SOUND

Sound Waves Speed of

Sound Ultrasound

Describe the production of sound by vibrating sources.

Sound waves

HAMMAD HUSSIAN

Sound Waves

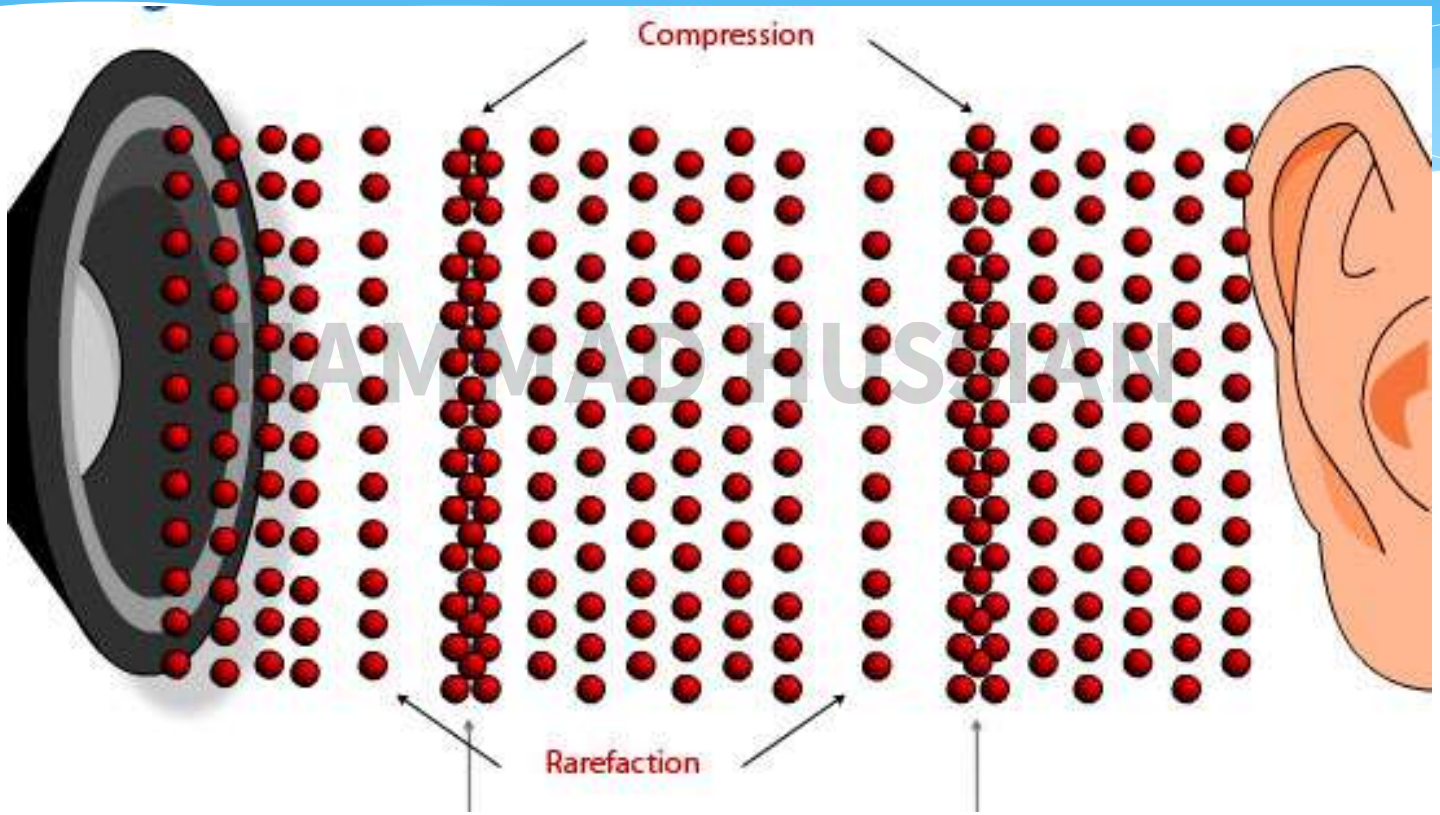
* Sound waves are caused by vibration
  * Vibrating guitar strings,
  * Vibrating air inside a trumpet
  * Vibrating prongs of tuning fork.
* Also, when hard objects are struck, they vibrate and produce sound waves

Describe the longitudinal nature of sound waves and describe compression and rarefaction.

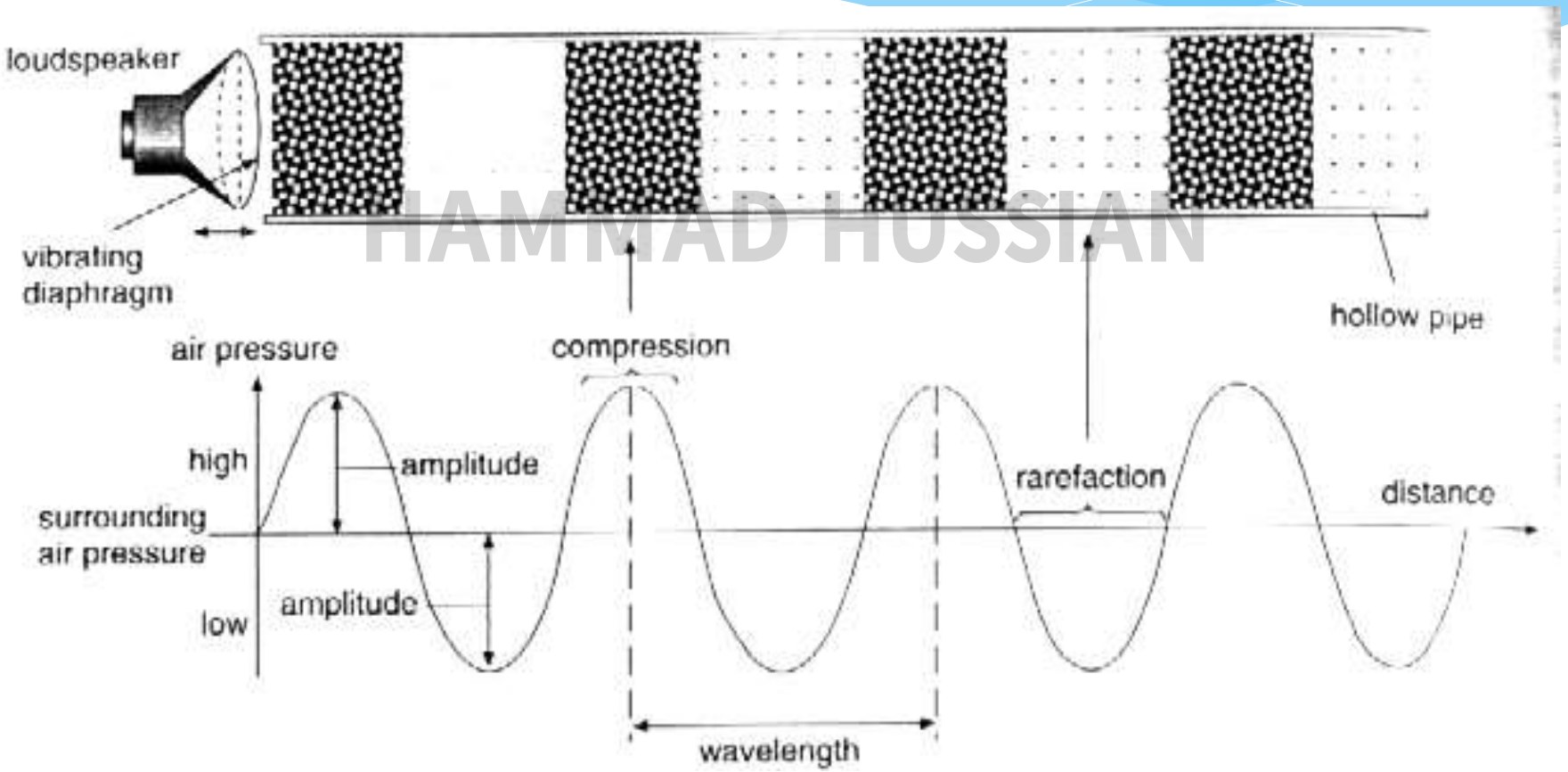
Sound waves

HAMMAD HUSSIAN

* Sound waves are longitudinal waves as the air oscillates backwards and forwards as the compression and rarefactions pass through it.
* When a compression passes, the air pressure rises. When a rarefaction passes, the pressure falls.
* The distance from on compression to the next is the wavelength.



Sound travels in air by forming a series of compression and rarefactions



State the approximate range of audible frequencies.

Sound waves

Audible Frequency

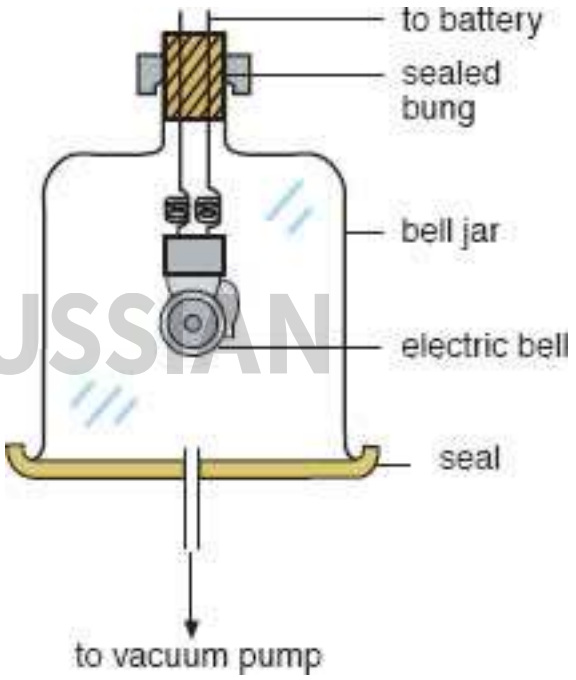
Frequencies (Hz)	Also Known As	Remarks
1-20	Infrasound	Not heard by human ears but can be felt as vibrations
20-20000	Audible Frequencies	The range of frequencies is also known as range of audibility.
20000 & above	Ultrasound	Mainly used in medical diagnosis.

Explain why a medium is required in order to transmit sound waves and describe an experiment to demonstrate this.

Sound waves

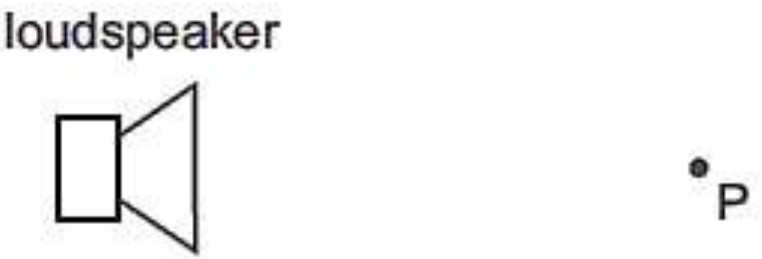
* Sound waves need a medium to travel through.
* Compressions and rarefactions can be formed only if there is a material which can be compressed and stretched.
* Therefore, sound cannot propagate through a vacuum.

