kx^2$; $x = A/\sqrt{2}$ pe KE = PE.
- Phase trick: SHM me v x se $\pi/2$ aage, a x se π aage ($a = -\omega^2 x$).

11 Solved numericals ($g = 10\ m/s^2$, $\pi^2 \approx 10$)

Q1. $x = 5 \sin(4\pi t + \pi/3)$ cm. Amplitude, frequency, period?
$A = 5$ cm, $\omega = 4\pi \Rightarrow \nu = 2$ Hz, $T = 0.5$ s. **Ans: 5 cm, 2 Hz, 0.5 s**

Q2. SHM me A = 10 cm, T = 2 s. Max velocity aur max acceleration?
$\omega = \pi$. $v_{max} = A\omega = 0.1\pi \approx 0.31$ m/s. $a_{max} = A\omega^2 = 0.1\pi^2 \approx 1$ m/s². **Ans: 0.31 m/s, ≈ 1 m/s²**

Q3. 1 kg mass, k = 100 N/m spring. Time period?
$T = 2\pi\sqrt{(1/100)} = 0.2\pi \approx 0.63$ s. **Ans: ≈ 0.63 s**

Q4. Kis displacement pe KE = PE? (A = 4 cm)
$x = A/\sqrt{2} = 2\sqrt{2} \approx 2.83$ cm. **Ans: ≈ 2.83 cm**

Q5. Pendulum ki length 4 guna. T?
$T \propto \sqrt{L} \Rightarrow$ 2 guna. **Ans: 2T**

Q6. 1 m pendulum lift me, lift 2.5 m/s² se upar accelerate kar rahi. T?
$g_{eff} = 12.5$. $T = 2\pi\sqrt{(1/12.5)} = 2\pi \times 0.283 \approx 1.78$ s. **Ans: ≈ 1.78 s**

Q7. Particle ki acceleration a = −16x. Time period?
$\omega^2 = 16 \Rightarrow \omega = 4 \Rightarrow T = 2\pi/4 = \pi/2 \approx 1.57$ s. **Ans: π/2 s**

12 Common mistakes

- Pendulum ka T mass pe depend maan lena.
- Spring-mass ka T g pe depend maan lena.
- Mean position pe acceleration max maan lena (wahan 0 hai, extreme pe max).
- KE ki frequency ν likhna (2ν hai).
- Bade angle pe bhi $T = 2\pi\sqrt{(L/g)}$ laga dena.
- Series springs ka k jod dena (series me reciprocal judte).

13 Formula sheet

Displacement	$x = A\cos(\omega t + \varphi)$
Velocity	$v = \omega\sqrt{(A^2 - x^2)}$, $v_{max} = A\omega$
Acceleration	$a = -\omega^2 x$, $a_{max} = A\omega^2$
Force law	$F = -kx$, $\omega = \sqrt{(k/m)}$
Energy	$E = \frac{1}{2}kA^2$, $KE = \frac{1}{2}k(A^2 - x^2)$
Spring	$T = 2\pi\sqrt{(m/k)}$
Pendulum	$T = 2\pi\sqrt{(L/g)}$
Springs	series $1/k = \Sigma 1/k_i$, parallel $k = \Sigma k_i$
Damped amplitude	A e^(−bt/2m)

14 Practice questions

1. Spring pe mass 4 guna. T?
2. SHM me amplitude 2 guna. Total energy?
3. Mean position pe speed 0.5 m/s, A = 5 cm. ω?
4. Seconds pendulum ko Moon pe le jao. Naya T?
5. Do springs (k, k) series me, mass m. T?

ANSWERS

1) 2T · 2) 4 guna · 3) ω = 0.5/0.05 = 10 rad/s · 4) 2√6 ≈ 4.9 s · 5) $k_{eq} = k/2 \Rightarrow T = 2\pi\sqrt{(2m/k)}$

15 Quick revision: exam se pehle 5 minute

SHM

- $a = -\omega^2 x$ (pehchaan).
- $v_{max} = A\omega$ (mean), $a_{max} = A\omega^2$ (extreme).
- v, x se π/2 aage; a, x se π.

ENERGY

- $E = \frac{1}{2}kA^2$ constant.
- KE = PE at $x = A/\sqrt{2}$.
- KE/PE frequency = 2v.

SYSTEMS

- Spring: $2\pi\sqrt{(m/k)}$, g pe nahi.
- Pendulum: $2\pi\sqrt{(L/g)}$, mass pe nahi.
- Seconds pendulum L ≈ 1 m.

DAMPED/FORCED

- Damping: amplitude exponentially kam.
- Resonance: driving = natural frequency.

Doubt hai? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka mock test do.