Q No.7.1: Name the two characteristics of SHM. (BWP-2019) (DGK-2019) (FED-2017) (FSB-2016) (SGD-2016)

(i) The total energy of an object executing S.H.M. will remain conserved.

(ii) Acceleration of an object executing S.H.M. is directly proportional to the displacement and always directed towards mean position. $(a \propto -x)$

Q No.7.2: Does frequency depend on amplitude for harmonic oscillator? (FSB-2019) (LHR-2019) (GUJ-2019) (GUJ-2019) (DGK-2018) (GUJ-2018) (DGK-2017) (LHR-2017) (FED-2017) (RWP-2017) (FSB-2016) (BWP-2016) (DGK-2016) (GUJ-2016)

Frequency of an oscillator can be calculated as

For Pendulum, $f = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$

For Mass Spring System , $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

Both formulae does not have any term which can describe amplitude, hence frequency of a harmonic oscillator does not depend upon amplitude.

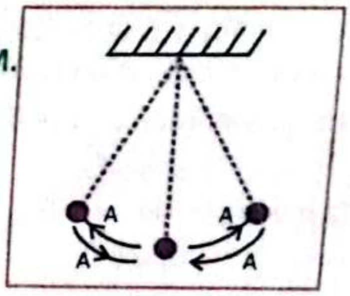
Q No.7.3: Can we realize an ideal simple pendulum? (FSB-2019) (RWP-2019) (GUJ-2019) (FSB-2018) (FSB-2017)(BWP-2017) (SGD-2017) (BWP-2016) (BWP-2016)

An ideal pendulum consists of a point mass suspended by a weightless, inextensible string and vibrate without any friction.

We cannot realize an ideal simple pendulum due to following reasons.

(i) It's difficult to have a point mass (very small size).
(ii) Every string has some elasticity.
(iii) String could not be weightless and inextensible.
(iv) Resistive forces (Air etc) can not be removed.

Q No.7.4: What is the total distance travelled by an object moving with S.H.M. in a time equal to its time period, if its amplitude is A?
(DGK-2021)(SGD-2018)(FSB-2016)



As shown in Figure If an object is oscillating with an amplitude "A", the total distance travelled by the object is four (4) times of its amplitude (S = 4A).

Q No.7.5: What happens to the period of simple pendulum if its length is doubled, what happens if the suspended mass is doubled? (MUL-2021) (SGD-2021) (LHR-2019) (LHR-2018) (SGD-2018) (BWP-2016)

The relation for Time Period is $T = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$

(i) If Length is double, $l' = 2l$

$$T' = 2\pi\sqrt{\frac{2l}{g}}$$

$$T' = \sqrt{2}\ [2\pi\sqrt{\frac{l}{g}}]$$

$$T' = \sqrt{2}\ T$$

$$T' = 1.41\ T$$

Its time period becomes 1.41 times than its initial Time Period.

(ii) When mass is doubled.

Time period of pendulum does not depend upon mass of bob hence by doubling mass and keeping length same will not alter its Time Period (T).

Q No.7.6: Does the acceleration of a simple harmonic oscillator remain constant during its motion? Is the acceleration ever zero? Explain. (FSB-2021) (DGK-2021) (RWP-2021) (SGD-2021) (BWP-2019) (SGD-2019) (FED-2018) (FSB-2017) (SGD-2017) (GRW-2017) (LHR-2016)

No, it does not remain constant.

Reason

By definition of S.H.M. ($a \propto -x$)

As acceleration varies with displacement hence it will not remain constant during S.H.M.

When the object is at mean position, the displacement is zero hence acceleration is also zero at mean position

$$a = o \text{ when } x = o.$$

When the object is at extreme position, the displacement is maximum hence acceleration is also $-x_o\omega^2$ at mean position

$$a = -x_o\omega^2 \text{ when } x = x_o.$$

Q No.7.7: What is meant by phase angle? Does it define angle between maximum displacement and the driving force? (MUL-2021) (SHW-2021) (GUJ-2021) (SHW-2019) (FED-2019) (RWP-2018) (SGD-2016) (GUJ-2016)

The angle which describes the displacement and direction of motion of an object executing S.H.M. is called phase angle.

