PHYSICS CLASS XI

CHAPTER – 15 WAVES

Q.1. A hospital uses an ultrasonic scanner to locate tumours in a tissue. What is the wavelength of sound in the tissue in which the speed of sound is 1.7 kms^{-1}? The operating frequency of the scanner is 4.2 MHz.

Ans. v = 1.7 km/s = 1700 m/s, v = 4.2 MHz = 4.2 $\times 10^6$ Hz

$$\lambda = \frac{v}{V} = \frac{1700}{4.2\times10^6}$$

$$= 0.405 \times 10^{-3}\text{m} = 0.405 \text{ mm} \approx 4.1 \times 10^{-4} \text{ m}$$

Q.2. Why should the difference between the frequencies be less than 10 to produce beats?

Ans. Human ear cannot identify any change in intensity is less than $\left(\frac{1}{10}\right)^{th}$ of a second. So, difference should be less than 10.

Q.3. In a hot summer day, pitch of an organ pipe will be higher or lower?

Ans. The speed of sound in air is more at higher temperature, as v × $\sqrt{T}$. As we know frequency v = $\frac{v}{\lambda}$ as v is more hence v will be more and accordingly pitch will be more.

Q.4. A sonometer wire is vibrating in resonance with a tuning fork. Keeping the tension applied same, the length of the wire is doubled. Under what conditions would the tuning fork still be in resonance with the wire?

Ans. The sonometer frequency is given by

$$V = \frac{n}{2L}\sqrt{\frac{T}{\mu}} \quad .....(i)$$

Now, as it vibrates with length L,

$$n = n_1$$

$$\therefore \quad v_1 = \frac{n_1}{2L}\sqrt{\frac{T}{\mu}} \quad .....(ii)$$

Dividing Eq. (i) by Eq. (ii), we get

$$\frac{V_1}{V_2} = \frac{n_1}{n_2} \times 2$$

To keep the resonance

$$\frac{V_1}{V_2} = 1 = \frac{n_1}{n_2} \times 2$$

$$\Rightarrow \quad n_2 = 2n_1$$

Hence, when the wire is doubled the number of loops also get doubled to produce the resonance. That is, it resonates in second harmonic.

Q.5. Show that when a string fixed at its two ends vibrates in 1 loop, 2 loops, 3 loops and 4 loops, the frequencies are in the ratio 1 : 2 : 3 : 4.

Ans. In case of a string fixed at two ends, when the string vibrates in n loops

$$v_n = \frac{n}{2l}\sqrt{\frac{T}{\mu}}$$

$$\Rightarrow \quad v_n \propto n$$

Q.6. A train standing at the outer signal of a railway station blows a whistle of frequency 400 Hz still air. The train begins to move with a speed of 10ms^{-1} towards the platform. What is the frequency of the sound for an observer standing on the platform? (sound velocity in air = 330 ms^{-1})

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Ans. Given, v = 400 Hz, v_s = 10m/s, v = 330 m/s

As the source is moving towards stationary observer apparent frequency will be more than the original.

v' = apparent frequency

$$= \frac{v \times V}{v - v_s} = \frac{330 \times 400}{330 \times 10}$$

= 412.5 Hz

Q.7. When two waves of almost equal frequencies n_1 and n_2 reach at a point simultaneously. What is the time interval between successive maxima?

Ans. Number of beats/sec = (n_1 – n_2)

Hence, time interval between two successive beats = time interval between two successive maxima = $\frac{1}{n_1 - n_2}$

Q.8. A narrow sound pulse (for example, a short pip by a whistle) is sent across a medium.

(i) Does the pulse have a definite (a) frequency, (b) wavelength, (c) speed of propagation?

(ii) If the pulse rate is 1 after every 20 s, (that is the whistle is blown for a split of second after every 20 s), is the frequency of the note produced by the whistle equal to 1/20 or 0.05 Hz?

Ans. (i) A short pip by a whistle

(a) will not have fixed wavelength.

(b) will not have a fixed frequency.

(c) will have definite speed that will be equal to speed of sound in air.

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(ii) 0.05 Hz will be the frequency of repetition of the short pip.

Q.9. Two sitar strings A and B playing the note 'Ga' are slightly out of tune and produce beats of frequency 6 Hz. The tension in the string A is slightly reduced and the beat frequency is found to reduce to 3 Hz. If the original frequency of A is 324 Hz, what is the frequency of B?

Ans. Given, frequency of A, f_A = 324 Hz

Now, frequency of B, $f_B = f_A \pm$ beat frequency

$= 324 \pm 6$

or f_B = 330 or 318 Hz

Now, if tension in the string is slightly reduced its frequency will also reduce from 324 Hz.

