Chapter three sound waves

Introduction

- Sound wave is a mechanical wave which produce sensation of hearing .it requires material medium to travel through it. Sound wave produced by vibrating object.
- Sound wave is a longitudinal wave consisting of a successive compression and rarefaction to which air is sensitive.
- Sound is a longitudinal wave created by vibrating objects such loud speakers and human vocal cords .the particles carry the sound vibrate in fixed positions parallel to the direction in which sound wave travels.

What is a sound?

- Sound wave is a mechanical wave that produces a sensation of hearing.

Conditions for hearing sound

- Vibrating body
- Material medium
- Receiver

Sources of sound waves

- Sound waves are produced by
  1. Vibrating strings such as guitar
  2. Vibrating surfaces such as drum
  3. Tubes which air column vibrates in musical instruments such trumpets and saxophones

Production of sound

- Sounds are produced by vibrating mater .any vibrating body produce sound.

Sound transmission

- Sound travels through solid, liquid and gases but Sound does not travel (propagate) through vacuum.

Experiments shows sound transmission

- An electric bell under a bell jar is connected to source of energy so that it rings, if air is in the bell jar a sound is heard but if all air is removed from the bell jar no sound is heard even through if it still ringing. Thus sound energy cannot travel vacuum it need s material medium like air.

Speed of sound

- Sound travels at different speeds through different materials. At room temperature (**20**℃) The speed of sound in air is **344m/s,** The speed of sound in water is **1500m/s**
- . Liquids are batter transmitters of sound than gases but Solids are best transmitters of sound than either liquid or gases.
- In general, the speed of sound is maximum in solids ,lesser in liquids and least gages
- The velocity of sound in the air is 330m/s at 0℃, for every 1℃ rise or fall in temperature ,the velocity of sound increased or decreased by 0.6℃. it is given by:

$$\mathbf{V = 330m/s + 0.6\frac{m/s}{^\circ C}\ xT}$$

Factors that effects speed of sound in air

- The following are factors that depend on speed of sound in air are **medium of sound is traveling in, change in humidity, wind and change in temperature of air.**
- When temperature of air rises, the speed of sound in air increases, so, speed of sound in air will be more on hot day than on cold days.
- The speed of sound travels slower in dry air but faster in humid air. In fact, as the humidity of air increases, the speed of sound increases.
- The following factors does not effects speed of sound in air
    - Change in wavelength
    - change in frequency
    - change in amplitude
    - change in pressure

Examples

1. What is the velocity of sound in air at 20℃? **[342m/s]**
2. The speed of sound in air is 348m/s. what is the temperature of sound?
   [30℃]
3. Calculate the speed of sound In air when the temperature is
   a) -20℃ b)40℃ d) 32℉ **[a)318m/s b)354m/s c) 330m/s]**

Class work

1. Why sound is important?
2. Describe sound?
3. Sound travels much more slowly than light, why?
4. State and explain the medium through which sound travels
5. Can sound travels though
   a) Iron b) water, through which is sound faster and why?

6) What is the speed of sound in air, water and iron?
7) Describe an experiment to show that sound cannot pass through a vacuum?
8) Determines the speed of sound at a temperature -5℃?
9) The speed of sound at 10℃ is 326m/s. calculate the speed of sound at 34℃
   [350.4m/s]
10) Calculate the speed of at -10℃ is 314m/s. calculate the speed of at
    a) -40℃
    b) 40℃ **[a)306 m/s b)354m/s]**
11) Calculate the temperature of sound at which the speed of sound is 331.5m/s
    [2.5℃]
12) Find the speed of sound at temperature of
    a) 30℃
    b) 45℃
    c) 182℉
    d) 60 ℃ **[a) 348m/s b) 357m/s c) 380m/s d) 336m/s]**
13) The speed of sound is 320m/s at 0℃. Calculate the temperature ,when its speed
    a) Increases by 1/10 of speed at 0℃
    b) Decreases 1/8 of the speed at 0℃ **[a) 53.33℃ b) -66.67℃]**