Experiment set up to show that sound cannot travel through a vacuum



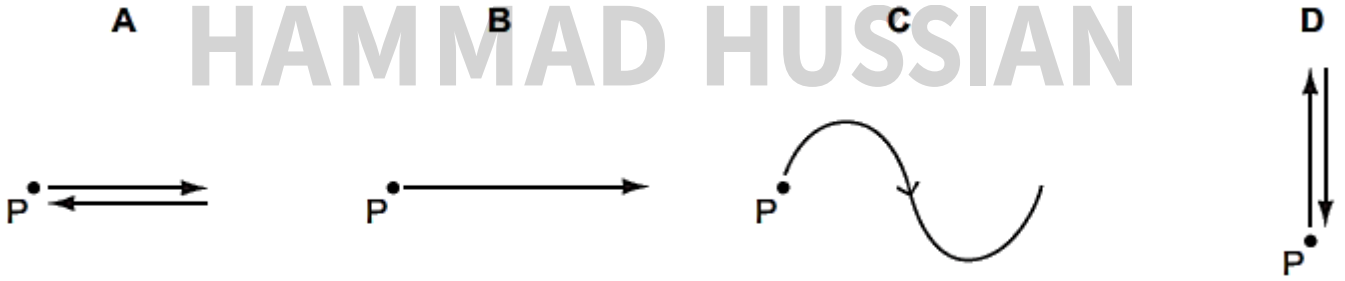
The sound becomes more and more faint as the air is pumped out. Finally no sound is heard even though the hammer can be seen hitting the bell.

1. The diagram shows a loudspeaker that is producing a continuous sound wave of frequency 200 Hz in air.



* Which diagram best shows how the sound causes a molecule at P to move during $\frac{1}{200}$ s?

A



A

2. A sound wave passes through the air, in the direction shown.

1. How does a particle of air move as the sound wave passes?

A moves to the right and stays there

B moves left and right

C moves up and stays there

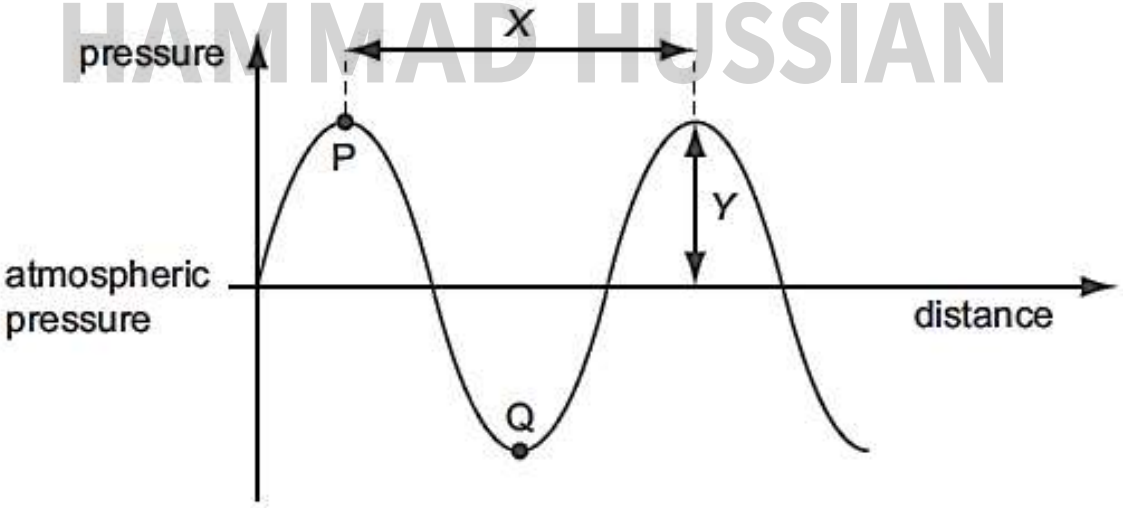
D moves up and down

B

3. Which type of wave cannot travel through a vacuum?

   A. infra-red radiation
   B. microwaves
   C. sound waves
   D. X-rays

4. The graph shows, at one instant, the pressure variation along a sound wave.



1. Which point on the diagram represents a rarefaction and what is the wavelength of the sound wave?

	rarefaction at	wavelength is
A	P	X
B	P	Y
C	Q	X
D	Q	Y

C

5. What is the approximate range of audible frequencies for most humans?

   A. 10 Hz to 10 000 Hz
   B. 20 Hz to 20 000 Hz
   C. 10 kHz to 10 000 kHz
   D. 20 kHz to 20 000 kHz

6. Which of the following can be heard by the human ear?
   A. A whistle emitting a wave of frequency 50 kHz.
   B. A bat emitting a wave of frequency of 30 kHz.
   C. An insect emitting a wave of 300 Hz.
   D. A vibrating spring emitting a wave of frequency of 5 Hz.

7. In which of the following frequency ranges is ultrasound found?

A. 1 Hz – 1 kHz
B. 2 kHz – 10 kHz
C. 11 kHz – 20 kHz
D. 21 kHz – 30 kHz

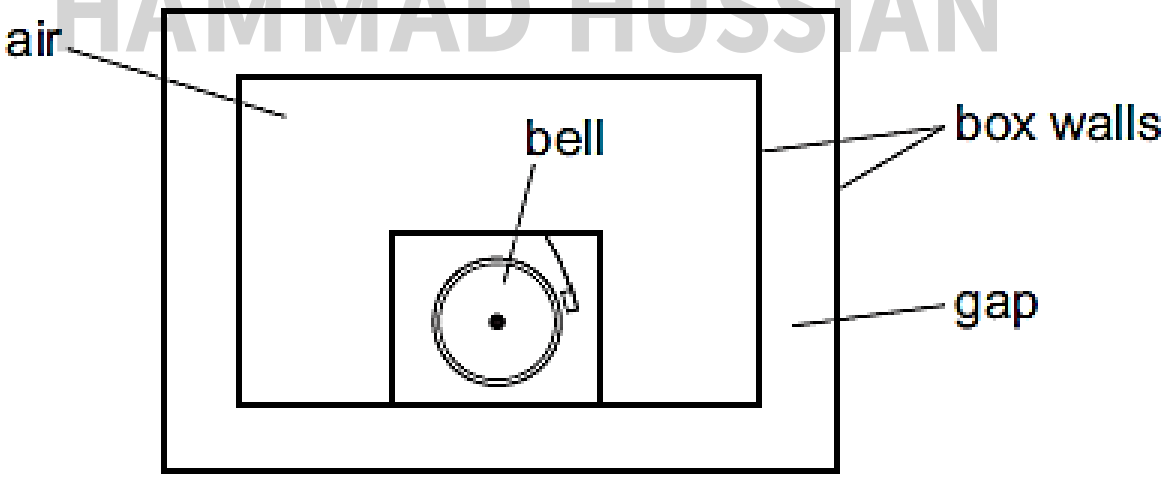
8. What is the approximate value of the highest frequency that can be heard by a young person?

A. 20 Hz
B. 200 Hz
C. 2000 Hz
D. 20 000 Hz

9. Which of the following does **not** produce a sound wave?

A. a bell ringing under water
B. a gun fired in a room with no echoes
C. a hammer hitting a block of rubber
D. an explosion in outer space

10. A battery-operated bell is surrounded by a box with double walls.

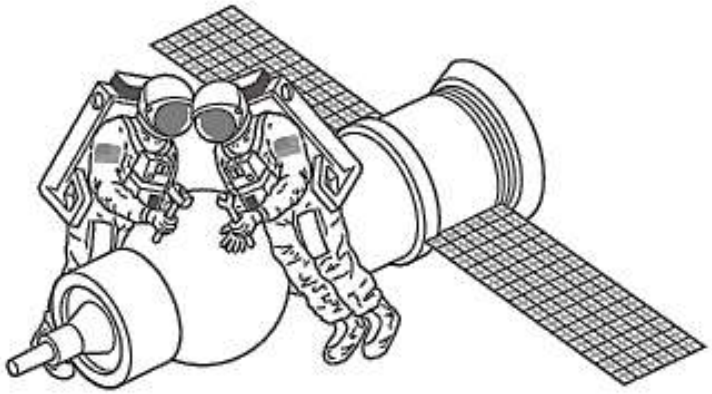


The bell is ringing but no sound at all is heard outside the box.

What is in the gap?

A. a solid
B. a liquid
C. a gas
D. a vacuum

11. Two astronauts without radios can only communicate in space if their helmets are touching.
12. There is no air in space.

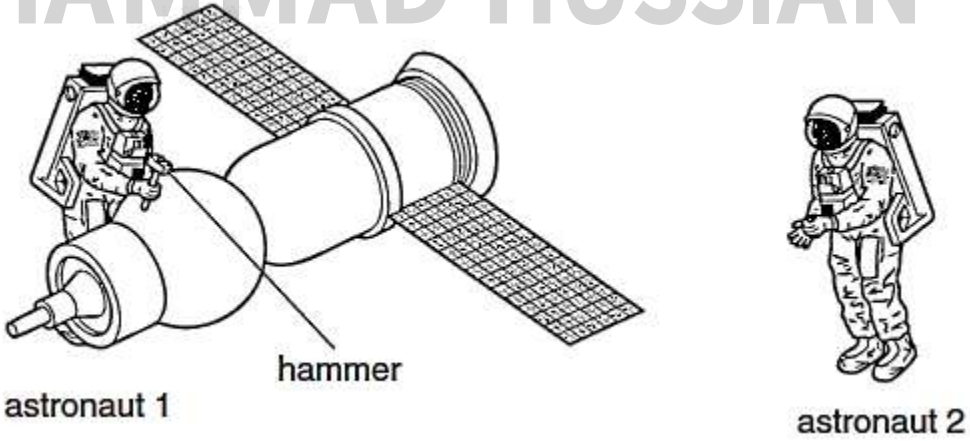


1. What does this show about sound?

	through a solid	through a vacuum
A	can travel	can travel
B	can travel	cannot travel
C	cannot travel	can travel
D	cannot travel	cannot travel