Now, if f_B = 330 and f_A reduces, then beat frequency should increase which is not the case if f_B = 318 Hz and f_A decrease the beat frequency should decrease, which is the case and hence f_B = 318 Hz.

Q.10. A metre – long tube open at one end, with a movable piston at the other end, shows resonance with a fixed frequency source (a tuning fork of frequency 340 Hz) when the tube length is 25.5 cm or 79.3 cm. Estimate the speed of sound in air at the temperature of the experiment. The edge effects may be neglected.

Ans. As there is piston at one end, it behaves as a closed organ pipe. Hence, it will produce odd harmonics only.

Hence, resonant frequencies will be first and third harmonic.

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In the fundamental mode, $\frac{\lambda}{4}$ = 4 = 25.5 cm

$\Rightarrow$ λ = 4 × 25.5 = 102 cm = 1.02 m

Speed of sound in air

$v = \nu\lambda = 340 \times (1.02) = 346.8$ m/s

Q.11. A tuning for A, marked 512 Hz, produces 5 beats per sec, where sounded with another unmarked turning fork B. If B is loaded with wax the number of beats is again 5 per sec. What is the frequency of the turning fork B when not loaded?

Ans. Frequency of A, ν_0 = 512 Hz

Number of beats/sec = 5

Frequency of B = 512 $\pm$ 5 = 517 or 507 Hz

On loading its frequency decreases from 517 to 505 so that number of beats/sec remain 5.

Hence, frequency of B when not loaded = 517 Hz.

Q.12. A pipe 20 cm long is closed at one end. Which harmonic mode of the pipe is resonantly excited by a source of 1237.5 Hz? (sound velocity in air = 330 ms^{-1})

Ans. Length of pipe (l) = 20 cm = 20 × 10^{-2} m

$$\nu_{funda} = \frac{v}{4L} = \frac{330}{4 \times 20 \times 10^{-2}}$$

$$\nu_{funda} = \frac{330 \times 100}{80} = 412.5 \text{ Hz}$$

$$\frac{\nu_{given}}{\nu_{funda}} = \frac{1237.5}{412.5} = 3$$

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Hence, 3rd harmonic mode of the pipe is resonantly excited by the source of given frequency.

Q.13. A train, standing at the outer signal of a railway station blows a whistle of frequency 400 Hz in still air. (i) What is the frequency of the whistle for a platform observer when the train (a) approaches the platform with a speed of $10ms^{-1}$? (b) recedes from the platform with a speed of $10ms^{-1}$? (ii) What is the speed of sound in each case? The speed of sound in still air can be taken as 340 ms^{-1}.

Ans. Given, v = 400 Hz, v = 340 m/s

(i) When train approaches the platform v_s = 10m/s

Hence, apparent frequency v'

$= \frac{v}{v-v_s} \times v = \frac{340\times400}{340-10} = 412.12$ Hz

(ii) When train recedes from the platform v_s = 10 m/s

Apparent frequency = v'

$= \frac{v\times V}{v+v_s} = \frac{340\times400}{340+10} = 388.6$ Hz

(ii) The speed of sound wave in each case will be same and is 340 m/s.

Q.14. A pipe 20 cm long is closed at one end. Which harmonic mode of the pipe is resonantly excited by a 430 Hz source? Will the same source be in resonance with the pipe if both ends are open?(speed of sound in air is 340 ms^{-1})

Ans. Given, L = 20 cm = 0.2 m, v_n = 430 Hz, v = 340 m/s

It will behave as closed organ pipe

$v_n = (2n-1)\frac{v}{4L}$, where n = 1,2,3,…

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$\Longrightarrow$ 430 = (2n – 1)$\frac{v}{4L}$ = (2n – 1) × $\frac{340}{4\times0.2}$

$\Longrightarrow$ $(2n-1)$ = $\frac{430\times(0.8)}{340}$ $\Longrightarrow$ 2n = $\frac{(430)(0.8)}{340}+1$

$\Longrightarrow$ n = $\frac{43\times4}{340}+\frac{1}{2}$ = $\frac{2\times172+340}{340\times2}$ = $\frac{684}{680}$ = 1.006

Hence, it will be the 1st normal mode or harmonic mode of vibration.

In a pipe open at both ends v_n = n × $\frac{v}{2l}$ = $\frac{n\times340}{2\times0.2}$ = 430

$\Longrightarrow$ n = $\frac{430\times2\times0.2}{340}$ = $\frac{43\times2\times2}{340}$ = 0.5

As n is not integer hence open organ pipe cannot be in resonance with the source.