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Reflection of sound

- the bouncing of sound when it hits a hard surface is called **reflection of sound**

Echo

- The reflection of sound wave is called echo. The repetition of sound when it is reflected from a distance object is called echo.
- Echoes travels twice the distance between the source of sound and reflecting body .therefore the speed of sound by echo method is:
  1. v = $\frac{2d}{t}$
  2. t = $\frac{2d}{v}$
  3. d = $\frac{v\,x\,t}{2}$ where v = velocity of sound, t= time and d is the distance between source of sound and reflecting body.
  4. v = $\frac{d}{t}$ not echo
- The minimum time persists sound the ear after exiting sound dies off is called **persistence of audibility or persistence of hearing.** This time equal to $\frac{1}{10}$sec or 0.1sec.

Conditions for formation echo

- The minimum distance between the source of sound and reflecting body is 17m.
- The wavelength of sound should be less than the height of the reflecting body.
- The intensity of sound should be sufficient so that it can be heard after reflection.

Reflecting bodies

- **The reflecting bodies of sound can be :**
  - Hard surfaces: are surfaces that reflect sound and does not absorb such as glass, stones , metals and wood
  - Soft surfaces: are surfaces that absorb sound but does not reflect sound. Such as clothes and rubber.

Reverberation

- Reverberation is series of reflection that fall on the ear from various reflectors one after another in a closed room forming a continuous rolling sound.

Uses of echo

- Determination of the depth of ocean (sea)
- Echo are used by bats ,dolphins, to locate their prey
- Trawler man (fisherman) for locating fish
- Army for locating gun positions of the enemy
- Geologists for mineral prospecting
- Dolphins communicate with each other.

Problems

1) Echo is heard after 5sec at 25℃. Find the distance between the source of sound and reflecting surface? **[862.5m]**
2) A boy stands 66.4m in front of high wall and then blows a whistle. Find the time of echo, if the speed of sound is 332m/s? **[0.4sec]**
3) A man stands between two parallel cliffs and fires a gun. He hears two successive echoes after 3sec and 5sec what is the distance between cliffs, if v = 330m/s. **[1320m]**

Class work

1) A person fires a gun in front of a building 167m away. If the speed of sound is 334m/s. calculate the time in which he hears an echo. **[1sec]**
2) An echo is heard after 0.8sec when a person fires a cracker, 132.8m from a high building. Calculate the speed of sound? **[332m/s]**
3) The speed of sound is 310m/s. a person fires a gun. An echo is heard after 1.5sec. Calculate the distance of person from a cliff from which echo take place? **[232.5m]**
4) A man stands in between two high rise building and blows a whistle. he hears two successive echoes after 0.4sec and 1.6sec. Calculate the distance between the buildings if speed of sound is 332m/s? **[332m]**
5) A man stands in between two parallel cliffs and explodes a cracker. he hears first echo after 0.6sec and a second echo after 2.4 sec. calculate the distance between the cliffs, if speed of sound is 336m/s ? **[504m]**
6) What time is required for sound to travel 5km if temperature is 150℃? **[14.7sec]**
7) What is the distance between two adjacent rarefactions in a sound wave whose velocity is 336m/s and whose frequency is 408Hz? **[0.82m]**
8) What is the shortest wavelength of sound that can be heard by human, if the frequency of audible sound lie between 20HZ and 20kz if v= 344m/s ? **[1.72m]**
9) The coldest and hottest temperatures ever recorded in a certain region are 800°F and 1340°F. What is the speed of sound at each temperature? **[293m/s , 364m/s]**
10) What is the frequency of sound traveling in air at 25℃ has wavelength equal to 1.7m? **[203 Hz]**
11) A shell fired at a target 800m distance was heard to strike it 5sec after leaving the sun. Compute the average horizontal velocity of shell? **[320m/s]**
12) The sound of thunderclap was heard 3sec after the flash was seen. if the temperature as that time was 50℃, find the distance of the cloud? **[1.08km]**

