Excel Coaching Classes

Time: 60min | **Physics ch 5,6** | **Marks: 20**

SECTION A

1. **Select and write the correct answer for the following multiple choice type of questions:** **3**

i. **When an air column in a pipe closed at one end vibrates such that three nodes are formed in it, the frequency of its vibrations is _______ times the fundamental frequency.**

☐ (A) 2 ☐ (B) 3
☐ (C) 4 ☑ (D) 5

ii. **Which one of the following is not a characteristics of S.H.M?**

☐ (A) Its acceleration is maximum in the extreme position.
☐ (B) It is the projection of a uniform circular motion on a diameter.
☐ (C) Its velocity is maximum at the mean position.
☑ (D) Its velocity time graph is a straight line.

iii. **Which of the following functions are sine and cosine functions?**

☐ (A) non-periodic ☐ (B) logarithmic
☑ (C) periodic ☐ (D) algebraic

2. **Answer the following questions:** **3**

i. **What do you know about restoring force?**

The force acting on a particle to bring it back to the original position is known as restoring force.

ii. **Calculate the velocity of a particle performing S.H.M. after 1 second, if its displacement is given by x = 5 sin $\left(\frac{\pi t}{3}\right)$ m.**

Given that, x = 5 sin $\left(\frac{\pi t}{3}\right)$ m

Velocity of a particle performing S.H.M. is given by,

$v = \frac{dx}{dt} = 5 \times \frac{d}{dt}\left[sin\left(\frac{\pi t}{3}\right)\right] = 5 \times \cos\left(\frac{\pi t}{3}\right) \times \frac{\pi}{3}$

In t = 1 second,

$v = 5 \times \frac{1}{2} \times \frac{\pi}{3}$ = **2.62 m/s**

<u>**Alternate method:**</u>

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

$= \frac{\pi}{3} \times \sqrt{(5)^2 - \left(5 \times \frac{\sqrt{3}}{2}\right)^2}$ ....(Substituting value of t = 1 s in equation of x)

$= \frac{3.142}{3} \times \sqrt{25 - \left(25 \times \frac{3}{4}\right)}$

$= \frac{3.142}{3} \times \sqrt{\left(25 \times \frac{1}{4}\right)}$

$= \frac{3.142}{3} \times \frac{5}{2}$ = **2.62 m/s**

iii. **Define the following term: Waning**

Minimum intensity of sound due to superposition of two sound waves is called waning.

SECTION B

Attempt any TWO questions of the following: **4**

3. **The equation of a transverse wave along a stretched string is y = 3 sin 2π$\left(\frac{t}{0.02} - \frac{x}{40}\right)$ with distances expressed in cm and time in second. Calculate the wavelength and frequency of the wave.**

The wavelength of the wave is 40 cm and frequency of the wave is 50 Hz.

4. A. **Define stationary waves.**

When two identical waves travelling along the same path in opposite directions interfere with each other, resultant wave is called stationary wave.

B. **Define linear simple harmonic motion.**

Linear S.H.M. is defined as the linear periodic motion of a body, in which force (or acceleration) is always directed towards the mean position and its magnitude is proportional to the displacement from the mean position.

5. **State the laws of simple pendulum.**

Laws of simple pendulum:

i. The period of a simple pendulum is directly proportional to the square root of its length.

∴ $T \propto \sqrt{L}$ ….(when g = constant)

ii. The period of a simple pendulum is inversely proportional to the square root of acceleration due to gravity.

∴ $T \propto \frac{1}{\sqrt{g}}$ ….(when L = constant)

iii. The period of a simple pendulum does not depend on its mass.

iv. The period of a simple pendulum does not depend on its amplitude (for small amplitude).

6. **A tuning fork P produces 5 beats/s with a tuning fork Q. The frequency of the fork P is 500 Hz. When the prongs of the tuning fork P are filed, the beat frequency is found to be 7 beats per second. Find the natural frequency of the tuning fork Q.**

The natural frequency of the tuning fork Q is 495 Hz.

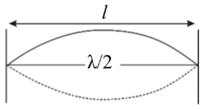
SECTION C

Attempt any TWO questions of the following: **6**

7. **Show that all harmonics are present on a stretched string between two rigid supports.**

i. Fundamental mode:

a. If a string is stretched between two rigid supports and is plucked at its centre, the string vibrates as shown in figure.



b. It consists of an antinode formed at the centre and nodes at the two ends with one loop formed along its length.

c. If λ is the wavelength and *l* is the length of the string, then

Length of loop = $\frac{\lambda}{2} = l$

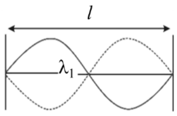
d. The frequency of vibrations of the string,

$$n = \frac{v}{\lambda} = \frac{1}{2l}\sqrt{\frac{T}{m}} \quad .... \left(\because v = \sqrt{\frac{T}{m}}\right)$$

