CHAPTER NO. 8(WAVES)

Question 8.1:- The wavelength of signals from radio transmitter is 1500 m and the frequency are 200 kHz. What is the wavelength of the transmitter operating at 1000 kHz and with what speed radio waves travel?

Solution:- Wavelength of signal from first transmitter = λ_1 = 1500 m = 1.5×10^3 m

Frequency of signal from first transmitter = f_1 = 200 kHz = 200×10^3 Hz

$f_1 = 2.0 \times 10^5$ Hz

Frequency of signal from second transmitter = f_2 = 1000 kHz = 1000×10^3 Hz

$f_2 = 1.0 \times 10^6$ Hz

Wavelength of signal from second transmitter = λ_2

Both transmitters emit radiowaves, so speed of radiated signal would be same from both.

Since, $v = f\,\lambda$

$f_1 \lambda_1 = f_2 \lambda_2$

$(2.0 \times 10^5)\,(1.5 \times 10^3) = (1.0 \times 10^6)\,\lambda_2$

$\lambda_2 = 3.0 \times 10^2$ m

λ_2 = 300 m

Speed of radio waves = $v = f_1 \lambda_1 = f_2 \lambda_2$

We use $v = f_1 \lambda_1$

$v = (2.0 \times 10^5)\,(1.5 \times 10^3)$

$v = 3.0 \times 10^8$ m s^{-1}

Question 8.2:- Two speakers are arranged in Fig 8.24. The distance between them is 3 m and they emit a constant tone of 344 Hz. A microphone P is moved along a line parallel to and 4.00 m from the line connecting the two speakers. It is found that tone of maximum loudness is heard and displayed on CRO hen microphone is on the center of the line and directly opposite each speaker. Calculate the speed of the sound.

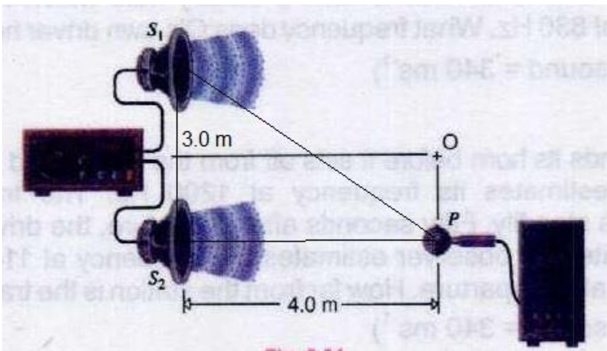

Fig. 8.24

Solution:- Frequency of note = f = 340 Hz

For constructive interference, $\Delta S = n\,\lambda$

At point O, $\Delta S = S_1O - S_2O = 0$ as n = 0.

The next loud signal is heard at point P, it means n = 1 at point P.

$\Delta S = S_1P - S_2P = \lambda$

We can find ΔS by using Pythagorean theorem to right angle triangle S_1S_2P.

$S_1S_2 = 3.0$ m

$S_2P = 4.0$ m

$S_1P = \sqrt{S_1S_2^2 + S_2P^2}$

$S_1P = 5.0$ m

$\Delta S = 5.0 - 4.0 = 1.0$ m

Speed of sound = $v = f\lambda = (344)(1)$

$v = 344\ m\ s^{-1}$

Question 8.3:- A stationary wave is established in a string which is 120 cm long and fixed at both ends. The string vibrates in four segments at a frequency of 120 Hz. Determine its wavelength and fundamental frequency?

Solution:- Length of the string = $l = 120$ cm = 1.2 m

Harmonic generated = $n = 4$

Frequency of harmonic generated = $f_4 = 120$ Hz

Wavelength of n^{th} harmonic in stretched string is $\lambda_n = 2l/n$

$\lambda_4 = 2l/4 = l/2 = 1.2/2$

$\lambda_4 = 0.6$ m

Fundamental harmonic = f_1

Frequency of n^{th} harmonic in stretched string is $f_n = n f_1$

$f_4 = 4 f_1$

$f_1 = f_4/4 = 120/4$

$f_1 = 30$ Hz

Question 8.4:- The frequency of the note emitted by a stretched string is 300 Hz. What will be the frequency of this note when

(a) The length of the wave is reduced by one-third without changing the tension.