B

12. Astronaut 1 uses a hammer to mend a satellite in space. Astronaut 2 is nearby. There is no atmosphere in space.



1. Compared with the sound heard if they were working on Earth, what does astronaut 2 hear?

A. no sound at all
B. a quieter sound
C. a sound of the same loudness
D. a louder sound

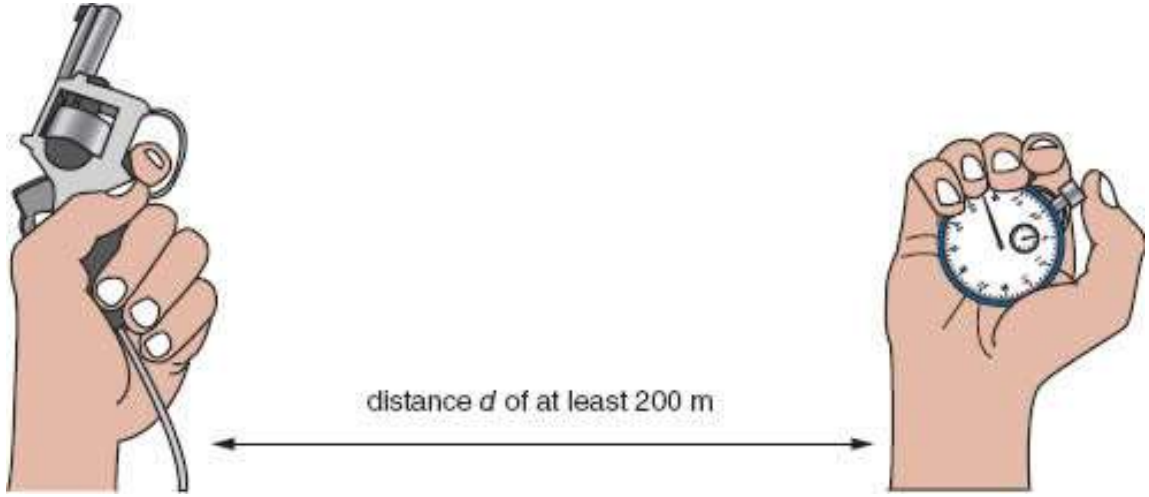
Describe a direct method for the determination of the speed of sound in air and make the necessary calculation.

Speed of sound

HAMMAD HUSSIAN

Speed of Sound

* Apparatus in determining speed of sound
  * Stopwatch
  * Tape metre
  * Any device producing sound (pistol)



* Procedure
  * Two people stand at least 200 m apart, one has a starting pistol and the other a stopwatch.
  * The person with the gun fires it and the one with the watch starts it when they see the smoke and stops it when they hear the bang.
  * The distance between them is found and the speed of sound worked out. The experiment should be done a few times to get an average result.

Problem Solving

1. Two observers A and B are 500 m apart at A and B. When a starting pistol is fired at A, the time interval between the seeing the flash, and hearing the sound of the pistol at B, is 1.5 s. Assuming no wind is blowing, what is the speed of sound in air?
2. A and B are two observers 1 km apart. There is a steady wind blowing. When a gun is fired at A the time interval between the flash and report observed at B is 3.04 s. Calculate the velocity of sound in air?

3. Two men stand facing each other, 200 m apart. When one fire a pistol the other hears a report 0.60 s after the flash. Calculate the velocity of sound in air.
4. A person is yelling from a woman's dorm window. If the speed of sound is 348 m/s and the distance from the dorm to the cafeteria is 87 meters, how long does it take the sound to reach the cafeteria?

5. Sound takes about 3 milliseconds to travel 1 m. How long will it take to travel from the centre of a cricket pitch to the spectators, 200 m away?
6. You are watching a thunderstorm. You notice that you hear the thunder 1.5 s s after you see the lightning. How far up is the storm taking place? (Speed of sound in air is 330 m/s)

State the order of magnitude of the speeds of sound in air, liquids and solids.

Speed of sound

Speed in Different Media

* The speed of sound differs in gases, liquids and solids.
* This is due to the differences in strength of the inter-atomic forces and closeness of the atoms in the three states.
* Compressions and rarefactions propagate faster in denser medium.

Speed of sound in different medium

Gases		Liquids (25°C)		Solid	
Material	*v* (m/s)	Material	*v* (m/s)	Material	*v* (m/s)
Hydrogen (0°C)	1286	Glycerol	1904	Diamond	12000
Helium (0°C)	972	Sea Water	1533	Pyrex Glass	5640
Air (20°C)	343	Water	1493	Iron	5130
Air (0°C)	331	Mercury	1450	Aluminium	5100

* Sound travels faster in liquids than in gases, and travels fastest in solids.

Explain how the loudness and pitch of sound waves relate to amplitude and frequency.

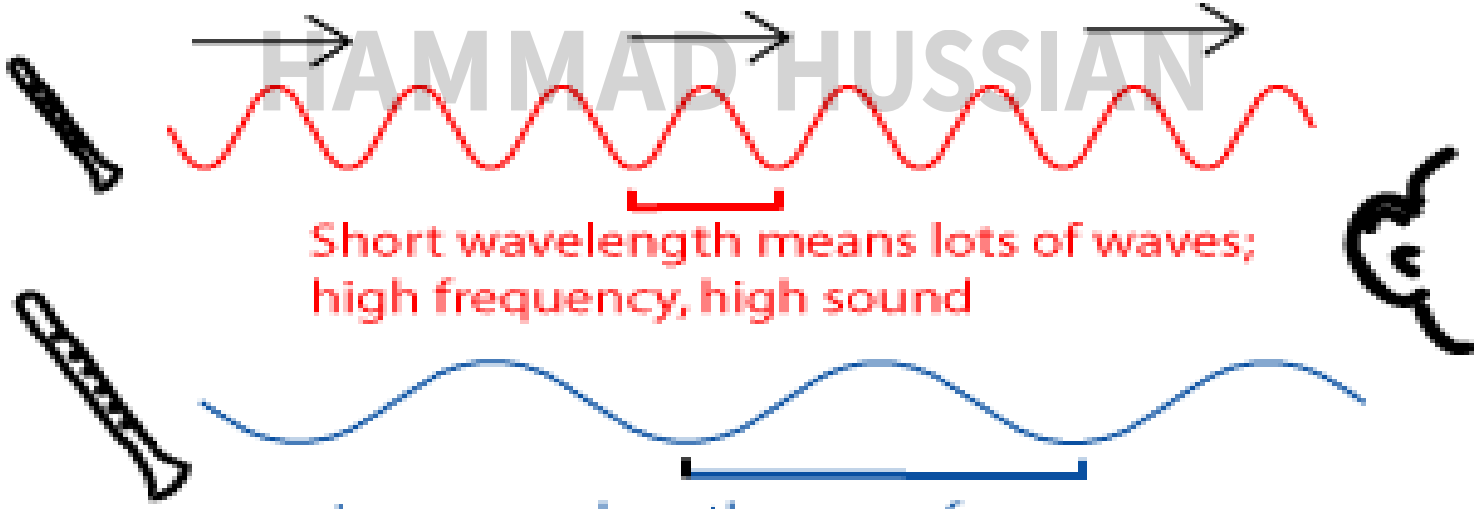
Speed of sound

Pitch & Frequency

* Any sound that you hear as a tone is made of regular, evenly spaced waves of air molecules.
* The most noticeable difference between various tonal sounds is that some sound higher or lower than others.
* The property which distinguishes the sound in this way is known as the pitch.

Wavelength, Frequency and Pitch

The waves are all travelling at about the same speed, so this is the number of each wave that will reach the ear in a hundredth of a second.



Short wavelength means lots of waves; high frequency, high sound

Long wavelength means fewer waves; low frequency, low sound

* The pitch of a note depend on its frequency.
* The higher the frequency of a sound, the higher its pitch.
* The pitch of the notes produced by a string instruments depend on the length of the strings.
* The longer the string, the lower the pitch (frequency).

Loudness & Amplitude

* Humans and animals sense a wide range of sound amplitude, volume or loudness--from the very quiet to the extremely loud.
* Loudness is measured in decibels, which really measures the energy of the sound.
* The loudness of sound depends on the amplitude of the wave.
* The bigger the amplitude, the louder the sound.

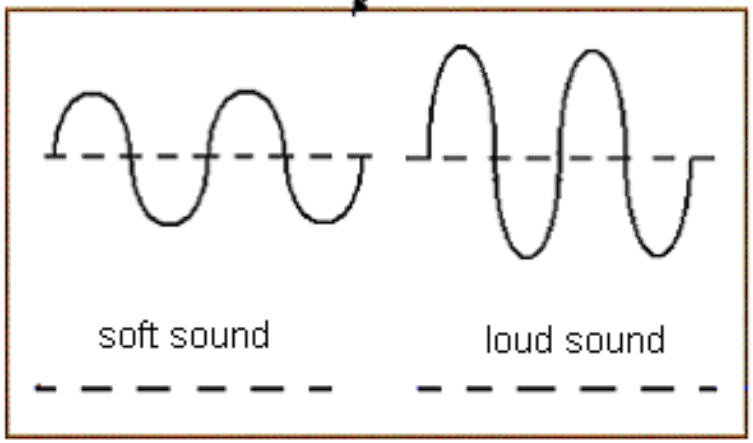
* A human can hear from very quiet sounds at 0.1 decibels to sounds at 120 decibels.
* At the high end of the scale, the energy can cause damage to the sensitive membranes in the ear.
* Younger people can usually have better hearing at the lower volumes than older people do.
* Animals can hear lower volumes and are more sensitive to louder noises than humans.