This is the lowest frequency with which the string can vibrate. It is the fundamental frequency of vibrations or the first harmonic.

ii. For second mode or first overtone:

a. For first overtone or second harmonic, two loops are formed in this mode of vibrations.



b. There is a node at the centre of the string and at its both ends.

c. If λ_1 is wavelength of vibrations, the length of one loop $= \frac{\lambda_1}{2} = \frac{l}{2}$

∴ $\lambda_1 = l$

d. Thus, the frequency of vibrations is given as

$$n_1 = \frac{1}{\lambda_1}\sqrt{\frac{T}{m}}$$

∴ $n_1 = \frac{1}{l}\sqrt{\frac{T}{m}}$

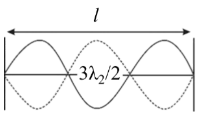
Comparing with fundamental frequency,

∴ $n_1 = 2n$.

Thus the frequency of the first overtone or second harmonic is equal to twice the fundamental frequency.

iii. For third mode or second overtone:

a. The string is made to vibrate in such a way that three loops are formed along the string as shown in figure.



b. If λ_2 is the wavelength, the length of one loop is $\frac{\lambda_2}{2} = \frac{l}{3}$

∴ $\lambda_2 = \frac{2l}{3}$

c. Therefore the frequency of vibrations is

$$n_2 = \frac{1}{\lambda_2}\sqrt{\frac{T}{m}}$$

∴ $n_2 = \frac{3}{2l}\sqrt{\frac{T}{m}}$

Comparing with fundamental frequency,

∴ $n_2 = 3n$.

Thus frequency of second overtone or third harmonic is equal to thrice the fundamental frequency.

iv. Similarly for higher modes of vibrations of the string, the frequencies of vibrations are as 4n, 5n, 6n…etc.

Thus all harmonics are present in case of a stretched string and the frequencies are given by, $n_p = pn$.

8. **A body of mass 0.2 kg performs linear S.H.M. It experiences a restoring force of 0.2 N when its displacement from the mean position is 4 cm. Determine**

i. force constant

ii. period of S.H.M. and

iii. acceleration of the body when its displacement from the mean position is 1 cm.

i. The force constant is **5 N/m**.

ii. The time period of SHM is **0.4π s.**

iii. Acceleration at x = 1 cm is **– 0.25 m s^{-2}.**

9. A. **Distinguish between progressive waves and stationary waves.**

Sr. No.	Progressive waves	Stationary waves
i.	The disturbance travels from one region to the other with definite velocity.	Disturbance remains in the region where it is produced, velocity of the wave is zero.
ii.	Amplitudes of all particles are same.	Amplitudes of particles are different.
iii.	Particles do not cross each other.	All the particles cross their mean positions simultaneously.
iv.	All the particles are moving.	Particles at the position of nodes are always at rest.
v.	There is no transfer of energy.	Energy is transmitted from one region to another.
vi.	Phases of adjacent particles are different.	All particles between two consecutive nodes are moving in the same direction and are in phase while those in adjacent loops are moving in opposite directions and differ in phase by 180°.

[Any four differences]

B. **State an equation of simple harmonic progressive wave travelling in the negative direction of X-axis.**

Equation of simple harmonic progressive wave travelling in the negative direction of X-axis,
$y(x,t) = A \sin (kx + \omega t)$

SECTION D

Attempt any ONE question of the following: **4**

10. A. **A set of 24 tuning forks is arranged in a series of increasing frequencies. If each fork gives 4 beats per second with the preceding one and the last sounds the octave of the first, find the frequencies of the first and the last forks.**

The frequencies of the first and the last forks are **92 Hz** and **184 Hz** respectively.

B. **What are harmonics and overtones?**

i. Harmonics:

a. The term 'harmonic' is used when the frequency of a particular overtone is an integral multiple of the fundamental frequency.

b. In strings and air columns, the frequencies of overtones are integral multiples of the fundamental frequencies. Hence, they are termed as harmonics.

c. All harmonics may not be present in a given sound.

ii. Overtones:

a. The tones whose frequencies are greater than the fundamental frequency are called overtones.

b. Overtones are only those multiples of fundamental frequency which are actually present in a given sound.

c. The first frequency higher than the fundamental frequency is called the first overtone, the next frequency higher is the second overtone and so on.