(b) The tension is increased by one-third without changing the length of the wire.

Solution:- Frequency of note from stretched string = $f = \frac{v}{\lambda} = 300$ Hz

(a) The length of wave is reduced by one third by keeping tension constant.

$\lambda_1 = \lambda - \frac{\lambda}{3} = \frac{2\lambda}{3}$

Now, the new frequency with reduced wavelength is f_1.

$f_1 = \frac{v}{\lambda_1} = \frac{v}{\frac{2\lambda}{3}} = \frac{3v}{2\lambda} = 1.5 f$

$f_1 = 1.5\,(300)$

$f_1 = 450$ Hz

(b) Frequency of fundamental frequency on a stretched string is $f = \frac{1}{2\,l}\sqrt{\frac{F}{m}}$

The tension is increased by one third without changing the length of the wire.

$F_2 = F + \frac{F}{3} = \frac{4\,F}{3}$

Now, the new frequency with increased tension is f_2.

$f_2 = \frac{1}{2\,l}\sqrt{\frac{F_2}{m}} = f = \frac{1}{2\,l}\sqrt{\frac{\frac{4\,F}{3}}{m}} = \frac{1}{2\,l}\sqrt{\frac{4\,F}{3\,m}}$

$f_2 = \sqrt{\frac{4}{3}}\left(\frac{1}{2\,l}\sqrt{\frac{F}{m}}\right) = \sqrt{\frac{4}{3}}\,f$

$f_2 = 1.154\ f = 1.154\ (300)$

<u>$f_2 = 346$ Hz</u>

Question 8.5:- An organ pipe has a length of 50 cm. Find the frequency of its fundamental note and the next harmonic when it is (a) Open at both ends (b) Closed at one end. (speed of sound=350 m s^{-1})

Solution:- Length of organ pipe = l = 50 cm = 0.50 m

Speed of sound = v = 350 m s^{-1}

(a) Pipe is open at both ends

$f_1 = v/2l = 350/(2)(0.50)$

<u>$f_1 = 350$ Hz</u>

$f_n = n\ f_1$ where n is an integer.

$f_2 = 2\ f_1 = 2\ (350)$

<u>$f_2 = 700$ Hz</u>

(a) Pipe is closed at one end

$f_1 = v/4l = 350/(4)(0.50)$

<u>$f_1 = 175$ Hz</u>

$f_n = n\ f_1$ where n is an odd integer.

$f_3 = 3\ f_1 = 3\ (175)$

<u>$f_3 = 525$ Hz</u>

Question 8.6:- A church organ consists of pipes, each open at one end, of different lengths. The minimum length is 30 mm and the longest is 4 m. Calculate the frequency range of the fundamental notes. (Speed of sound=340 m s^{-1})

Solution:- Length of smallest pipe = l_{min} = 30 mm = 0.03 m

Length of longest pipe = l_{max} = 4 m

Speed of sound = v = 340 m s^{-1}

Pipe is closed at one end so we will use the relation for fundamental harmonic $f_1 = v/4l$

$f_{min} = v/4l_{max} = 340/(4)(4)$

$f_{min} = 21$ Hz

$f_{max} = v/4l_{min} = 340/(4)(0.03)$

$f_{max} = 2833$ Hz

Frequency range of fundamental harmonics is 21 Hz to 2833 Hz.

Question 8.7:- Two tuning forks exhibit beats at a beat frequency of 3 Hz. The frequency of one fork is 256 Hz. Its frequency is then lowered slightly by adding a bit of wax to one of its prongs. The two forks then exhibit a beat frequency of 1 Hz. Determine the frequency of second fork.

Solution:- Beat frequency = n = 3 Hz

Frequency of one tuning fork = $f_1 = 256$ Hz

We know that beat frequency of two tuning fork is $f_1 - f_2 = \pm n$

$f_2 = f_1 \pm n$

$f_2 = 256 \pm 3 = 259$ Hz or 253 Hz

It means there are two possibilities for frequency of second tuning fork.