13) A sonar signal sent vertically downward from a ship is reflected from the ocean floor and detected 3sec later. If the speed of sound in water is 1500m/s. what is the depth of the ocean in kilometer?. **[2.25km]**

14) A person stands at a point 300m in front of the face of a sheer cliff. If the person shows shout, how much time will elapse before echo is heard? The temperature of air is 20℃. **[1.75sec]**

15) A sound wave is sent from a ship a point just below the water surface and the sound received 1.75sec later. Taking the speed of sound in water 1500m/s . how deep is the sea under the ship? **[1312.5m]**

16) Thunder was heard 2.3sec after the lighting if the temperature was 25℃, how far was the lighting? **[793.5m]**

17) An object is dropped into a deep well which has water. If the wall is 20m deep. How long after the object is dropped will splash is heard if temperature of air is 20℃? **[2.08sec]**

18) A geologist camped 6000m a volcano as it erupts.
(a) How much time elapse before the geologist hears the sound from the eruption? If temperature of air is 20℃
(b) How much time does it take for the seismic the wave s travel through granite with speed of 4000m/s. **[a) 17sec b) 1.5sec]**

19) Ali and Abdi go for a walk along abandoned railroad truck, Ali puts one ear next to a rail, while Abdi 300m away taps in the rail with a stone. How much sooner does Ali hear the sound if speed of sound in steel is 6500m/s? **[0.05sec]**

Law of reflection of sound

- The law of reflection of sound states that:
  1. Incident ray (wave) reflected wave and normal lies on the same plane at point of incidence.
  2. The angle of incidence always equal to the angle of reflection.

<i =<r

Application of reflection of sound

1. Hearing aid : it is a device used by people with difficulty in hearing
2. Bulb horn: it is a cone shaped wind instrument used for signaling in bicycles, cars, buses and boats.
3. **Stethoscope;** is a medical instrument used by the doctors for listening to the sounds produced by within human body especially in the heart and lungs.

Exercise

Answer all the following questions

1. Explain the reflection of sound
2. What condition for formation echoes
3. State law of reflection of sound
4. Describe two application of reflection of sound
5. List two uses of echo
6. Define reverberation
7. What methods are used for reducing excessive reverberation in big halls?
8. State advantages and disadvantages of reverberation
9. How do the following use echo
    a. Army
    b. Geologist
    c. Fisherman
10. A cannon flash seen but it takes 6sec for sound heard to reach the person ear. How far away was the cannon?
11. A ship 1200m off shore fires a gun. How long after the gun is fired will it be heard on the shore?
12. An echo is heard after 0.8sec when a person fires a gun 132.8m from a high building, calculate the speed of sound?
13. The speed of sound 310m/s. a person fires a gun and echo is heard after 1.5sec. Calculate the distance of person from the cliff after echo is heard?

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Properties of sound

- There are three physical properties of sound which are
  - The intensity of sound
  - Frequency
  - Harmonic contentment

Properties of sound	**effects**
Intensity of sound	loudness
Frequency	pitch
Harmonic content	quality

Intensity of sound

- The rate of sound energy flows through a unit area is called intensity of sound.
  1. $I = \frac{E}{Axt}$ since $p = \frac{E}{A}$
  2. $I = \frac{P}{A}$ since $A = 4\pi r^2$
  3. $I = \frac{P}{4\pi r^2}$
  4. $I_1.r_1^2 = I_2.r_2^2$
  5. $\frac{I_1}{I_2} = \frac{p_1}{p_2}$
  6. $I = \frac{1}{r^2}$
- SI unit of intensity of sound is watt per square meter (w/m^2) and watt per centimeter square (w/cm^2) in C.G. S system.
- The intensity of sound depends on the amplitude of sound. The loudness is how loud or soft sound to be perceived. It depends on the amplitude of sound waves.
- The soft sound (faint sound) has small amplitude of sound but the loud sound has large amplitude of sound wave.