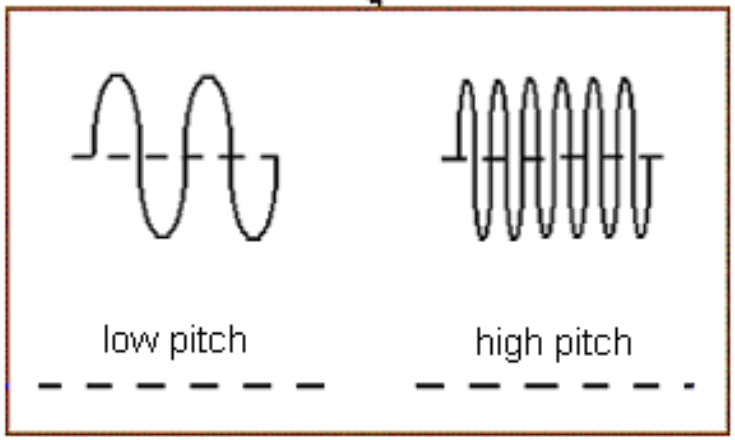
Decibel (dB)	Loudness of Sound
0	near silence; threshold of hearing
10	leaves rustling
20	whisper
30	quiet home
40	quiet conversation
50	normal conversation (50-60 dB)
70	hair dryer; vacuum cleaner
80	city traffic
90	thunder; lawn mower
100	chain saw; large orchestra
110	car horn
120	rock concert
130	threshold of pain
140	jet taking off

Sound waves

Loudness depends on **amplitude**

Pitch depends on **frequency**





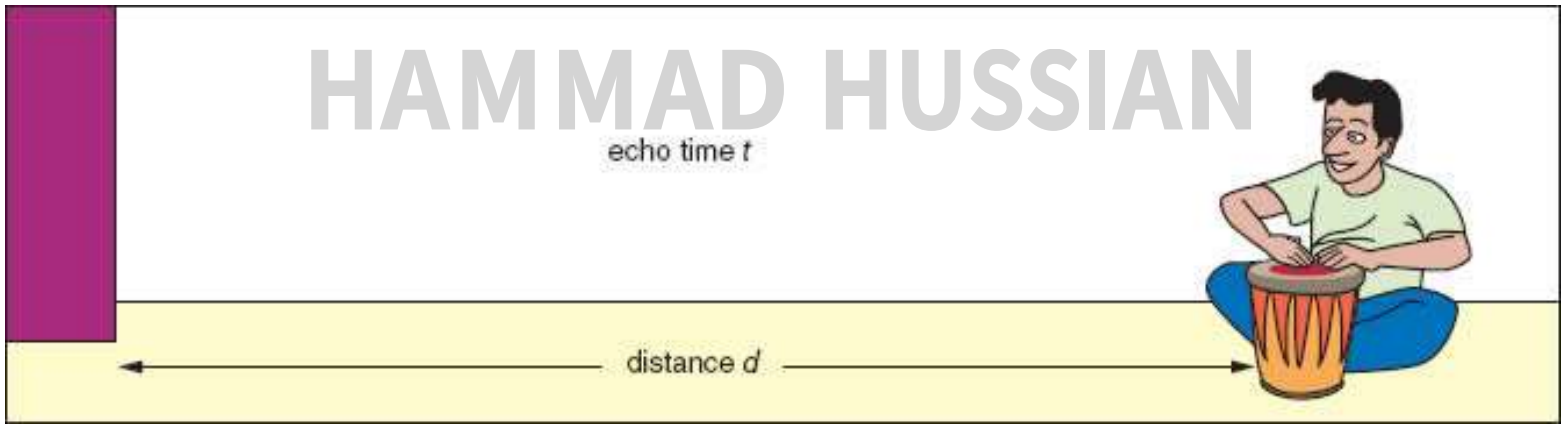
Describe how the reflection of sound may produce an echo.

Speed of sound

Echo

* Sound waves can be reflected by large, hard surfaces like buildings, walls and cliffs.
* If the reflected sound is heard as a separate sound after an interval of silence, it is called an echo.
* If the original sound just seems prolonged, this effect is known as reverberation.
* To hear distinct echoes, the reflecting surface must be far enough from the source of the sound.

Using Echoes to Find Distances



$$\text{Speed of Sound} = \frac{\text{Distance}}{\text{Time Taken}} = \frac{2d}{t}$$

* The principles of calculating the distance to the wall is used in several devices, including:
  * Echo-sounder that measures the depth of water under the boat. It sends pulses of sound waves towards the sea-bed and measures the echo time.
  * Radar that used microwaves instead of sound waves. It detects the position of aircraft by measuring the 'echo times' of microwave pulses reflected from them.

Problem Solving

1. A person standing 99 m from the foot of a tall cliff claps his hand and hears an echo 0.6 s later. Calculate the velocity of sound in air.
2. A pulse of ultrasound takes 0.1 s to travel to the sea-bed and return, and the speed of sound in water is 1400 m/s. How deep is the sea?
3. A man is cutting down a tree with an axe. He hears the echo of the impact of the axe hitting the tree after 1.6 s. If the speed of sound is 330 m/s, how far is the tree from the obstacles?

4. John shouts loudly in front of a mountain. After 5.2 seconds, he heard the echo of his voice. If the mountain is 858 metres away from john, determine the speed of sound in air.

$$\text{speed of sound} = \frac{2d}{t}$$

$$\text{speed of sound} = \frac{2(858)}{5.2}$$

$$\text{speed of sound} = 330 \text{ m/s}$$

5. Ah Sern shouts in front of a high wall. He hears the echo of his voice 2.5 second later. If the velocity of sound in air is 340 m/s, calculate the distance between him and the wall.

4. John shouts loudly in front of a mountain. After 5.2 seconds, he heard the echo of his voice. If the mountain is 858 metres away from john, determine the speed of sound in air.
5. Ah Sern shouts in front of a high wall. He hears the echo of his voice 2.5 second later. If the velocity of sound in air is 340 m/s, calculate the distance between him and the wall.
6. A man shouts loudly close to a high wall. He hears one echo. If the man is 40 m from the wall, how long after the shout will the echo be heard? (Speed of sound in air = 330 m/s)

7. A ship is 220 metres from a large cliff when it sounds its foghorn. Speed of sound in air is 330 m/s
   a. When the echo is heard on the ship, how far has the sound travelled?
   b. What time delay is there before the echo is heard?
   c. The ship changes its distance from the cliff. When the echo time is 0.5 seconds, how far is the ship from the cliff.

8. A boat is fitted with an echo-sounder which uses ultrasound with a frequency of 40 kHz.
   a. What is the frequency of the ultrasound in Hz?
   b. If ultrasound pulses takes 0.03 seconds to travel from the boat to the sea-bed and return, how deep is the water under the boat?
   c. What is wavelength of the ultrasound in water?

   Speed of sound in water = 1400 m/s

Describe the factors which influence the quality (timbre) of sound waves and how these factors may be demonstrated using a c.r.o.

Speed of sound

HAMMAD HUSSIAN

Sound Quality

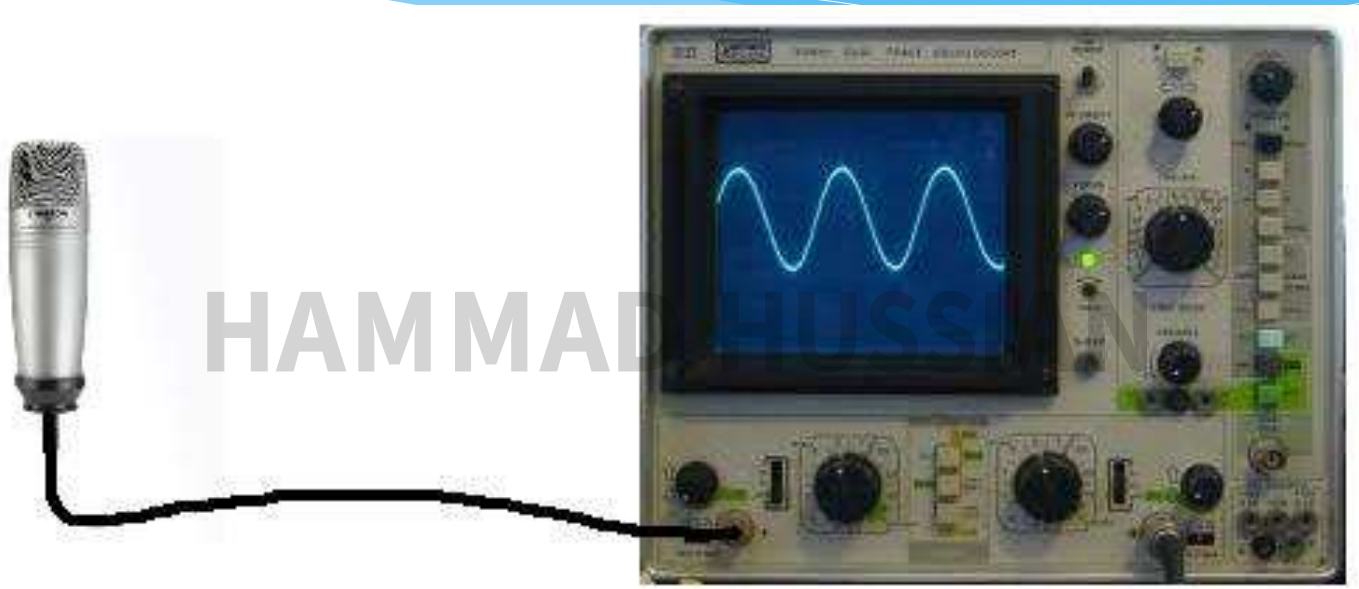
* Sound "quality" or "timbre" describes those characteristics of sound which allow the ear to distinguish sounds which have the same pitch and loudness.

Example

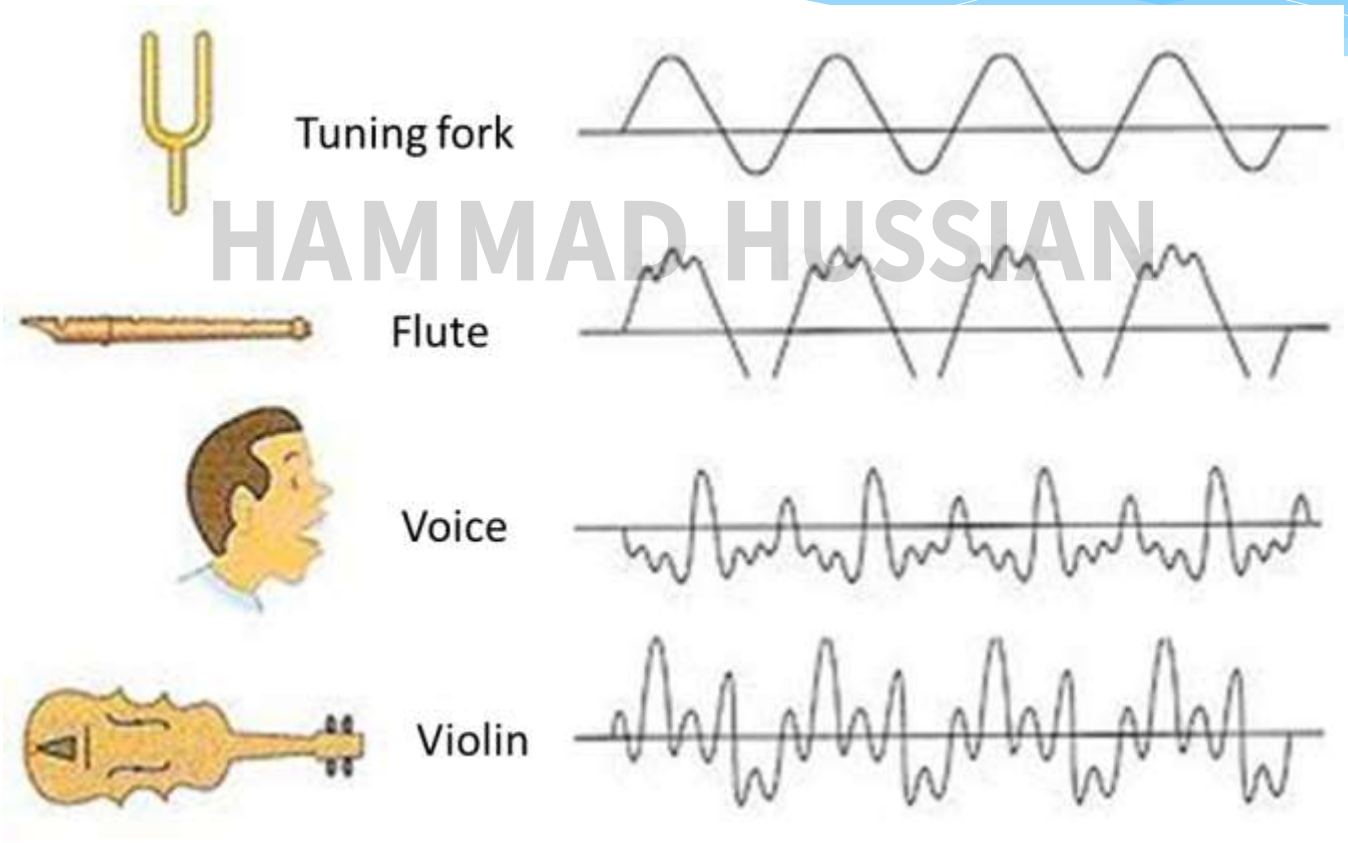
* When two musicians playing same musical note, but one is on guitar and another one is playing flute, the pitch and loudness for the note would be the same
* The frequency of the sound wave due to the resonance of the sound wave, pressure and wave form of the sound from the instrument would be different.
* Hence we listen two different sound and can differentiate between the two, this characteristic of the sound is known as **Timbre**, as the main characteristics of the sound wave are same like its pitch, flow and loudness, but we are able to differentiate between the sound due to change of the source.

