CBSE Test Paper 03

Chapter 15 Waves

1. 56 tuning forks are arranged in a series that each fork gives 4 beats/sec, with the previous one. The frequency of last fork is 3 times that of first. Then frequency of first fork is **1**
   a. 60 Hz
   b. 110 Hz
   c. 56 Hz
   d. 52 Hz
2. If a star emitting orange light moves away from the earth, its color will **1**
   a. appear yellow
   b. remain the same
   c. turns gradually blue
   d. appear red
3. A stretched string resonates with tuning fork frequency 512 Hz when length of the string is 0.5 m. The length of the string required to vibrate resonantly with a tuning fork of frequency 256 Hz would be **1**
   a. 0.5 m
   b. 0.25 m
   c. 1 m
   d. 2 m
4. A sound wave has frequency 500 Hz and velocity 350 m/s. What is the distance between the two particles having phase difference of 60^{o} **1**
   a. 11.6 cm
   b. 120 cm
   c. 70 cm
   d. 0.7 cm
5. The quantity similar to extension or compression of the spring in sound wave propagation (air) is **1**
   a. the change in air density
   b. the change in air particles

c. the change in air composition
d. the change in air humidity

6. Sound waves of wavelength λ travelling in a medium with a speed of v m/s enter into another medium where, its speed is 2v m/s. What is the wavelength of the sound wave in the second medium? **1**

7. Why does sound travel faster in iron than in Water or air? **1**

8. We cannot hear echo in a room. Explain? **1**

9. Estimate the speed of sound in air at STP. The mass of 1 mole of air is 29.0×10^{-3} kg. **2**

10. At what temperature (in °C) will the speed of sound in air be 3 times its value at 0°C? **2**

11. A rocket is moving at a speed of 200 ms^{-1} towards a stationary target. While moving, it emits a wave of frequency 1000 Hz. Some of the sound reaching the target gets reflected back to the rocket as an echo. Calculate the frequency of sound as detected by the person at the position of target and frequency of echo as detected by the rocket. Given, the velocity of sound = 330 ms^{-1}. **2**

12. The equation of a wave is given by y = 6 sin 10πt + 8 cos 10πt, where y is in centimetre and t in second. Determine the constants involved in the standard equation of the wave. **3**

13. From the equation y - A sin $\frac{2\pi}{\lambda}(vt - x)$, establish the relation between particle velocity and wave velocity. **3**

14. Briefly explain propagation of sound waves in air. **3**

15. A transverse harmonic wave on a string is described by y(x,t) = 3sin(36t + 0.018x + $\frac{\pi}{4}$), where *x* and *y* are in cm and *t* in s. The positive direction of *x* is from left to right. **5**
    a. Is this a travelling wave or a stationary wave? If it is a travelling wave, what is the speed and direction of its propagation?
    b. What is its amplitude and frequency?
    c. What is the initial phase at the origin?
    d. What is the least distance between two successive crests in the wave?

Answer

1. b. 110 Hz

 Explanation: Frequency of beats is given by

 f_{beat} = $|f_1 - f_2|$

 given $f_{beat} = 4$

 thus $4 = f_1$ - f2

 $4 = f_2 - f_3$

 and so on $4 = f_{55} - f_{56}$

 we get 56 such equations on adding all equations we get

 $220 = f_1 - f_{56}$

 given $f_{56} = 3f_1$

 on substituting we get

 $f_1 = 110$ Hz

2. d. appear red

 Explanation: Due to doppler effect for source moving away from stationary observer

 $f_1 = \frac{v}{v+u} \times f$

 Frequency will decrease thus wavelength will increase thus signal will shift toowards red light.

3. c. 1 m

 Explanation: Using $v = \frac{1}{2L}\sqrt{\frac{F}{u}}$

 If F and u are kept constant thus v is inversly proportional to L. Thus if v is halved then L will be doubled.

 So for v= 256 hz , L become 1m.

4. a. 11.6 cm

 Explanation: Here Frequency = 500 Hz

Velocity = 350 m/s

Phase difference = 600

As wavelength = velocity /frequency = 350/500 = 0.7 m

Now, path difference = $\left(\frac{\lambda}{2\pi}\right)$ phase difference

Path difference =$\left(\frac{0.7}{2\pi}\right)\left(\frac{\pi}{3}\right)$ =0.116 m = 11.6 cm

5. a. the change in air density

Explanation: As in air wave propagates in the form of compression (increase in density of air) and rarefaction (decrease in density of air).