Threshold of hearing

- The intensity faintest audible sound that human ear can hear (detect) is called threshold of hearing.
- The threshold of hearing is 10^{-12} W/m^2 in SI system and $10^{-16} w/cm^2$ in C.G.S system. Below this intensity. the sound is too soft for the ear to hear.

  $I_0 = 10^{-12} w/m^2$ ----------in SI unit

  $I_0 = 10^{-16} w/cm^2$ ---------- in C.G.S system

Threshold of pain

- The loudest intensity of sound that human ear can heard is called threshold of pain.
- The threshold of pain is 1.0 W/m^2 or $10^0 w/m^2$. This intensity a sound is so loud it becomes uncomfortable for the ear.

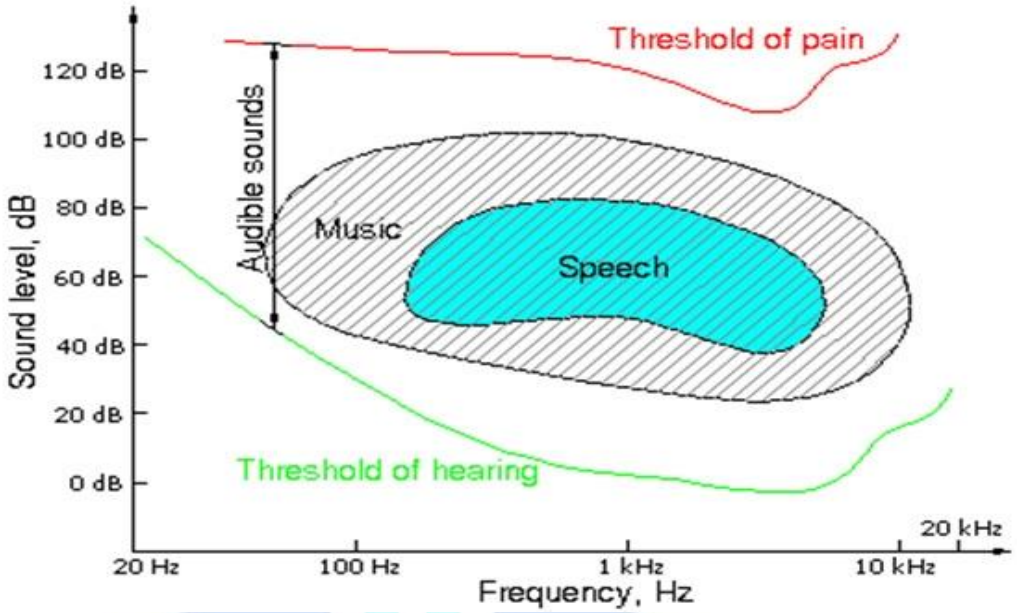
Intensity level of sound

- The comparison of intensity of sound to threshold of hearing is called intensity level of sound (β). The intensity level of sound can calculated by logarithmic equation which is:

$$\boldsymbol{\beta = 10db\log\frac{I}{I_0}}$$ where I = intensity of sound and I_0 = threshold of hearing

$I_0 = 10^{-12} w/m^2$ in SI

$I_0 = 10^{-16} w/cm^2$ in C.G.S system



- The unit of intensity level of sound is decibel (db).Bell is another unit of intensity level of sound.