* Timbre Depends on:
  * Wave form of sound
  * Sound pressure
* Timbre Does Not Depends on:
  * Pitch
  * Loudness

Sound Waveform



Sound wave → Microphone → Electrical Signal → Oscilloscope



1. A boy strikes a rigid metal fence with a stick to create a sound along the fence. A girl listens with her ear against the fence. One second after the fence is struck, the girl hears a sound through the air.

How long will it take for the sound to reach the girl through the fence?

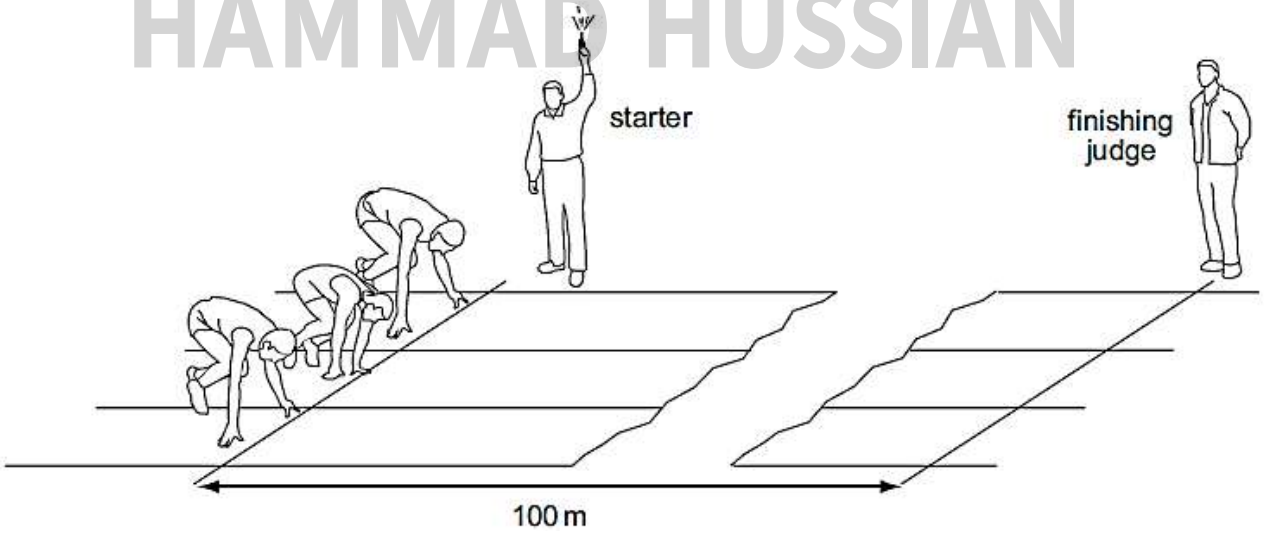
A. 0 second
B. less than 1 second
C. 1 second
D. more than 1 second

2. A flash of lightning and the corresponding thunder clap are detected 6 s apart. It is calculated that the lightning struck about 1800 m away.

   On which assumption is the calculation based?

   A. Light reaches us almost instantaneously, but sound travels at 300 m/s.
   B. Light travels 300 m/s faster than sound.
   C. Sound reaches us almost instantaneously, but light travels at 300 m/s.
   D. The sound of the thunder was emitted 6 s after the flash.

3. A 100 metre race is started by firing a gun. The gun makes a bang and a puff of smoke comes out of the gun as shown.



1. When does the finishing judge see the smoke and hear the bang?

	sees the smoke	hears the bang
A	immediately	immediately
B	immediately	after about 0.3 s
C	after about 0.3 s	immediately
D	after about 0.3 s	after about 0.3 s

B

4. Which equation can be used to calculate the speed of sound?

A $\text{speed} = \frac{\text{distance}}{\text{time}}$

B $\text{speed} = \text{distance} \times \text{time}$

C $\text{speed} = \frac{\text{time}}{\text{distance}}$

D $\text{speed} = \text{time} + \text{distance}$

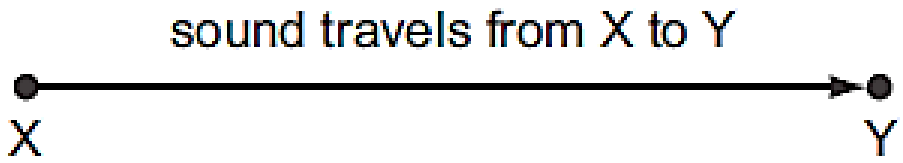
A

5. A starting pistol is fired 640 m away from a spectator.

1. The spectator hears the sound of the starting pistol two seconds after seeing the flash from the gun.
2. What is the speed of sound in air?

A. 160 m/s
B. 320 m/s
C. 640 m/s
D. 1280 m/s

6. In an experiment to measure the speed of sound, a student uses a stopwatch to find how long a sound takes to travel from X to Y. She does this six times.



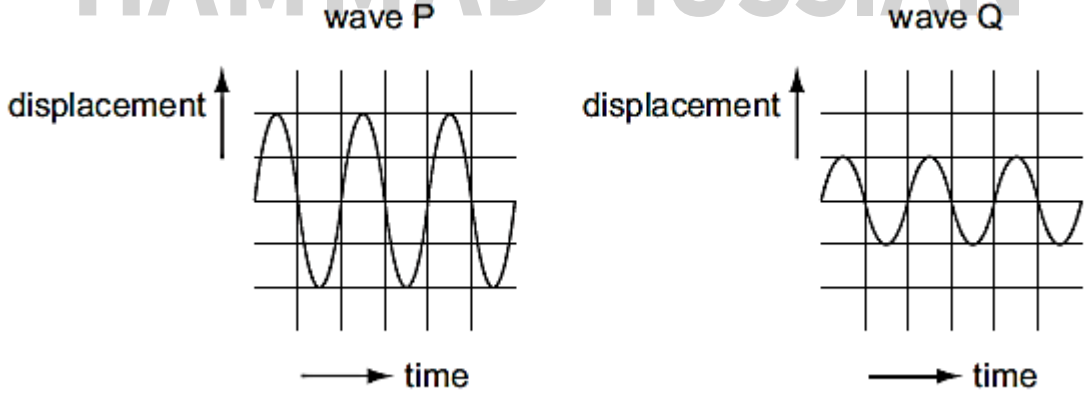
The table shows her results.

	time / s
first	0.5
second	0.7
third	0.6
fourth	0.4
fifth	0.9
sixth	0.5

What value for the time should be used to calculate the speed of sound?

A. 0.4 s
B. 0.5 s
C. 0.6 s
D. 0.9 s

7. The diagrams represent two different sound waves.



How do the frequency and pitch of P compare with the frequency and pitch of Q?

	frequency of P	pitch of P
A	greater than Q	higher than Q
B	greater than Q	same as Q
C	same as Q	higher than Q
D	same as Q	same as Q

D

8. A fire alarm is not loud enough. An engineer adjusts it so that it produces a note of the same pitch which is louder.

   What effect does this have on the amplitude and on the frequency of the sound?

	amplitude	frequency
A	larger	larger
B	larger	same
C	same	larger
D	same	same

B

9. Sounds are made by vibrating objects. A certain object vibrates but a person nearby cannot hear any sound.

10. Which statement might explain why nothing is heard?

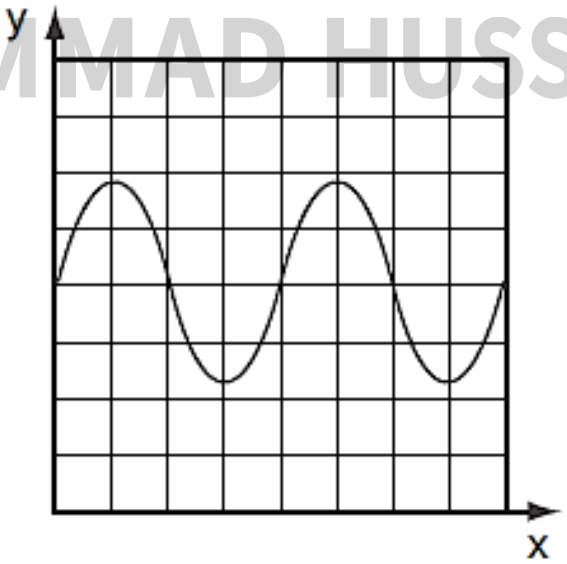
A. The amplitude of the sound waves is too large.
B. The frequency of the vibration is too high.
C. The sound waves are transverse.
D. The speed of the sound waves is too high.