It is the angle subtended by an object moving with angular velocity "ω" in time "t" $\theta = \omega t$

Hence phase angle does not define angle between maximum displacement and driving force.

Q No.7.8: Under what condition does the addition of two S.H.M. produce a resultant, which is also simple harmonic? (FSB-2021) (BWP-2021) (DGK-2021) (SHW-2019)

When motions of two objects are superimposed to produce S.H.M. as a resultant, the following conditions must be fulfilled

(i) Both SHMs have same amplitude.

(ii) Both SHMs have same frequency.

(iii) There must be a constant phase difference between both SHMs.

Q No.7.9: Show that in SHM the acceleration is zero when the velocity is greatest and velocity is zero when the acceleration is greatest. (SHW-2018)(GUJ-2016)

The acceleration and velocity can be calculated as

$$a = -\omega^2 x \quad ; \quad v = \omega\sqrt{x_o^2 - x^2}$$

At mean position $x = 0$

$$a = 0 \quad ; \quad v = \omega\sqrt{x_o^2 - 0^2}$$

$$; \quad v = \omega x_o$$

At mean position acceleration is zero whereas velocity is maximum.

At extreme position $x = x_o$

$$a = -\omega^2 x_o \quad ; \quad v = \omega\sqrt{x_o^2 - x_o^2}$$

$$; \quad v = 0$$

At extreme position acceleration is maximum whereas the velocity is zero.

Q No.7.10: In relation to S.H.M., explain the equation. (FED-2018)

(i) $y = A\sin(\omega t + \phi)$ *(ii)* $a = -\omega^2 x$

(i) $y = A\sin(\omega t + \phi)$ gives instantaneous displacement during SHM.

y = instantaneous displacement

A = Amplitude

ϕ = initial phase

$\omega t + \phi$ = Phase angle

t = time

(ii) $a = -\omega^2 x$ gives instantaneous acceleration during SHM

a = instantaneous acceleration

x = instantaneous displacement

ω = angular frequency

Negative sign shows that direction of acceleration is towards mean position.

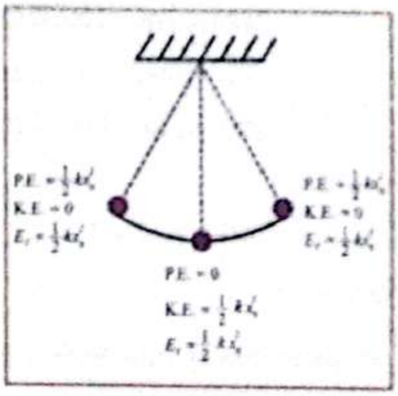
Q No.7.11: Explain the relation between total energy, potential energy and kinetic energy for a body oscillating with SHM. (BWP-2021)

For an isolated system executing S.H.M., the total energy remains conserved and calculated as

E_T = P.E. + K.E. Where resistive forces (e.g. friction) are neglected

$$P.E. = \frac{1}{2} k x^2$$

$$K.E. = \frac{1}{2} k x_0^2 \left(1 - \frac{x^2}{x_0^2}\right)$$



At mean position P.E. is minimum whereas K.E. is maximum.

At extreme position K.E. is minimum whereas P.E. is maximum.

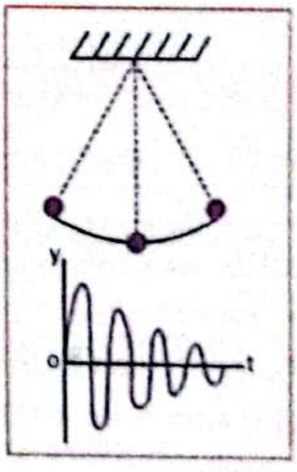
Q No.7.12: Describe some common phenomena in which resonance plays an important role.
(FSB-2021) (DGK-2021) (GUJ-2021) (RWP-2018) (GUJ-2018) (FED-2017) (MUL-2017) (FSB-2016) (DGK-2016) (RWP-2016)

Resonance occurs when frequency produced due to applied force becomes equal to the natural frequency of the object executing S.H.M. It can be observed in following examples.