1B = 10dB

Examples

1. The power of sound is 0.02w. find the intensity of sound wave with radius of
   a) 2m
   b) 3m **[a) $4 \times 10^{-4} w/m^2$ b) $1.8 \times 10^{-4} w/m^2$]**
2. Sound has intensity of $4 \times 10^{-6} w/m^2$. What is the intensity level of sound? **[66db]**
3. What is the intensity of 60db sound? **[$10^{-12} w/m^2$]**
4. What is the intensity in w/cm^2 of sound wave whose intensity level is 50db? **[$10^{-11} w/cm^2$]**
5. The intensity of sound 1m away a speaker is $8w/cm^2$. What will be the intensity of sound at a distance of 10m away from the speaker? [**$0.08 w/m^2$]**

Class work

Do all questions

1. What is the intensity in w/m^2 of a sound which has an intensity level of 30db **[$10^{-9}w/m^2$]**
2. What is the intensity level in Bell (B) of a sound which has an intensity of $10^{-11}w/cm^2$? **[5B]**
3. The intensity of sound is determined to be $10^{-10}w/m^2$. What is the intensity level of sound?
4. A window whose area is $1.52m^2$ opens on a street where the street noise results in intensity level of 80db. How much acoustic power enters the windows by the sound wave? **[$1.52 x10^{-4}w$]**
5. A sound has an intensity of $7 x 10^{-11}w/cm^2$, what is the intensity level of sound? **[58.8db]**
6. The intensity of sound is determined to be $4.5x10^{-10}w/cm^2$, what is the intensity level of sound? **[6.65B]**
7. Find the intensity in w/m^2 corresponding to an intensity level of 10db? **[$10^{-11}w/m^2$]**
8. Find the intensity level in decibels for a sound wave of intensity
   a) $2.5 x 10^{-10}w/cm^2$
   b) $10^{-6.5}w/m^2$ **[a)6.4B b) 5.5B]**
9. A band has produced an intensity level of 110db, what is the sound intensity? **[$10^{-1}w/m^2$ or $0.1w/m^2$]**
10. One sound has intensity level of 60db, while second sound has 70db, what is the difference combined intensity level? **[70.4db]**
11. One sound is 600times as intense as another sound, what is the difference intensity level of these two sounds in decibel? **[27.8db]**
12. 10 typist in a room give rise to an average sound intensity of 58db, what is the intensity level in the room when additional three typist each generating the same amount of noise being to type? **[59db]**

Frequency and Pitch

- Pitch is the characteristics of sound that depends on the frequency the ear receives; we usually distinguish b/w a musical tone and noise.
- Pitch is the change of frequency. The pitch depends on the frequency of the wave reaching the ear. The sound with high pitch has high frequency and the sound with a low frequency have low pitch.
- A Sound with short wavelength has a high pitch and a sound with a long wavelength have low pitch**.**

Harmonic content and quality (timbre)

- Harmonics are frequencies which are multiples of the fundamental frequency. Harmonic content determines the quality of sound. The simplest harmonic content is called the fundamental tone. The other ones are overtones of the fundamental tone. Overtones are frequencies higher than the fundamental frequency.
- Quality of sound depends on the number of harmonics. Quality means how pleasant sound is.

Harmonics	Overtone
1st harmonics	----------
2nd harmonics	1st overtone
3rd harmonics	2nd overtone
4th harmonics	3rd overtone
5th harmonics	4th overtone

Range of audibility

- The audible range frequencies called audible range. The human audible range is from 20Hz to 20000Hz or 20 kHz.
- The human ear cannot hear sound of frequencies less than 20Hz and more than 20000Hz. The human ear can hear sounds having frequencies from 20Hz to 20000Hz (20 kHz).

Infrasound or infrasonic sound

- The human ear can easily detect (hear) frequencies between 20Hz to 20000Hz.
- A sound has frequency b/w 20Hz up to 20000Hz is called sonic sound (sonic vibration). Or the sound waves which we are able to hear are called sonic sound or audible sound.
- The sound of frequencies less than 20Hz are known as infrasonic sound or infrasound.
- Any sound with a frequency below the audible range of hearing (i.e., less than 20 Hz) is known as an **infrasound (infrasonic vibrations)**
- Infrasonic sounds are very low frequency sounds and cannot be heard by human being.
- Infrasonic sound produced by those object which vibrate very slowly such as **earthquakes**

- Some animals like Elephants, whales, giraffes, rhinoceroses, peacocks, and hippopotamuses produce infrasonic sound.

