

Section 12.1

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1. How does the sound produced by a vibrating object in a medium reach your ear?

Solution:

When an object vibrates, it necessitates the surrounding particles of the medium to vibrate. The particles that are adjacent to vibrating particles are forced to vibrate. Hence the sound produced by a vibrating object in a medium is transferred from particle to particle till it reaches your ear.

Section 12.2

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1. Explain how sound is produced by your school bell.

Solution:

When the school bell is hit with a hammer, it moves forward and backwards producing compression and rarefaction due to vibrations. This is how sound is produced by the school bell.

2. Why are sound waves called mechanical waves?

Solution:

Sound waves require a medium to propagate to interact with the particles present in it. Therefore sound waves are called mechanical waves.

3. Suppose you and your friend are on the moon. Will you be able to hear any sound produced by your friend?

Solution:

No. Sound waves require a medium to propagate. Due to the absence of atmosphere on the moon and since sound cannot travel in vacuum, I will not be able to hear any sound produced by my friend.

Section 12.2.3

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1. Which wave property determines (a) loudness, (b) pitch?

Solution:

(a). Amplitude - The loudness of the sound and its amplitude is directly related to each other. Larger the amplitude louder is the sound.

(b). Frequency - The pitch of the sound and its frequency is directly related to each other. If the pitch is high then the frequency of sound is also high.

2. Guess which sound has a higher pitch: guitar or car horn?**Solution:**

The pitch of a sound is directly proportional to its frequency. Therefore, the guitar has a higher pitch when compared to a car horn.

3. What are wavelength, frequency, time period and amplitude of a sound wave?**Solution:**

- (a) Wavelength - Wavelength can be defined as the distance between two consecutive rarefactions or two consecutive compressions. The SI unit of wavelength is meter (m).
- (b) Frequency - Frequency is defined as the number of oscillations per second. The SI unit of frequency is hertz (Hz).
- (c) Amplitude - Amplitude can be defined as the maximum height reached by the trough or crest of a sound wave.
- (d) Time period - The time period is defined as the time required to produce one complete cycle of a sound wave.

4. How are the wavelength and frequency of a sound wave related to its speed?**Solution:**

Wavelength, speed, and frequency are related in the following way:

Speed = Wavelength x Frequency

$$v = \lambda \nu$$

5. Calculate the wavelength of a sound wave whose frequency is 220 Hz and speed is 440 m/s in a given medium.**Solution:**

Given that,

Frequency of sound wave = 220 Hz.

Speed of sound wave = 440 m/s.

Calculate wavelength.

We know that,

Speed = Wavelength X Frequency

$$v = \lambda \nu$$

$$440 = \text{Wavelength} \times 220$$

$$\text{Wavelength} = 440/220$$

$$\text{Wavelength} = 2$$

Therefore, the wavelength of the sound wave = 2 meters.

6. A person is listening to a tone of 500 Hz sitting at a distance of 450 m from the source of the sound. What is the time interval between successive compressions from the source?

Solution:

The time interval between successive compressions from the source is equal to the time period and time period is reciprocal of the frequency. Therefore, it can be calculated as follows:

$$T = 1/F$$

$$T = 1/500$$

$$T = 0.002 \text{ s.}$$

7. Distinguish between loudness and intensity of sound.

Solution:

The amount of sound energy passing through an area every second is called intensity of a sound wave. Loudness is defined by its amplitude.

Section 12.2.4

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7. In which of the three media, air, water or iron, does sound travel the fastest at a particular temperature?

Solution:

Sound travels faster in solids when compared to any other medium. Therefore, at a particular temperature, sound travels fastest in iron and slowest in gas.

Section 12.3.2

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1. An echo is heard in 3 s. What is the distance of the reflecting surface from the source, given that the speed of sound is 342 m s^{-1} ?

Solution:

$$\text{Speed of sound } (v) = 342 \text{ ms}^{-1}$$

$$\text{Echo returns in time } (t) = 3 \text{ s}$$

$$\text{Distance travelled by sound} = v \times t = 342 \times 3 = 1026 \text{ m}$$

In the given interval of time, sound must travel a distance which is twice the distance of reflecting surface and source.

$$\text{Therefore, the distance of reflecting surface from the source} = 1026/2 = 513 \text{ m.}$$

Section 12.3.3

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1. Why are the ceilings of concert halls curved?

Solution:

Ceilings of concert halls are curved to uniformly spread sound in all directions after reflecting from the walls.

Section 12.4

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1. What is the audible range of the average human ear?

Solution:

20 Hz to 20,000 Hz. Any sound less than 20 Hz or greater than 20,000 Hz frequency is not audible to human ears.

2. What is the range of frequencies associated with (a) Infrasound? (b) Ultrasound?

Solution:

(a). 20 Hz

(b). 20,000 Hz.