10. Music is produced by the loudspeaker of a radio.

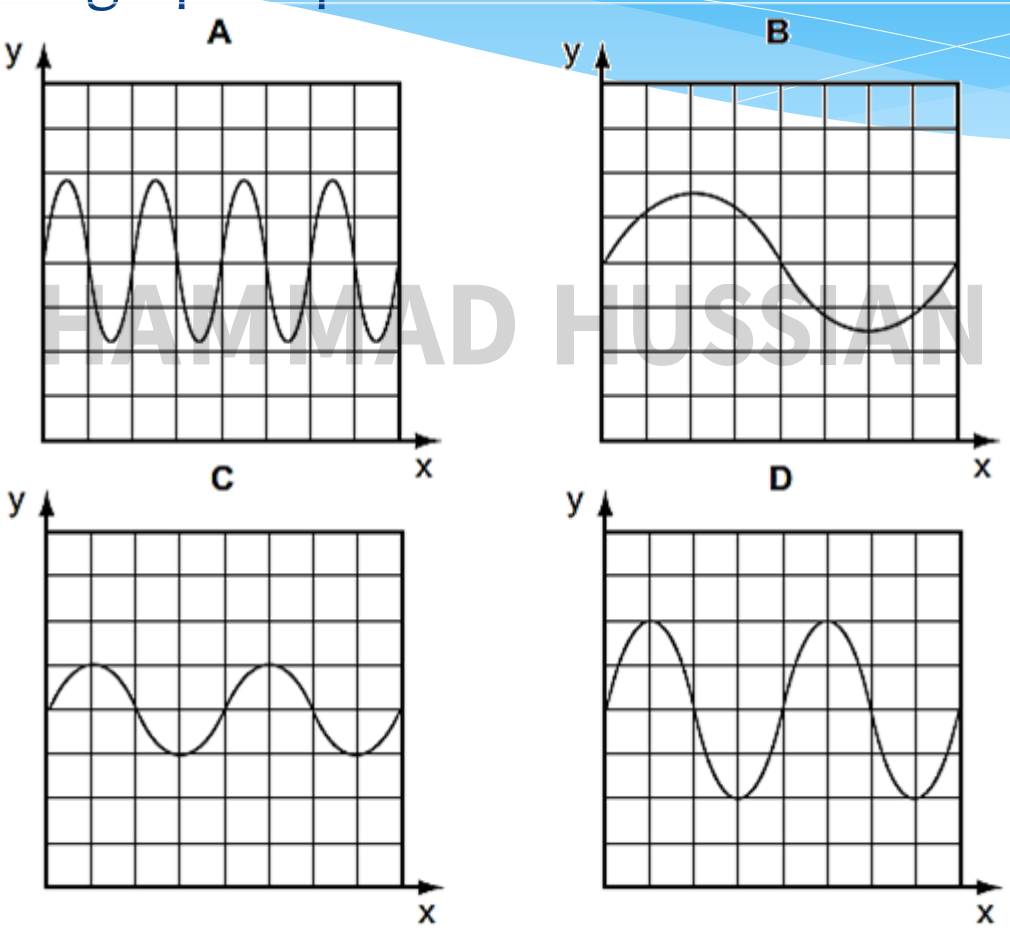
    Which property of the sound wave increases when the music is made louder?

A. amplitude
B. frequency
C. speed
D. wavelength

11. The graph represents a sound wave. The horizontal (x) axis represents time.

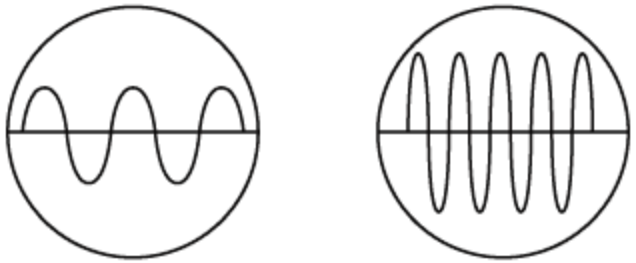


1. The frequency of the sound is increased.
2. The graphs below are shown to the same scale. Which graph represents the new sound wave?



A

12. Two sound waves P and Q are displayed on an oscilloscope with the same time-base and Y-plate settings for each.



1. Which statement correctly describes the pitch and the loudness of the two sounds?

A. P has a higher pitch and is louder than Q.
B. P has a higher pitch and is quieter than Q.
C. P has a lower pitch and is louder than Q.
D. P has a lower pitch and is quieter than Q.

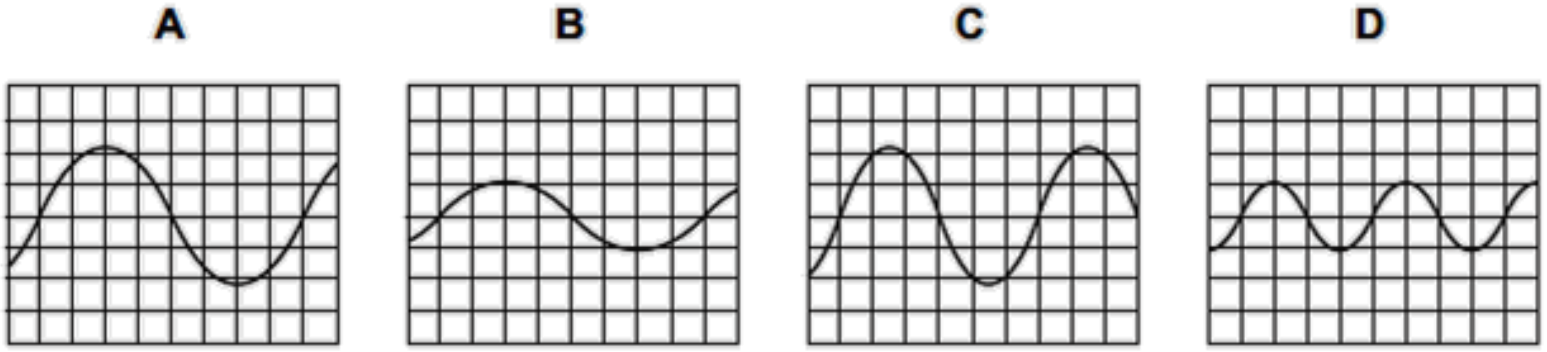
13. Which change will lower the pitch of a sound?

A. decreasing its amplitude
B. decreasing its frequency
C. increasing its amplitude
D. increasing its frequency

14. The diagrams show oscilloscope traces of sounds picked up by microphones. The oscilloscope controls are set in the same position for all the traces.

15. Which trace shows the sound that is both loud and low-pitched?

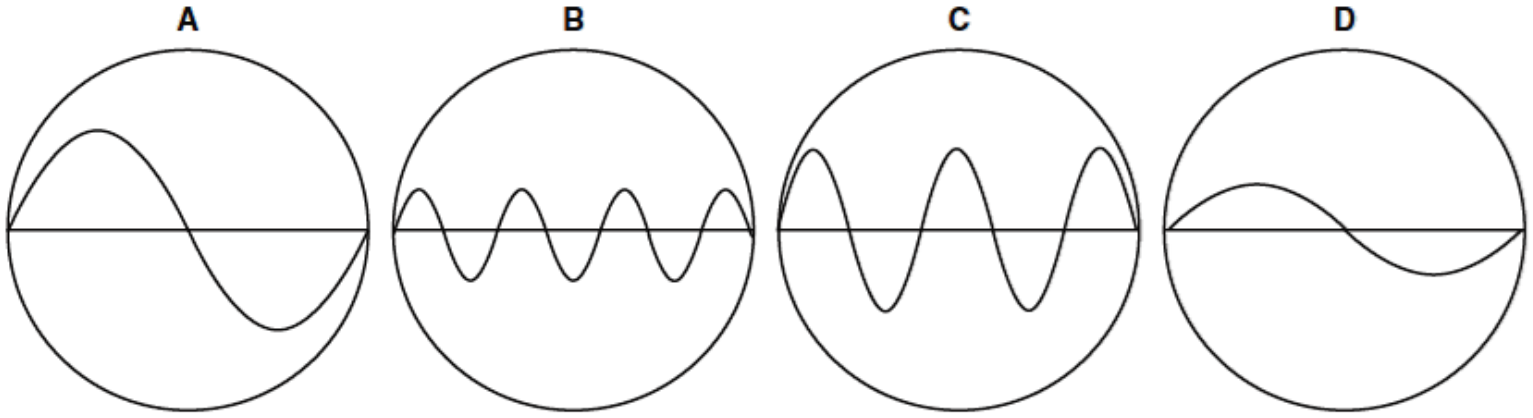
A



A

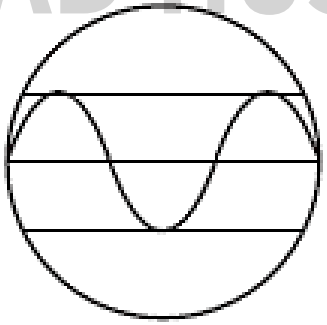
15. The diagrams represent sound waves displayed on an oscilloscope.

Assuming the controls of the oscilloscope remain the same for each sound, which diagram represents the quietest sound with the highest frequency?



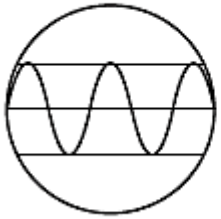
B

16. The diagram shows the trace produced on a cathode-ray oscilloscope (c.r.o.) by a sound.

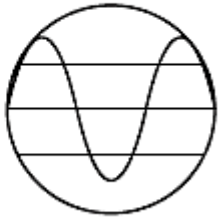


Which trace is produced when both the loudness and the pitch of the sound are increased?

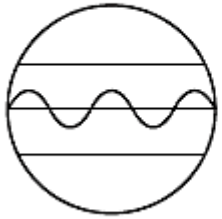
A



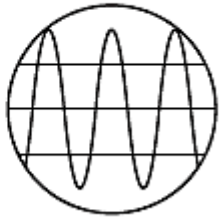
B



C



D



D

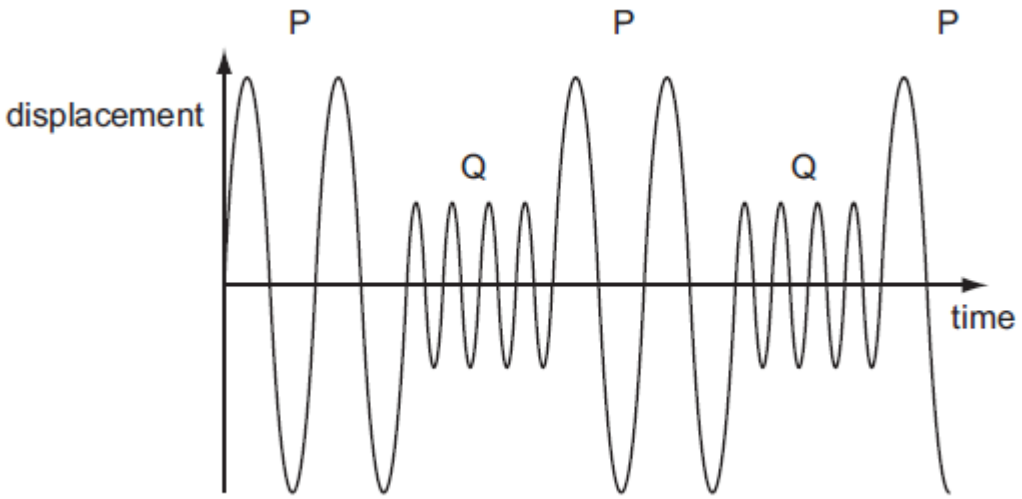
17. A police car with its siren sounding is stationary in heavy traffic. A pedestrian notices that, although the loudness of the sound produced does not change, the pitch varies.