Ultrasound

- Any sound with a frequency above the audible range of hearing (i.e., more than 20 000 Hz) is known as an **ultrasound (ultrasonic vibrations)**.
- Ultrasonic sounds cannot be heard be heard by human beings and it has frequencies higher than 20000Hz. Ultrasonic sounds are very high frequency sounds.
- Dogs, monkey, cats, bats, dolphin are animals which can hear ultrasonic sound. Dogs can hear ultrasonic sound of frequency up to 50000Hz. So, dogs are used for detective work by police.

Uses of ultrasound

- Ultrasound is used in industries and hospitals for medical purposes, some important uses of ultrasound are given below.
  - **Echo sounders**
    - Ships are used to measure the depth of sea and beneath of water. An echo Sounder sends pulses of ultrasound downwards towards the sea bed, and then time delay can be measured.
  - **Echo cleaning or ultrasound cleaning**
    - Using ultrasound, delicate machinery can be cleaned without dismantling it. The machinery is immersed in tank of liquid, and then vibrations of high power ultrasound are used to dislodge the bits of dirt and gases.
    - In hospitals, concentrated beams of ultrasound can be used to break up kidney stones and all gas stones without patients needing surgery.
  - **Homogenizing milk and cosmetics**
    - For breaking complex particles of the fat to be simple particles.
  - **Ultrasound scan**
    - To picture unborn babies, ultrasound scanners are used, to get detail information.
  - **Sonar**
    - Used by bats and dolphins to locate their prey
    - Used by submarines ,and commercial fishing boats to find schools of fish
    - Used for navigation and ranging
    - Used by scientists to map ocean floor
    - Used to make special glasses for blind people.
    - Bats produce ultrasonic sound while screaming we cannot hear the scream of bat because its screams consists of ultrasonic sound having a frequency much higher than 20000Hz which is beyond our limit of hearing.

Forced vibrations and Resonance

Forced vibrations

- Forced vibrations occurs when the object is forced to vibrate at a particular frequency by periodic input force .objects which are free to vibrate will have one or natural frequency at which they vibrate.
- The setting up of vibration in an object by vibrating force is called forced vibration.

Examples of forced vibration

1. **Bridges** ; crosswind in valley caused the bridge to resonate and collapse
2. **Vehicles;** the body of bus, motorcycle vibrates when it travelling at a particular speed.
3. **Glass**; a glass is broken by sound wave vibrating at resonant frequency of the glass**.**

Resonance

- Resonance is the tendency of a system to vibrate at maximum amplitude at the natrul
- A vibrating object can cause sound object with the same natural frequency to vibrate with a large amplitude .Resonance occurs when the natural frequency of two object are the same. The word resonance comes from Latin and means to "resound" - to sound out together with a loud sound.
- Resonance only occurs when the first object is vibrating at the natural frequency of the second object .Resonance is a common cause of sound production in musical instruments.

Condition of resonance

- Resonance occurs when the frequency of the applied force is exactly equal to the natural frequency of the vibrating body.

Examples of resonance

- Systematic vibration pendulums
- Resonance in air column and turning fork

Doppler Effect

- The change in pitch produced by a relative motion of source and observer is known as Doppler Effect.
- There are three important cases of relative motion of source and observer which are :

Case 1Source of sound is moving and observer is stationary

The observer frequency is given by

$$\mathbf{F = f_s\left(\frac{V}{V \pm V_S}\right)}$$

Toward	**away**
$\mathbf{F = f_s\left(\frac{V}{V-V_S}\right)}$	$\mathbf{F = f_s\left(\frac{V}{V+V_S}\right)}$