Section 12.5.1

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1. A submarine emits a sonar pulse, which returns from an underwater cliff in 1.02 s. If the speed of sound in salt water is 1531 m/s, how far away is the cliff?

Solution:

Time (t) taken by the sonar pulse to return = 1.02 s

Speed (v) of sound in salt water = 1531 m s⁻¹

Distance travelled by sonar pulse = Speed of sound × Time taken
= 1531 × 1.02 = 1561.62 m

Distance of the cliff from the submarine = (Total distance travelled by sonar pulse) / 2
= 1561.62 / 2
= 780.81 m.

Exercise Questions

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1. What is sound and how is it produced?

Solution:

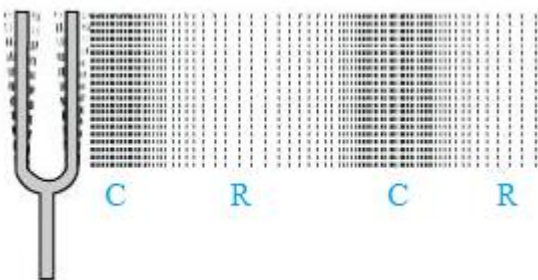
Sound is produced

due to vibrations. When a body vibrates, it forces the adjacent particles of the medium to vibrate. This results in a disturbance in the medium, which travels as waves and reaches the ear. Hence sound is produced.

2. Describe with the help of a diagram, how compressions and rarefactions are produced in the air near a source of sound.

Solution:

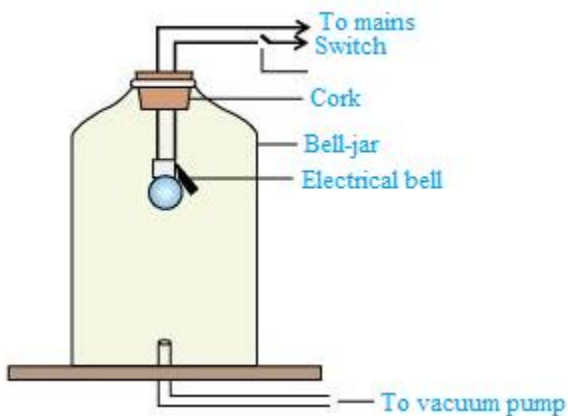
When the school bell is hit with a hammer, it moves forward and backwards producing compression and rarefaction due to vibrations. When it moves forward, it creates high pressure in its surrounding area. This high-pressure region is known as compression. When it moves backwards, it creates a low-pressure region in its surrounding. This region is called rarefaction.



3. Cite an experiment to show that sound needs a material medium for its propagation.

Solution:

Take an electric bell and hang it inside an empty bell-jar which is fitted with a vacuum pump (as shown in the figure below).



Initially, one can hear the sound of the ringing bell. Now, pump out some air from the bell-jar using the vacuum pump. You will realize that the sound of the ringing bell

decreases. If you keep on pumping the air out of the bell-jar, then glass-jar will be devoid of any air after some time. Now try to ring the bell. No sound is heard but you can see bell prong is still vibrating. When there is no air present in the bell jar, a vacuum is produced. Sound cannot travel through vacuum. Therefore, this experiment shows that sound needs a material medium for its propagation.

4. Why sound wave is called a longitudinal wave?

Solution:

The vibration of the medium that travels parallel to the direction of the wave or along in the direction of the wave, is called a longitudinal wave. The direction of particles of the medium vibrates parallel to the direction of the propagation of disturbance. Therefore, a sound wave is called a longitudinal wave.

5. Which characteristics of the sound help you to identify your friend by his voice while sitting with others in a dark room?

Solution:

Quality of sound is a characteristic that helps us identify the voice of a particular person. Two people may have the same pitch and loudness, but their qualities will be different.

6. Flash and thunder are produced simultaneously. But thunder is heard a few seconds after the flash is seen, why?

Solution:

The speed of sound is 344 m/s whereas the speed of light is 3×10^8 m/s. The speed of light is less when compared to that of light. Due to this reason, the thunder takes more time to reach the Earth as compared to the light speed which is faster. Hence, lightning is seen before whenever we hear the thunder.

7. A person has a hearing range from 20 Hz to 20 kHz. What are the typical wavelengths of sound waves in air corresponding to these two frequencies? Take the speed of sound in air as 344 m s^{-1} .