18. Which line in the table describes the amplitude and the frequency of the sound?

	amplitude	frequency
A	constant	varying
B	constant	constant
C	varying	constant
D	varying	varying

A

18. A police car siren emits two different sounds P and Q. These are produced alternately. The diagram represents the sounds emitted.



Which sound is the louder and which has the lower pitch?

	louder	lower pitch
A	P	P
B	P	Q
C	Q	P
D	Q	Q

A

19. Which word correctly completes the sentence below?

    An echo is a sound wave which is …… by a large obstacle.

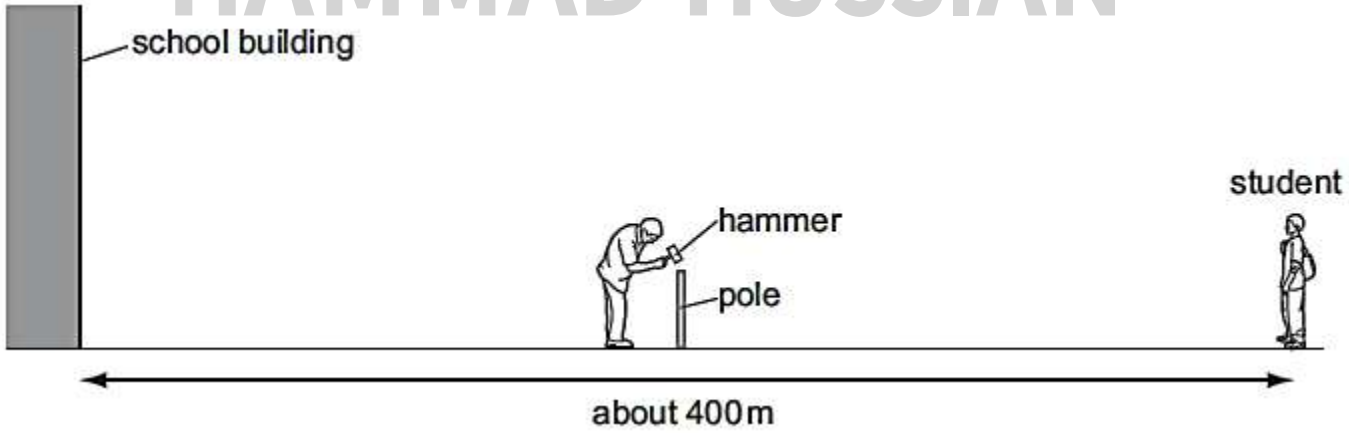
A. absorbed
B. dispersed
C. reflected
D. refracted

20. A girl stands at a distance from a large building. She claps her hands and a short time later hears an echo.

Why is an echo produced when the sound waves hit the building?

A. The sound waves are absorbed.
B. The sound waves are diffracted.
C. The sound waves are reflected.
D. The sound waves are refracted.

21. A sports field is next to a large school building. At the far side of the sports field, a student sees a groundsman hammer a pole into the ground.



The student hears two bangs each time the hammer hits the pole.

Why does the student hear two bangs?

	first bang caused by	second bang caused by
A	sound of hammer hitting pole	sound of pole hitting hammer
B	sound reaching left ear	sound reaching right ear
C	sound reaching student directly	sound due to echo from school building
D	sound reflected back from school building	sound reaching student directly

C

22. An ultrasonic tape-measure is used to find the distance to a wall. It sends out an ultrasonic pulse and times how long it takes for the reflected pulse to return from the wall.

The ultrasound has a frequency, a wavelength and a speed.

Which pair of values is needed to find the distance to the wall?

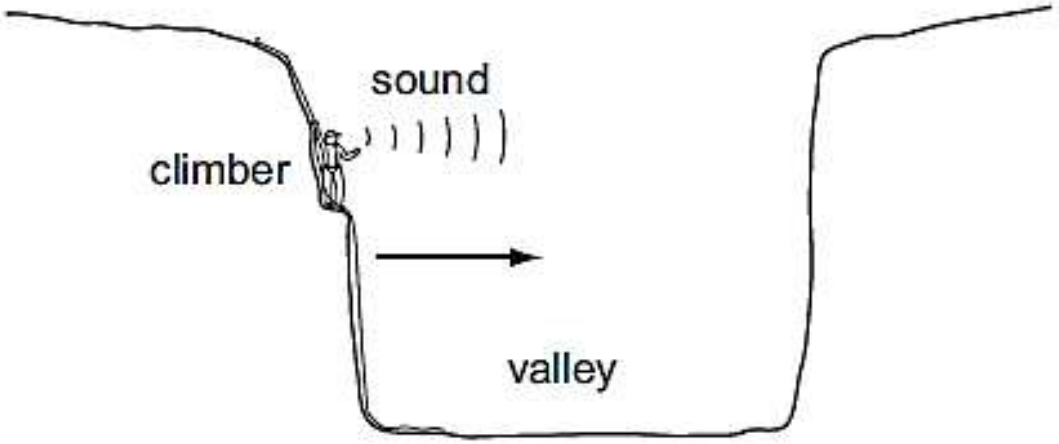
A. frequency and wavelength
B. frequency and time taken for the pulse to return
C. speed and time taken for the pulse to return
D. wavelength and time taken for the pulse to return

23. When the horn on a ship is sounded, the passengers hear an echo from a cliff after 4.0 s.

    If the speed of sound is 340 m/s, how far away is the cliff?

A. 170 m
B. 340 m
C. 680 m
D. 360 m

24. To estimate the width of a valley, a climber starts a stopwatch as he shouts. He hears an echo from the opposite side of the valley after 1.0 s.

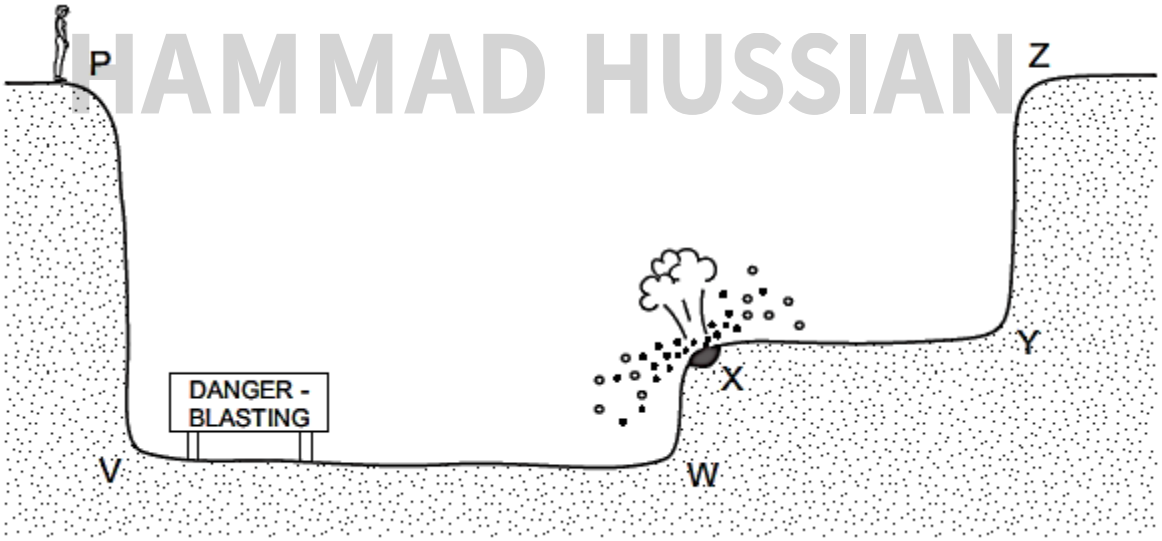


The sound travels at 340 m/s.

What is the width of the valley?

A. 85 m
B. 170 m
C. 340 m
D. 680 m

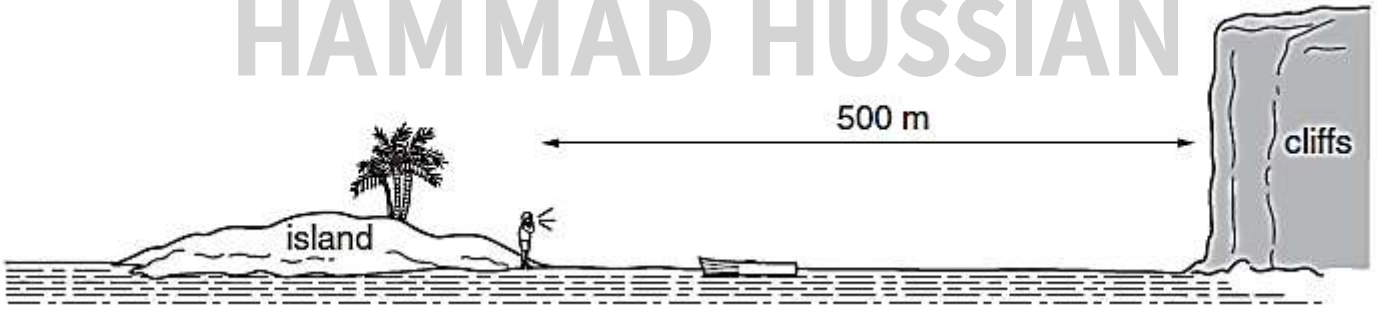
25. An engineer standing at P hears the sound of an explosion at X.



1. After the explosion, she hears two bangs. One bang is heard a fraction of a second after the other.
2. The second bang is an echo from

A. XY.
B. PV.
C. ZY.
D. WX.

26. A boy is stranded on an island 500 m from the shore.



1. He shouts for help, but all he can hear in reply is the echo of his shout from some cliffs.
2. Sound travels at 340 m/ s through the air.
3. What is the time interval between the boy shouting and hearing the echo?

A $\frac{500}{340}$s B $\frac{2 \times 500}{340}$s C $\frac{340}{500}$s D $\frac{2 \times 340}{500}$s

B

27. During a thunderstorm, there is an interval of 1.70 s between an observer seeing the lightning and hearing the thunder. The speed of sound is 340 m/s.