Case 1 Observer is moving and source of sound is stationary

The observer frequency is given by

$$\mathbf{F = f_s\left(\frac{V \pm V_0}{V}\right)}$$

Toward	**away**
$\mathbf{F = f_s\left(\frac{V+V_o}{V}\right)}$	$\mathbf{F = f_s\left(\frac{V-V_o}{V}\right)}$

Case 3 Observer and source of sound are moving

The observer frequency is given by

$$\mathbf{F = f_s\left(\frac{V \pm V_0}{V \pm V_S}\right)}$$

Toward	**away**
$\mathbf{F = f_s\left(\frac{V+V_o}{V-V_S}\right)}$	$\mathbf{F = f_s\left(\frac{V-V_o}{V+V_S}\right)}$

Where f is the frequency heard by observer, fs is the frequency of the source and V_S is the velocity of source

Examples

1. A train moving at speed of 40m/s blows its whistle which has frequency of 500Hz. Find the frequency heard by stationary observer as train
   a) Approaches b) recedes if V = 345m/s [**a) 566Hz b)448Hz]**
2. A boy moving towards or away from stationary source whistling a frequency of 65Hz. Find the frequency heard by observer when he approaches or recedes away from the source ,if V = 340m/s **[661Hz, 639Hz]**
3. A car travels at speed of 33.5m/s, it siren emitting sound at frequency of 400Hz. What is the frequency heard by a passenger in a taxi traveling 24.6m/s in opposite direction as taxi approaches or recedes if V = 345m/s. **[475Hz ,339Hz]**

Class work

1) A locomotive approaches a crossing at 95km/hr. it horn has frequency of 85/sec and the temperature 15℃. What is the frequency of the sound heard by watchman? [**309]**
2) What is the frequency of sound a listener hears as train, with horn sounding passes at 60km/hr, if the frequency of the horn is 320/sec. the temperature is 25℃. **[305Hz]**
3) A train approaches a station at a constant speed of 25m/s sounding at a 750Hz whistle.
   a) What is the frequency is perceived by an observer on the platform of the station
   b) After the train passes the station platform , what is the frequency is perceived by the observer as the train moves away if T =20℃ [**809Hz , 699Hz]**
4) A factory whistle near a road side emit a sound of frequency 500Hz a) what is the apparent frequency heard by a passenger in a car that approaching the factory and is moving away from the whistle ? if T = 20℃ . [**537Hz ,694Hz]**

Standing waves in pipes

- **Standing** waves (stationary waves) in a tube set up by vibrations of the air molecules within the pipe are due to the sum of two traveling waves moving down the tube in opposite directions.
  1. –open tube or open at both end
  2. Open-closed tube

Open pipes

- If the air column is open at both ends, longitudinal waves are generated which travels through the air column to the closed end of the pipe .there are two identical waves traveling in opposite directions produce standing waves in the pipe. ,
- In an open pipes anti nodes will always occurs at the two open ends. Therefore the fundamental tone will have one node in the center of the pipe and two antinodes at the two ends.

1. $\boldsymbol{\lambda_n = \frac{2l}{n}}$
2. $\mathbf{F_n = \frac{n.v}{2l}}$
3. $\mathbf{F = nf_1}$ **n=1,2,3 ……**

Closed pipes

- If one end of tube is open and other end is closed, we will get a node at one end and anti node at other end . The harmonic series consists of only odd integer multiples of the fundamental frequency (f, 3f ,5f, 7f …..)
- The wavelength and frequencies of standing sound wave in an open –closed pipes is given by

1. $\boldsymbol{\lambda_n = \frac{4l}{n}}$ **2.** $\mathbf{F_n = \frac{n.v}{2l}}$ **3.** $\mathbf{F = nf_1}$ **n=1,,3 ,5, 7……**