Solution:

For sound waves,

Speed = Wavelength X frequency

$$v = \lambda \times f$$

Speed of sound wave in air = 344 m/s

a. For $f = 20 \text{ Hz}$

$$\lambda_1 = v/f_1 = 344/20 = 17.2 \text{ m}$$

b. For $f_2 = 20,000 \text{ Hz}$

$$\lambda_2 = v/f_2 = 344/20,000 = 0.0172 \text{ m}$$

Therefore, for human beings the hearing wavelength is in the range of 0.0172 m to 17.2 m.

8. Two children are at opposite ends of an aluminum rod. One strikes the end of the rod with a stone. Find the ratio of times taken by the sound wave in the air and in aluminum to reach the second child.

Solution:

Consider the length of aluminum rod = d

Speed of sound wave at 25°C , $V_{\text{Al}} = 6420\text{ ms}^{-1}$

Time taken to reach other end

$$t_{\text{Al}} = d/(V_{\text{Al}}) = d/6420$$

Speed of sound in air, $V_{\text{air}} = 346\text{ ms}^{-1}$

Time taken by sound to each other end,

$$t_{\text{air}} = d/(V_{\text{air}}) = d/346$$

Therefore, the ratio of time taken by sound in aluminum and air,

$$t_{\text{air}} / t_{\text{Al}} = 6420 / 346 = 18.55$$

9. The frequency of a source of sound is 100 Hz. How many times does it vibrate in a minute?

Solution:

Frequency = (Number of oscillations) / Total time

Number of oscillations = Frequency \times Total time

Given,

Frequency of sound = 100 Hz

Total time = 1 min (1 min = 60 s)

Number of oscillations or vibrations = $100 \times 60 = 6000$

The source vibrates 6000 times in a minute and produces a frequency of 100 Hz.

10. Does sound follow the same laws of reflection as light does? Explain.

Solution:

Yes. Sound follows the same laws of reflection as light. The reflected sound wave and the incident sound wave make an equal angle with the normal to the surface at the point of incidence. Also, the reflected sound wave, the normal to the point of incidence, and the incident sound wave all lie in the same plane.

11. When a sound is reflected from a distant object, an echo is produced. Let the distance between the reflecting surface and the source of sound production remains the same. Do you hear echo sound on a hotter day?

Solution:

An echo is heard when time interval between the reflected sound and the original sound is at least 0.1 second. As the temperature increases, the speed of sound in a medium

also increases. On

a hotter day, the time interval between the reflected and original sound will decrease and an echo is audible only if the time interval between the reflected sound and the original sound is greater than 0.1 s.

12. Give two practical applications of reflection of sound waves.

Solution:

(i) Reflection of sound is used to measure the speed and distance of underwater objects. This method is called SONAR.

(ii) Working of a stethoscope - the sound of patient's heartbeat reaches the doctor's ear through multiple reflections of sound.

13. A stone is dropped from the top of a tower 500 m high into a pond of water at the base of the tower. When is the splash heard at the top? Given, $g = 10 \text{ m s}^{-2}$ and speed of sound = 340 m s^{-1} .

Solution:

Height (s) of tower = 500 m

Velocity (v) of sound = 340 m s^{-1}

Acceleration (g) due to gravity = 10 m s^{-2}

Initial velocity (u) of the stone = 0

Time (t_1) taken by the stone to fall to tower base

As per second equation of motion:

$$s = ut_1 + \left(\frac{1}{2}\right) g (t_1)^2$$

$$500 = 0 \times t_1 + \left(\frac{1}{2}\right) 10 (t_1)^2$$

$$(t_1)^2 = 100$$

$$t_1 = 10 \text{ s}$$

Time (t_2) taken by sound to reach top from tower base = $500/340 = 1.47 \text{ s}$.

$$t = t_1 + t_2$$

$$t = 10 + 1.47$$

$$t = 11.47 \text{ s}.$$

14. A sound wave travels at a speed of 339 m s^{-1} . If its wavelength is 1.5 cm, what is the frequency of the wave? Will it be audible?

Solution:

Speed (v) of sound = 339 m s^{-1}

Wavelength (λ) of sound = $1.5 \text{ cm} = 0.015 \text{ m}$

Speed of sound =
Wavelength \times Frequency
 $v = \lambda \times \nu$
 $\nu = v / \lambda = 339 / 0.015 = 22600 \text{ Hz}.$

The frequency of audible sound for human beings lies between the ranges of 20 Hz to 20,000 Hz. The frequency of the given sound is more than 20,000 Hz, therefore, it is not audible.

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15. What is reverberation? How can it be reduced?

Solution:

The continuous multiple reflections of sound in a big enclosed space is reverberation. It can be reduced by covering walls and ceiling of enclosed space with the help of sound absorbing materials such as loose woollens, fibre boards.

16. What is loudness of sound? What factors does it depend on?

Solution:

Loud sounds have high energy. Loudness directly depends on the amplitude of vibrations. It is proportional to the square of the amplitude of vibrations of sound.