If we consider $f_2 = 259$ Hz correct and frequency of first tuning fork f_1 is decreased by loading wax on one of its prongs, the beat frequency will increase but actually beat frequency is decreasing. It means $f_2 = 259$ Hz is wrong.

So correct frequency is $f_2 = 253$ Hz.

Question 8.8:- Two cars P and Q are travelling along a motorway in the same direction. The leading car P travels at a steady speed of 12 m s^{-1}, the other car Q, travelling at a steady speed of 20 m s^{-1}, sound its horn to emit a steady which P's driver estimates, has a frequency of 830 Hz. What frequency does Q's own driver hear? (Speed of sound=340 m s^{-1}).

Solution:- Speed of car P = $v_P = 12$ m s^{-1}

Speed of car Q = $v_Q = 20$ m s^{-1}

Relative speed of car Q w.r.t. car P = $u_s = v_Q - v_P = 8$ m s^{-1}

Speed of sound = v = 340 m s^{-1}

Apparent frequency = f ' = 830 Hz

Actual frequency = f

When source is moving towards observer, apparent frequency and actual frequency are linked as $f' = \frac{v}{v - u_s} f$

$(830) = \frac{340}{340 - 8} f$

f = (830)(332)/(340)

f = 810 Hz

Question 8.9:- A train sounds its horn before it sets off from the station and an observer waiting on the platform estimates its frequency at 1200 Hz. The train then moves off and accelerates steadily. 50 seconds after departure, the driver sound the horn again and the platform observer estimates the frequency at 1140 Hz. Calculate the train speed 50 s after departure. How far from the station is the train after 50 s? (Speed of sound = 340 m s^{-1})

Solution:- Actual frequency = f = 1200 Hz

Apparent frequency = f = 1140 Hz

Speed of sound = v = 340 m s^{-1}

When source is moving away from observer, apparent frequency and actual frequency are linked as $f' = \frac{v}{v + u_s} f$

$1140 = \frac{340}{340 + u_s} 1200$

$340 + u_s = (340(1200)/(1140)$

$340 + u_s = 357.9$

$U_s = 17.9$ m s^{-1}

Time taken by train = t = 50 s

Distance travelled = S = v_{av} t = $(\frac{u_s}{2})$ (t)

$S = \frac{1}{2} (17.9)\ (50)$

S = 448 m

Question 8.10:- The absorption spectrum of faint galaxy is measured and the wavelength of one of the lines identified as the calcium α lines is found to be 478 nm. The same line has a wavelength of 397 nm when measured in a laboratory. (a) Is the galaxy moving towards or away from the earth? (b) Calculate the speed of the galaxy relative to earth. (speed of light=3.0 x 10^{8} m s^{-1}).

Solution:- Speed of light = c = 3.0 x 10^{8} m s^{-1}

Apparent wavelength = λ' = 478 nm = 4.78 x 10^{-7} m

Apparent frequency = f ' = c/λ' = (3 x 10^{8})/(4.78 x 10^{-7}) = 6.27 x 10^{14} Hz

Actual wavelength = λ = 397 nm = 3.97 x 10^{-7} m

Actual frequency = f = c/λ = (3 x 10^{8})/(3.97 x 10^{-7}) = 7.56 x 10^{14} Hz

(a) The apparent wavelength is greater than actual wavelength, it means galaxy is moving away from the earth.

OR

The apparent frequency is less than actual frequency, it means galaxy is moving away from the earth.

(b) When source of waves is moving away from observer, apparent frequency and actual frequency are linked as $f' = \frac{c}{c + u_s} f$

$c + u_s = c\left(\frac{f}{f'}\right) = (3.0 \times 10^8)(7.56 \times 10^{14})/(6.27 \times 10^{14})$

$(3.0 \times 10^8) + u_s = 3.61 \times 10^8$

$u_s = (3.61 \times 10^8) - (3.0 \times 10^8)$

$u_s = 0.61 \times 10^8 \text{ m s}^{-1}$

$u_s = 6.1 \times 10^7 \text{ m s}^{-1}$