6. Frequency in the first medium, ν = $\frac{v}{\lambda}$
We know that frequency will remains the same as before in the second medium too.
$\therefore \nu' = \nu \Rightarrow \frac{2v}{\lambda'} = \frac{v}{\lambda} \Rightarrow \lambda' = 2\lambda$ which means the wavelength will become double that of the previous one.

7. Sound travel faster in iron or solids because iron or solid is highly elastic as compared to water (liquids) or air (gases).

8. We know that the basic condition for an echo to be heard is that the obstacle should be rigid and of large size. Also the obstacle should be at least at a distance of 17m from the source. Since the length of the room is generally less than 17m, the conditions for the production of Echo are not satisfied. Hence no echo is heard in a room.

9. We know that volume of any gas at STP is 22.4 litre.
Density of air at STP is
$\rho_0 = \left(\frac{\text{mass}}{\text{volume at STP}}\right)_{\text{for one mole of air}}$
$= \frac{29.0\times10^{-3}\text{kg}}{22.4\times10^{-3}m^3} = 1.29\ \text{kgm}^{-3}$
According to Laplace's correction over Newton's formula,
Speed of sound, v = $\sqrt{\frac{\gamma P}{\rho_0}}$
= $\left[\frac{1.01\times10^5\times1.4\ \text{Nm}^{-2}}{1.29\text{kgm}^{-3}}\right]^{1/2}$ [$\gamma = 1.4$ (air) = ratio of two specific heats and P = 1.01 × 10^5 N/m^2 = atmospheric pressure]
= 331.3 ms^{-1}

10. We know that, speed of sound, v $\propto \sqrt{T}$, T being absolute temperature.
where, T is in kelvin.
$\therefore \frac{V_t}{V_0} = \sqrt{\frac{273+t}{273+0}}$ = 3 (say, the required temperature is t°C)
$\Rightarrow \frac{273+t}{273}$ = 9
$\Rightarrow$ t = (9 $\times$ 273) - 273 = 2184°C

11. Here, the speed of source, V_S = 200 ms^{-1}, actual frequency ν =1000Hz

Target is at rest i.e. the speed of the observer, V_0 = 0

As source is moving towards the target or observer, therefore, apparent frequency
ν = ν_0 $\left(1-\frac{V_s}{V}\right)^{-1}$ = 1000 × $\left(1-\frac{200}{330}\right)^{-1}$
= 1000 ×$\left(\frac{130}{330}\right)^{-1}$ = 1000 $\times \frac{330}{130} \approx$ 2538 Hz
In the second case, target is the source of echo, which is at rest(i.e. V_S =0). Rocket's

detector is the listener.
$\therefore \nu' = \nu\left(\frac{V+V_o}{V}\right)$= 2538 × $\left(\frac{330+200}{330}\right) \approx$ 4076 Hz

12. Given, y =6 sin 10πt + 8 cosπ cm...(i)
Now the general equation of this type of wave is
y = A sin($\omega t + \phi$)
$= A \sin \omega t \cos \phi + A \cos \omega t \sin \phi$
$= (A \cos \phi) \sin \omega t + (A \sin \phi) \cos \omega t$.......(ii)
Comparing Eqs.(i) and (ii), we get
$A \cos \phi = 6$.......(iii)
and A sin ϕ = 8 ....(iv)
Time period,$T = \frac{2\pi}{\omega} = \frac{2\pi}{10\pi} = 0.2$s
Squaring and adding Eqs.(iii) and (iv), we get
$A^2\left(\cos^2 \phi + \sin^2 \phi\right) = 6^2 + 8^2$
= 36 + 64 = 100

or A^2 = 100
$\therefore$ A = 10 cm, the amplitude of the given wave.
Dividing Eq.(iv) by (iii), we get
$\tan \phi = \frac{8}{6}$ = 1.3333

$\therefore \phi = \tan^{-1}(1.3333) = 53°8'$, the value of phase angle of the given wave in the question