17. Explain how bats use ultrasound to catch prey.

Solution:

Bats have the ability to produce high-pitched ultrasonic squeaks. These squeaks get reflected by objects like preys and return to their ears. This helps a bat to know how far his prey is.

18. How is ultrasound used for cleaning?

Solution:

Objects that need to be cleansed are put in a cleaning solution and ultrasonic sound waves are passed through the solution. The high frequency of ultrasound waves helps in detaching the dirt from the objects. In this way ultrasound is used for cleaning purposes.

19. Explain the working and application of a sonar.

Solution:

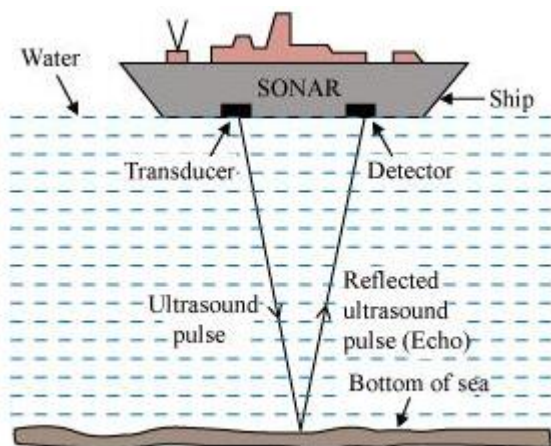
SONAR is an abbreviation of **Sound Navigation And Ranging**. It is an acoustic device used in measuring the direction, speed, and depth of under-water objects viz. ship wrecks and submarines using ultrasound.

Also, it is used to determine the depth of oceans and seas.

A beam of ultrasonic sound is produced and travels through the sea water which is transmitted by the transducer. When it reflects an echo is produced which is detected and recorded by the detector. It is then converted into electrical signals. The distance is represented by 'd' of the under-water object is calculated from the time (represented as 't') taken by the echo to return with speed (represented as 'v') is expressed as,

$$2d = v \times t.$$

This method of measuring distance is also referred to as echo-ranging.



20. A sonar device on a submarine sends out a signal and receives an echo 5 s later. Calculate the speed of sound in water if the distance of the object from the submarine is 3625 m.

Solution:

Time (t) taken to hear the echo = 5 s

Distance (d) of object from submarine = 3625 m

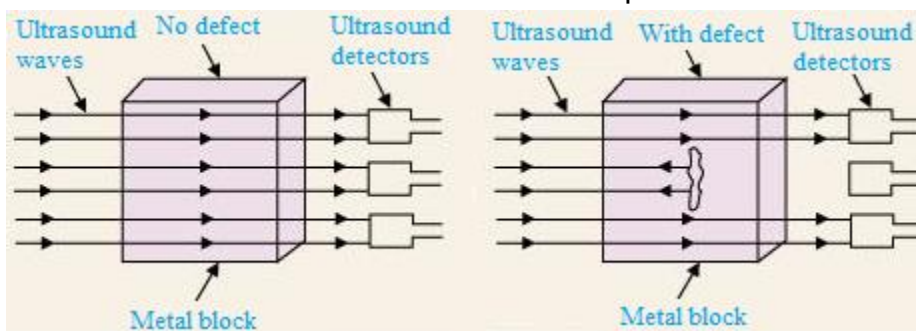
Total distance travelled by SONAR during reception and transmission in water = 2d

Velocity (v) of sound in water = $2d/t = (2 \times 3625) / 5$

= 1450 ms^{-1}

21. Explain how defects in a metal block can be detected using ultrasound.**Solution:**

Defective metal blocks will not allow ultrasound to pass through it and reflect it back. This technique is used in detecting defects in metal blocks. Make a set up as shown in the figure with ultrasound being passed through one end and detectors placed on the other end of a metal block. Since the defective part of the metal block does not allow ultrasound to pass through it, it will not be detected by the detector. In this way, defects in metal blocks can be detected with the help of ultrasound.

**22. Explain how the human ear works.****Solution:**

Various sounds produced by particles in our surroundings are collected by pinna that transfers these sounds to the ear drum through the ear canal. The eardrum begins to vibrate back and forth briskly as soon as the sound waves fall on it. The vibrating Eardrum initiates the small bone hammer to vibrate. These vibrations are passed from the hammer to the third bone stirrup via the second bone anvil. The stirrup strikes the membrane of the oval window to pass its vibration to the cochlea. The liquid in the cochlea produces electrical impulses in the nerve cells. These electrical impulses are carried to the brain by the auditory nerve. They are interpreted by the brain as sound and hence we get a sensation of hearing.