- When a pendulum is pushed with a periodic/rythemic force, its amplitude gets increased.
- When frequency of a radio becomes equal to one of the transmitting frequency, we can hear the sound.
- Food gets heated in microwave oven due to resonance between water and fat molecules of it.

Q No.7.13: If a mass system is hung vertically and set into oscillations, why does the motion eventually stop? (FSB-2021) (LHR-2021) (MUL-2021) (BWP-2019) (MUL-2019) (DGK-2018) (SGD-2018) (LHR-2017) (RWP-2017) (SHW-2017) (GUJ-2017) (LHR-2016)

In the presence of resistive forces (e.g. friction, air resistance, gravity) the energy of oscillator is dissipated to overcome these forces. Due to loss of energy as heat and other forms the system cannot oscillate indefinitely and stops eventually.



SHORT QUESTIONS AND ANSWERS

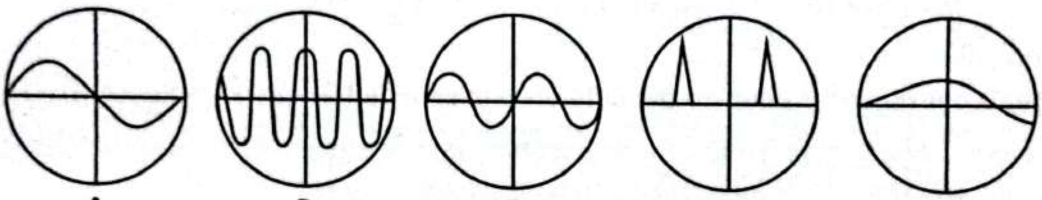
Complete Video Lecture (A) (B)

Q No.8.1: What features do transverse waves have in common with longitudinal waves? OR What features do longitudinal waves have in common with transverse waves? OR Write common features of longitudinal waves have in common with transverse waves.
(DGK-2021) (DGK-2019) (SGD-2019) (LHR-2017) (RWP-2017) (SGD-2017) (LHR-2016) (RWP-2016)

- Both are mechanical waves.
- Both transport energy from one point to another
- Both can produce interference, diffraction, refraction & reflection
- Both satisfy $v = f\lambda$

Q No.8.2: The five possible waveforms obtained, when the output from a microphone is fed into the Y-input of cathode ray oscilloscope, with the time base on, are shown in fig. 8.23. These waveforms are obtained under the same adjustment of the cathode ray oscilloscope controls. Indicate the waveform.

(a) Which trace represents the loudest note?
Correct option (D) Reason: Greater the amplitude of wave louder the note will be
(b) Which trace represents the highest frequency?
Correct option (B) Reason: More the number of waves per second, higher the frequency will be



A B C D E

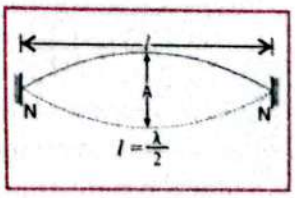
Q No.8.3: Is it possible for two identical waves travelling in the same direction along a string to give rise to a stationary wave? (FSB-2021) (LHR-2021) (SHW-2021) (GUJ-2021) (FSB-2019) (BWP-2019) (DGK-2019) (GUJ-2019) (GUJ-2018) (DGK-2017) (LHR-2017) (SGD-2016)

It is not possible for two identical waves travelling in same direction along a string to give rise to a stationary wave.

Reason

Stationary wave can only be produced by superposition of two identical waves having same frequency travelling in opposite direction along a string.

Q No.8.4: A wave is produced along a stretched string but some of its particles permanently shows zero displacement. What type of wave is it?

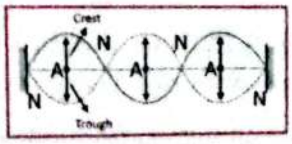


It is a stationary wave. when two waves having same frequency, traveling in opposite direction superpose each other, they will produce stationary waves.

Reason

In stationary waves, at some points resultant displacement is permanently zero and called node.

Q No.8.5: Explain the terms crest, trough, node and antinode. (MUL-2017)



Crest	A part of wave which is above than mean position is called crest.
Trough	A part of wave which is below than mean position is called trough.
Node	The points in a stationary wave at which resultant displacement remains zero are called nodes.
Antinode	The points in a stationary wave at which resultant displacement remains maximum are called antinodes.