13. The velocity with which the wave travels in space is called the wave velocity , whereas particle velocity is the velocity with which the particles are vibrating to transfer the energy in form of a wave. The relation between wave velocity and particle velocity is given as:
The given wave equation is y = A sin $\frac{2\pi}{\lambda}(vt - x)$ = A sin $\left(\frac{2\pi v}{\lambda}t - \frac{2\pi}{\lambda}x\right)$
or y = A sin (ωt - kx),
because $2\pi\frac{v}{\lambda} = 2\pi v$ = ω = angular frequency
and $\frac{2\pi}{\lambda}$ = k = propogation constant.
$\therefore$ particle velocity $\frac{dy}{dt}$ = $\frac{dA\sin(wt-kx)}{dt}$ =A ω cos (ωt - kx)
and $\frac{dy}{dx}$ = $\frac{dA\sin(wt-kx)}{dx}$ = -AK cos (ωt - kx)
$\therefore$ wave velocity v = $\frac{dx}{dt}$ = $\left(\frac{dy}{dt}.\frac{-dx}{dy}\right)$ = $\frac{\omega}{k}$
Hence we conclude that particle velocity $\frac{dy}{dt}$ = (-$\frac{dy}{dx}$) $\times$ wave velocity
Here $\frac{dy}{dx}$ is the slope of displacement position graph for given wave motion.
$\therefore$ Particle velocity = - (slope of displacement - position graph) $\times$ wave velocity.

14. Sound waves in air are propagated as longitudinal waves. Longitudinal waves are the types of waves in which displacement of the particles in the propagation medium take place horizontally with the direction of the wave. When the vibration of the sound source applies pressure at a frequency of its own vibration then this situation begins. During their propagation, waves can be reflected, refracted or attenuated by the medium. As the sound wave passes through the air, it compresses or expands a small region of the air. It causes a change in the density of that air region, which in turn induces a change in pressure in that region. As pressure is force per unit area, so there is a restoring force whose magnitude is directly proportional to the disturbance which causes compression. If a particular air region is compressed, the molecules in that region are packed together and they tend to move out to the adjoining region. Consequently, the density of the adjoining region is also increased, and compression is created there . As a result, the air in the first region undergoes rarefaction. If a region is comparatively rarefied then the surrounding air will rush in making the rarefaction move the adjoining region. In this way, compression or rarefaction moves

from one region to another, making the propagation of a disturbance possible in the air. Such a wave which travels in the form of compression and rarefaction is called a longitudinal wave. Thus, it is clear that sound waves in air are longitudinal waves.

15. a. Progressive wave equation travelling from right to left is given by the displacement function:

   y(x, t) = a sin ($\omega t + kx + \theta$) ...(i)

   where, a = amplitude , ω= angular frequency, θ = phase constant

   The given equation is:

   $y(x,t) = 3\sin\left(36t + 0.018x + \frac{\pi}{4}\right)$ ....(ii)

   On comparing both the equations, we find that the given equation (ii) represents a travelling wave, propagating from right to left.

   From equations (i) and (ii), we can write: ω = 36 rad/s and k = 0.018 cm^{-1}

   We know that:

   Frequency of wave, $\nu = \frac{\omega}{2\pi}$ and Wavelength of wave, $\lambda = \frac{2\pi}{k}$

   Also speed, v = $\nu\lambda$

   $\therefore v = \left(\frac{\omega}{2\pi}\right) \times \left(\frac{2\pi}{k}\right) = \frac{\omega}{k} = \frac{36}{0.018} = 2000\mathrm{cm/s} = 20\mathrm{m/s}$

   Hence, the speed of the given travelling wave is 20 m/s.

   b. On comparing (i) and (ii), amplitude of the given wave, a = 3 cm

   Frequency of the given wave:

   $\nu = \frac{\omega}{2\pi} = \frac{36}{2\times3.14} = 5.73Hz$

   c. On comparing equations (i) and (ii), we find that the initial phase angle, $\theta = \frac{\pi}{4}$

   d. The distance between two successive crests or troughs is equal to the wavelength of the wave.

   Wavelength is:

   $\lambda = \frac{2\pi}{k} = \frac{2\times3.14}{0.018} = 348.89\mathrm{cm} = 3.49\mathrm{m}$