Examples

1) A 1.5m tube is open at both end if the speed of sound in the air in the tube is 330m/s. what is
   a) Fundamental frequency (first harmonic)
   b) The wavelength of the first overtone (second harmonic)

   [a) 110Hz b) 3m]
2) A 3rd harmonic standing wave appears on 1.8m closed pipe when the frequency is 32Hz. What is the speed of the wave on the pipe? **[76.8m/s]**

Practice

Do all questions

1. Standing waves formed in an open pipe of 8m long if the velocity of sound is 30m/s . calculate
   a) The first harmonic frequency
   b) The second harmonic frequency
   c) The wavelength of second harmonic tone **[a)1.875Hz b) 3.75Hz c)8m]**
2. A closed pipe has length of 50cm. what are the lowest frequencies to which it will resonate, if v = 340m/s? **[170Hz, 510Hz , 850Hz]**
3. An open pipe has length of 50cm. What are three lowest frequencies to which it resonates? if v = 340m/s **[340Hz, 680Hz , 1020Hz]**
4. An open pipe at both ends has a length of 1.8m,and speed of sound in the air is 342m/s.
   a. Calculate the fundamental frequency for the open pipe
   b. The third harmonic frequency
   c. Calculate the fundamental frequency and the third harmonic frequency if the pipe closed at end

   [a) 95Hz b) 285Hz c) 47.5Hz, 142.5Hz]

Beat frequency

- Beats are fluctuations in sound intensity that occur when there is interference between two sound waves of equal intensity and slightly different frequency. As the wave reaches your ear, you will hear a single tone whose intensity is modulated.
- Beat frequency is the resultant of two tones sounded together. It is the difference in frequency of two waves.

  1) $B_F = F_2 - F_1$
- The unit of beat frequency is beat per second (beat/sec).

Examples

1. Two source of sound having a frequency of 50Hz and 60Hz are sounded together find the beat frequency **[10]**
2. Two turning fork are sounded together if the frequency of the first turning fork is 332Hz and their beat frequency is 4find the frequency of second turning fork? **[336Hz]**
3. Find the beat frequency of two sources that have frequencies 200Hz and 300Hz? **[100]**

Class work

Do all questions

1. Two source of sound having a frequency of 150Hz and 160Hz are sounded together find the beat frequency **[10beat/sec]**
2. find the beat frequency when following pairs of frequencies are sounded together
   a) 256Hz , 261Hz
   b) 512Hz , 508Hz **[a) 5beat/sec b) 4beat/sec]**
3. Compute the beat frequency if the wave frequencies are 550Hz and 1000Hz respectively? **[450beat/sec]**
4. Compute the beat frequency if the two frequencies of waves are 750Hz and 380Hz respectively? **[370beat/sec]**
5. Two turning fork are sounded together if the frequency of the first turning fork is 300Hz and their beat frequency is 40 find the frequency of second turning fork? **[340Hz]**
6. Find the beat frequency of two sources that have frequencies 20Hz and 80Hz? **[60beat/sec]**

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Vibrating strings

- The frequency of vibrating string depends on its length, tension, diameter and its density.
- the properties of vibrating string can be studied by instrument called **sonometer**

Law of length

- the frequency of vibrating string is inversely proportional to its length

  $$F_1.L_1 = F_2.L_2$$

  Where f_1 and f_2 are frequencies of the vibrating string and the L_1 and L_2 is the length of the string.

Examples

1) Two strings having a frequency of 200Hz and 100Hzn vibrates if the length of fist string is 20cm what is the length of other string? **[ ]**
2) Two strings having a frequency of 20cm and 40cm vibrates if the length of fist string is 20Hz what is the frequency of other string? **[ ]**

Law of tension

- the frequency of vibrating string is directly proportional to the square root of its tension

  $$F_1.\sqrt{T_1} = F_2.\sqrt{T_2}$$

  Where f_1 and f_2 are frequencies of the vibrating string and the L_1 and L_2 is the length of the string.

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