Q.15. Organ pipes are used in musical instruments. These are used to produce musical sound by blowing air into the pipe. These pipes are of two types. Open organ pipe which are open at both ends and closed organ pipes which are closed at one end.

Musical sound produced by closed organ pipe is of lesser quality than that of open organ pipe.

(i) What is the reason behind richness of quality due to open organ pipe?

(ii) What values of life do you learn from this study?

Ans. (i) For an open organ pipe fundamental frequency is given by $v_o\,\frac{v}{2L}$

where, v is the speed of sound and L is the length of the pipe.

All harmonics v_o, $2v_o$, $3v_o$, $4v_o$,… are present in the musical sound of open organ pipe.

In closed organ pipe fundamental frequency is given by

$$v_o' = \frac{v}{4L}$$

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In this only odd harmonics v_o', $3v_o'$, $5v_o'$,…. Are present.

This is the reason behind the richness of sound quality in open organ pipe.

(ii) The thing we should learn from the study of this topic is enhancement in quality of work. We should learn how to increase our quality of performance. Whatever we are doing, we should try to do it with quality.

Q.16. A train, standing in a station – yard blows a whistle of frequency 400 Hz in still air. The wind starts blowing in the direction from the yard to the station with a speed of 10ms^{-1} . What are the frequency, wavelength and speed of sound for an observer standing on the station's platform? Is the situation exactly identical to the case when the air is still and the observer runs towards the yard at a speed of 10ms^{-1}? The speed of sound in still air can be taken as 340 ms^{-1} .

Ans. Here, given v = 400 Hz

v_w = 10m/s = speed of wind

Speed of sound in still air = 340 m/s

As the wind is blowing in the same direction as wave hence effective speed of sound = v + v_w = 340 + 10 = 350 m/s

On platform as both source and observer are at rest hence frequency remains unchanged v = 400 Hz.

Wavelength $\lambda = \frac{v+v_w}{V} = \frac{350}{400}$ = 0.875 m.

When air is still v_w = 0

Observer's speed = v_0 = 10ms^{-1}

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$v_s = 0$

As observer moves towards the source

$v' = \frac{v+v_0}{v} \times$ v

Q.17. A SONAR system fixed in a submarine operates at a frequency 40.0 kHz. An enemy submarine moves towards the SONAR with a speed of 360 km/h. What is the frequency of sound reflected by the submarine? Take the speed of sound in water to be 1450 ms^{-1}.

Ans. Frequency of SONAR v = 40 kHz = 40×10^3 Hz

Speed of observer/enemy's submarine

$= 360$ km/h $= \frac{360 \times 1000}{60 \times 60} = 100 m/s$

Given, speed of sound wave in water = 1450 m/s

As observer is moving towards stationary source hence apparent frequency observed will be

$v' = \left(\frac{v+v_0}{v}\right)$v $= \frac{(1450+100)}{1450} \times 40 \times 10^3$

$v' = 4.276 \times 10^4$ Hz

The wave is reflected by the submarine.

Now, submarine of the enemy will act as a source and SONAR will be observer.

Hence, apparent frequency observed

$v'' = \frac{v \times V}{v - v_s} = \frac{1450 \times 4.276 \times 10^4}{1450 - 10}$

$= 4.59 \times 10^4$ Hz = 45.9 kHz

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Q.18. A bat is flitting about in a cave, navigating via ultrasonic beeps. Assume that the sound emission frequency of the bat is 40 kHz. During one fast swoop directly towards a flat wall surface, the bat is moving at 0.03 times the speed of sound in air. What frequency does the bat hear reflected off the wall?

Ans. Frequency of sound emitted by the bat v = 40 kHz

Velocity of bat v_s = 0.03 v (by question)

Here v is the speed of sound.

Apparent frequency reaching the wall

$$v' = \frac{v \times V}{v - v_s} = \frac{v}{v - 0.03v} \times 40 \text{ kHz}$$

$$= \frac{40}{0.97} \text{ kHz} = 41.23 \text{ kHz}$$

The frequency will be reflected by the wall and now wall will acts as source.

Hence, $v_s = 0$

As observer is now moving towards a stationary source.

v_0 = speed of the bat = 0.03 v

Now apparent frequency observed by the bat

$$v'' = \left(\frac{v + v_0}{v}\right) v' = \left(\frac{v + 0.03v}{v}\right)(41.23 \text{ kHz})$$

$$= 1.03 \times 41.23 \text{ kHz} = 42.47 \text{ kHz}$$

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