11. **Discuss analytically, the composition of two S.H.M.s of same period and parallel to each other. Also find the equation of resultant amplitude and phase difference.**

Analytical treatment	Consider a particle simultaneously subjected to two S.H.M.s having the same period and along same path (let it be along the x-axis), but of different amplitudes and initial phases. The resultant displacement at any instant is equal to the vector sum of its displacements due to both the S.H.M.s at that instant. i. Let the two linear S.H.M's be given by equations, $x_1 = A_1 \sin(\omega t + \phi_1)$ ….(1) $x_2 = A_2 \sin(\omega t + \phi_2)$ ….(2) where A_1, A_2 are amplitudes; ϕ_1, ϕ_2 are initial phase angles and x_1, x_2 are the displacement of two S.H.M's in time 't'. ω is same for both S.H.M's. ii. The resultant displacement of the two S.H.M's is given by, $x = x_1 + x_2$ ….(3) iii. Using equations (1) and (2) , equation (3) can be written as, $x = A_1 \sin(\omega t + \phi_1) + A_2 \sin(\omega t + \phi_2)$ $= A_1 [\sin\omega t \cos\phi_1 + \cos\omega t \sin\phi_1] + A_2 [\sin\omega t \cos\phi_2 + \cos\omega t \sin\phi_2]$ $= A_1 \sin\omega t \cos\phi_1 + A_1 \cos\omega t \sin\phi_1 + A_2 \sin\omega t \cos\phi_2 + A_2 \cos\omega t \sin\phi_2$ $= [A_1 \sin\omega t \cos\phi_1 + A_2 \sin\omega t \cos\phi_2] + [A_1 \cos\omega t \sin\phi_1 + A_2 \cos\omega t \sin\phi_2]$

	$\cos \omega t \sin \phi_2]$ $\therefore$ $x = \sin \omega t\, [A_1 \cos \phi_1 + A_2 \cos \phi_2] + \cos \omega t\, [A_1 \sin \phi_1 + A_2 \sin \phi_2]$ ….(4) iv. As A_1, A_2, ϕ_1 and ϕ_2 are constants, we can combine them in terms of another convenient constants R and δ as $A_1 \cos \phi_1 + A_2 \cos \phi_2 = R \cos\delta$ ….(5) and $A_1 \sin \phi_1 + A_2 \sin \phi_2 = R \sin \delta$ ….(6) v. Using equations (5) and (6), equation (4) can be written as, $x = \sin \omega t.\, R \cos \delta + \cos \omega t. R \sin \delta = R\, [\sin \omega t \cos \delta + \cos \omega t \sin \delta]$ $\therefore$ $x = R \sin (\omega t + \delta)$ ....(7) Equation (7) is the equation of an S.H.M. of the same angular frequency (hence, the same period) but of amplitude R and initial phase δ. It shows that the combination (superposition) of two linear S.H.M.s of the same period and occurring along the same path is also an S.H.M.
Resultant amplitude (R):	Resultant amplitude is, $R = \sqrt{(R\, \sin \delta)^2 + (R\, \cos \delta)^2}$ Squaring and adding equations (5) and (6) we get, $(A_1 \cos \phi_1 + A_2 \cos \phi_2)^2 + (A_1 \sin \phi_1 + A_2 \sin \phi_2)^2 = R^2\cos^2\delta + R^2\sin^2\delta$ $\therefore$ $A_1^2\cos^2\phi_1 + A_2^2 \cos^2\phi_2 + 2A_1 A_2 \cos \phi_1 \cos\phi_2 + A_1^2 \sin^2\phi_1 + A_2^2\sin^2\phi_2 + 2A_1A_2 \sin\phi_1 \sin\phi_2$ $= R^2 (\cos^2\delta + \sin^2\delta)$ $\therefore$ $A_1^2 (\cos^2\phi_1 + \sin^2\phi_1) + A_2^2 (\cos^2\phi_2 + \sin^2\phi_2) + 2A_1A_2 (\cos \phi_1 \cos \phi_2 + \sin\phi_1 \sin\phi_2) = R^2$ $\therefore$ $A_1^2 + A_2^2 + 2A_1A_2 \cos (\phi_1 - \phi_2) = R^2$ $\therefore$ $R = \pm\sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos\,(\phi_1 - \phi_2)}$ ....(8) Equation (8) represents resultant amplitude of two S.H.M's.
Resultant (initial) phase (δ):	Dividing equation (6) by (5), we get, $\frac{A_1 \sin \phi_1 + A_2\, \sin \phi_2}{A_1\, \cos \phi_1 + A_2 \cos \phi_2} = \frac{R\, \sin \delta}{R\, \cos \delta} = \tan \delta$ $\therefore$ $\delta = \tan^{-1} \left[\frac{A_1 \sin \phi_1 + A_2 \sin \phi_2}{A_1 \cos \phi_1 + A_2 \cos \phi_2}\right]$ ....(9) Equation (9) represents resultant or initial phase of two S.H.M's.