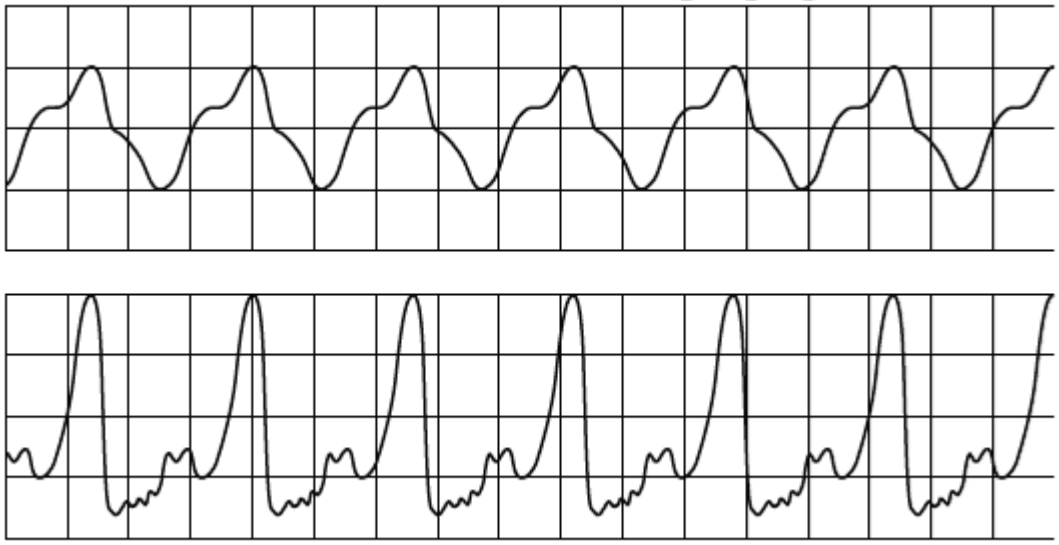
    What is the distance between the observer and the storm?

    A. 100 m
    B. 200 m
    C. 578 m
    D. 1160 m

28. A ship sends a pulse of sound vertically downwards to the sea bed. An echo is heard 0.4 seconds later. If the speed of sound in the water is 1200 m/s, how deep is the water below the ship?

A. 240 m
B. 480 m
C. 1500 m
D. 3000 m

29. The sounds produced by two musical instruments are directed towards a microphone connected to an oscilloscope (cro). The waveforms produced on the screen are shown.

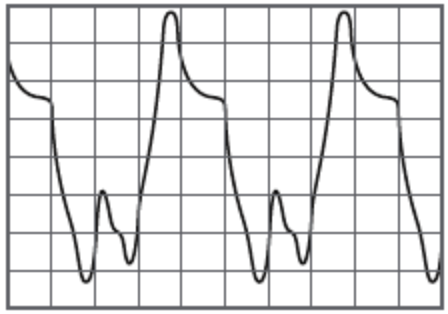


1. The waveforms show that the sounds produced have a different property.
2. What is the property?

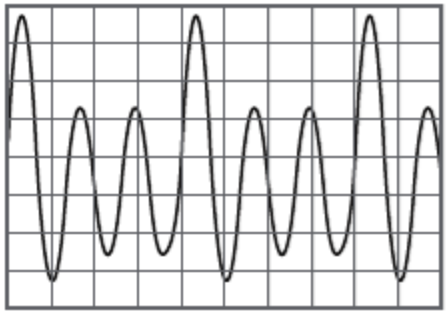
A. frequency
B. speed
C. timbre (quality)
D. wavelength

30. Wave forms are shown on an oscilloscope for a flute and a bassoon playing the same note. The oscilloscope settings are the same for both wave forms.

flute



bassoon



What is the difference between the two sounds?

A. the amplitude
B. the frequency
C. the quality (timbre)
D. the wavelength

Define ultrasound.

Ultrasound

HAMMAD HUSSIAN

Ultrasound

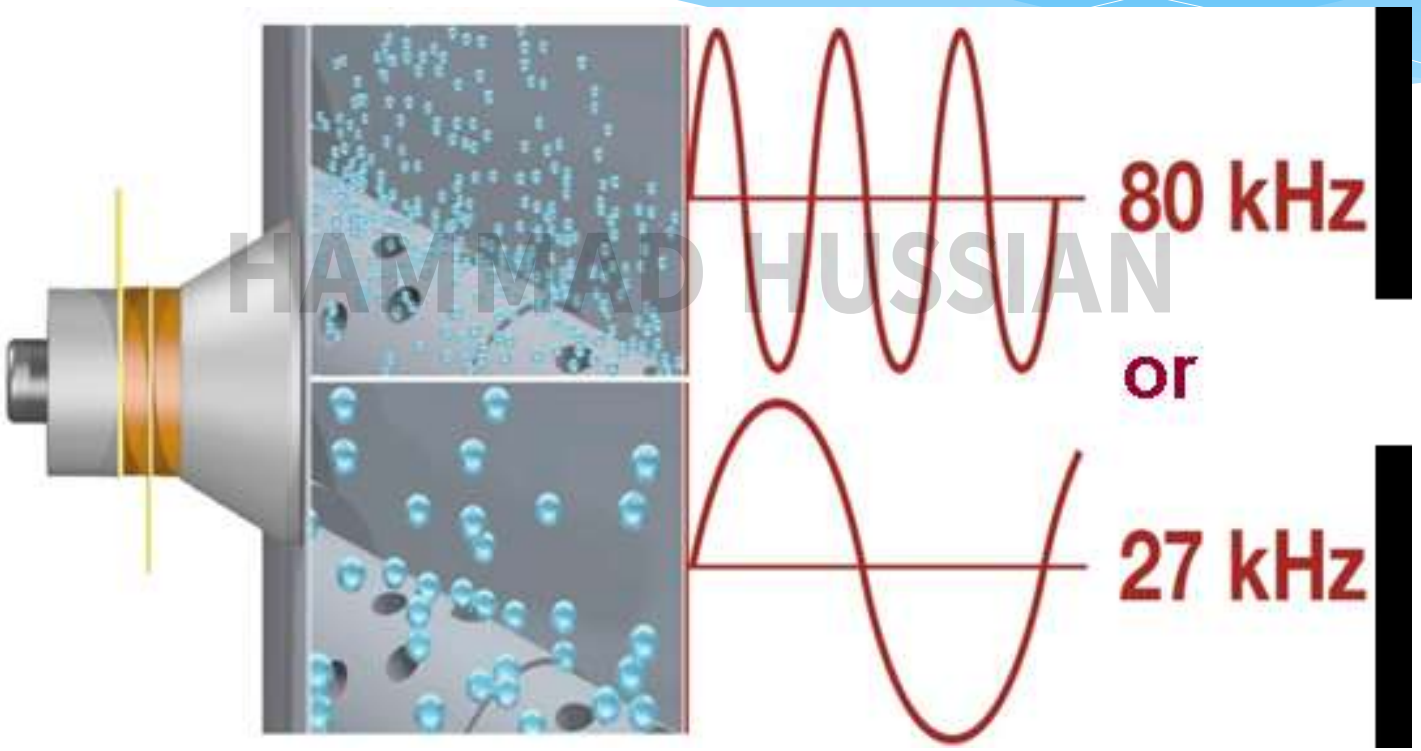
* Ultrasound is the type of sound wave with frequencies greater than 20 kHz.
* Ultrasound cannot be heard by humans, but only other animals can hear them.
* Ultrasound has many medical and commercial uses.

Describe the uses of ultrasound in cleaning, quality control and pre-natal scanning.

Ultrasound

Ultrasonic Cleaning

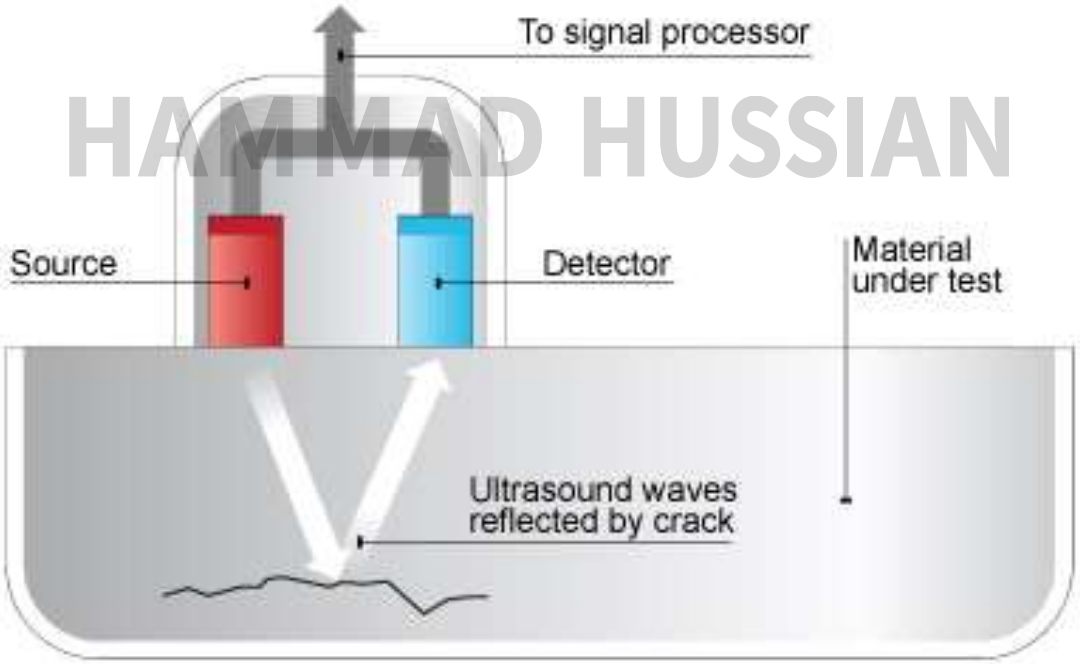
* An **ultrasonic cleaning** is a process that uses ultrasound (usually from 20–400 kHz) and an appropriate cleaning solvent (sometimes ordinary tap water) to clean items.
* Ultrasonic cleaners are used to clean many different types of objects, including jewelry, watches, dental and surgical instruments, industrial parts and electronic equipment.



NDT

* Nondestructive testing is a method of finding defects in an object without harming the object.
* In the aircraft industry, NDT is used to look for internal changes or signs of wear on airplanes.
* The railroad industry also uses nondestructive testing to examine railway rails for signs of damage.

* Ultrasonic waves are emitted from a transducer into an object and the returning waves are analyzed.
* If an impurity or a crack is present, the sound will bounce off of them and be seen in the returned signal



Ultrasonic scanning

* The ultrasound is sent into the patients body.
* At each **boundary** between different tissues or organs some of the ultrasound is **reflected**.
* The depth of each layer is calculated using the time taken for each reflected wave to return.
* The reflected waves (echoes) are usually processed to produce a picture of the inside of the body on a screen.