Chapter 8: Waves

Q No.8.6: Why does sound travel faster in solids than is gases? (BWP-2021) (RWP-2021) (GUJ-2021) (SGD-2019) (FED-2019) (MUL-2019) (RWP-2018) (GUJ-2018) (FSB-2018) (FED-2018) (GUJ-2017) (BWP-2017) (DGK-2017) (SHW-2017) (SGD-2017) (LHR-2016) (FED-2016)

Speed of sound can be calculated as $v=\sqrt{\frac{E}{\rho}}$ $\begin{cases} E = \text{modulus of elasticity} \\ \rho = \text{density of medium} \end{cases}$

The ratio of modulus of elasticity to density in solid is greater than ratio of modulus of elasticity to density in gases.

$\left(\frac{E}{\rho}\right)_{Solid} > \left(\frac{E}{\rho}\right)_{gas}$ Resultantly the speed of sound in solid is greater in solids ($v_{solid} > v_{gas}$)

Q No.8.7: How are beats useful in tuning musical instruments? (FED-2021) (MUL-2021) (GUJ-2021) (GUJ-2021) (FSB-2019) (LHR-2019) (MUL-2019) (LHR-2018) (FED-2018) (RWP-2018) (SGD-2018) (FSB-2016) (DGK-2016) (LHR-2016) (BWP-2016) (GUJ-2016)

Beats can be observed by superposition of two waves having slightly different frequency travelling in same direction.

- To tune a musical instrument upto a required frequency it should be sounded with a known frequency.
- Number of beats per second gives information regarding difference of the frequencies.
- The tension in string of instrument is varied as the difference of frequencies become zero.
- As no beats are observed it means both instruments have same frequencies.
- Hence instrument is tuned upto a desired frequency.

Q No.8.8: When two notes of frequencies f_1 and f_2 are sounded together, beats are formed. If $f_1 > f_2$ what will be frequency of beats?

i). $(f_1 + f_2)$ ii). $(\frac{1}{2}f_1 + f_2)$ iii). $(f_1 - f_2)$ iv). $(\frac{1}{2}f_1 - f_2)$

Correct option (iii)

Number of beats per second is equal to the difference in sounded frequencies hence $(f_1 - f_2)$

Q No.8.9: As a result of a distant explosion, an observer senses a ground tremor and then hears the explosion. Explain the time difference. (DGK-2019) (SGD-2019) (GUJ-2019) (LHR-2018) (RWP-2017)

Due to explosion waves are produced and move through ground (solid) and air (gas). The ratio of modulus of elasticity to density in solid is greater than ratio of modulus of elasticity to density in gases.

$$\left(\frac{E}{\rho}\right)_{Solid} > \left(\frac{E}{\rho}\right)_{gas}$$

Therefore

$$v_{solid} > v_{gas}$$

Firstly the observers sense a ground tremor and then hear the explosion.

Q No.8.10: Explain why sound travels faster in warm air than in cold air. (DGK-2021) (MUL-2021) (SGD-2021) (BWP-2019) (DGK-2019) (GUJ-2019) (DGK-2018) (SGD-2018) (MUL-2017) (GUJ-2017) (FSB-2016) (BWP-2016) (DGK-2016) (LHR-2016) (SGD-2016) (GUJ-2016)

As $\frac{v_t}{v_o} = \sqrt{\frac{T}{T_o}}$ OR $v \propto \sqrt{T}$

- Speed of sound v varies directly as square root of absolute temperature (T).
- With increase in temperature thermal K.E of gas molecules also increases.
- Greater the temperature more will be speed of sound. Therefore, sound travels faster in warm air than in cold air.

Q No.8.11: How should a sound source move with respect to an observer so that the frequency of its sound does not change? (DGK-2019) (BWP-2016) (LHR-2016)

The change in frequency is observed if sound source and observer have relative motion between them. If they are stationary with respect to each other then no variation in frequency is observed.

- Both are moving with same velocity (same speed same direction)
- Sound source is at a fixed point and observer is rotating on an exact circular path around the source.