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## SOUND (Revision)

## SECTION A: TYPICAL EXAM QUESTIONS

## QUESTION 1 – 10 minutes

A boy standing 85m from a high wall is hitting a drum. He realises that the echo coincides exactly with striking his drum every 0,5s.

- 1.1. Calculate the speed of sound using this information. (3)
- 1.2. If the drum skin vibrates at 100Hz, calculate the wavelength of the sound waves. (4)

## QUESTION 2 – 10 minutes

Someone taps against a fence pole while you are holding your ear against another fence pole 1000m further along. The speed of the sound through the wire connecting the poles is  $5000\text{m}\cdot\text{s}^{-1}$ . (Speed of sound in air:  $340\text{m}\cdot\text{s}^{-1}$ )

- 2.1. How soon will you hear the sound coming through the wire? (4)
- 2.2. How much later will you hear the sound through the air? (3)

## QUESTION 3 – 5 minutes

The timekeepers at an athletics meeting are some distance away from the starter. They start their stopwatches when they hear the shot of the starter pistol rather than when they see the smoke.

- 1.1 Does their error work to the runner's advantage or disadvantage? (1)
- 1.2 Explain your answer. (4)



**Teacher Note:** Stress to Learners that energy moves through the medium causing particles to vibrate about a fixed position. The middle of a rarefaction and a compression corresponds to position of rest.

## SECTION B: SOLUTIONS AND HINTS

## QUESTION 1:

$$1.1. \text{ Speed} = \frac{\text{distance}}{\text{time}} = \frac{85\text{m}}{0,25\text{s}} = 340\text{m}\cdot\text{s}^{-1} \quad (3)$$

$$1.2. \quad v = f \times \lambda$$

$$340 = 100 \times \lambda$$

$$\lambda = 340/100 = 3,4\text{m} \quad (4)$$

## QUESTION 2:

$$2.1. \text{ speed} = \frac{\text{distance}}{\text{time}}$$

$$\text{time} = \frac{\text{distance}}{\text{speed}} = \frac{1000}{5000} = 0,2\text{s} \quad (4)$$

$$2.2. \text{ In air: time} = \frac{\text{distance}}{\text{Speed}} = \frac{1000}{340} = 2,94\text{s} \quad (3)$$

## QUESTION 3:

- 3.1. Their error works to the runner's advantage. (1)
- 3.2. Because light moves much faster than sound, therefore there is a time lapse between seeing the smoke and hearing the shot. (2)
- The total time taken by the athlete end up being less than what it would be if they started timing when they saw the smoke. (2)

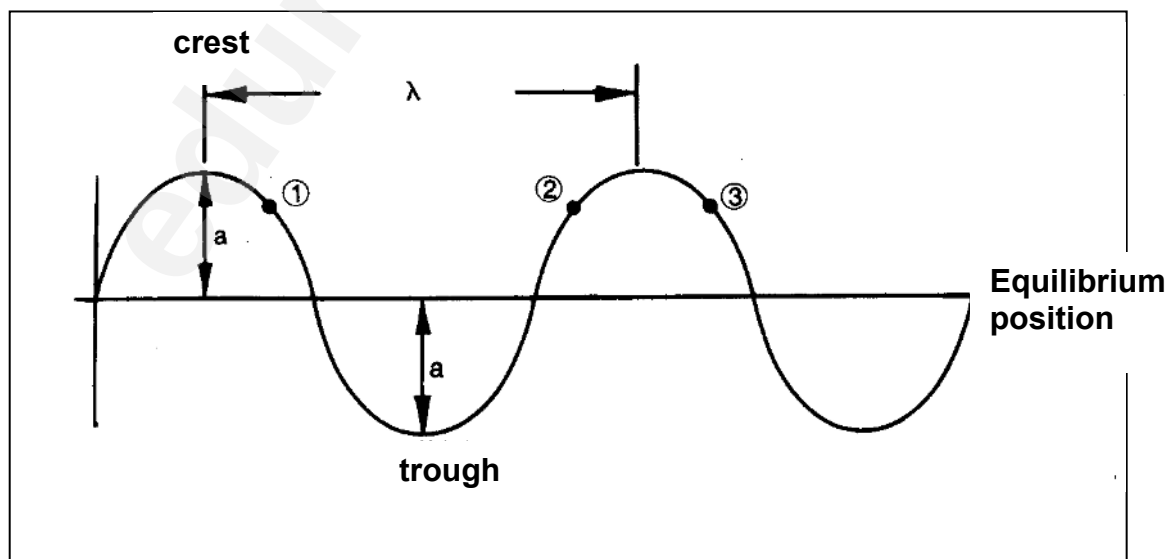
## SECTION C: ADDITIONAL CONTENT NOTES

## 1. Introduction

There are many kinds of waves known to man. There are sound waves, water waves, light waves etc. A vibration is needed to start a wave.

A vibration is a regular backward and forward motion of an object.

A wave has the following properties:



- Amplitude (a) : The maximum distance of disturbance from the equilibrium or rest position.
- Wavelength ( $\lambda$ ) : The distance between two consecutive crests or troughs, or between any two consecutive points that are in phase (1 and 3) which is measured in metres (m).
- Frequency (f) : The amount of waves that pass a certain point in one second and is measured in Hertz (Hz) or  $s^{-1}$ .
- Period (T): The time taken for a pulse to pass a certain point and is measured in seconds (s).
- Wave equation:  $v = f \lambda$  where  $v$  = velocity of the wave is measured in  $m \cdot s^{-1}$ .
- The Principle of Superposition : **If two waves arrive at the same point, the resulting disturbance is the vector sum of the disturbances due to each wave.**
- Constructive interference **occurs when two waves arrive at the same point in phase.**
- Destructive interference **occurs when two waves arrive at the same point out of phase.**

## 2. Sound Waves

### 2.1. How Sound is Produced

- Sound waves are a form of longitudinal wave.
- Energy is needed to make sound. For example tapping a tuning fork or supplying electrical energy to a loudspeaker or beating the drums.
- To produce a sound, objects must vibrate. If the frequency of the sound is too low or too high the human ear cannot hear it. Human ears can hear sound frequencies between 20Hz and 20 000Hz.
- Sound energy cannot pass through a vacuum, it needs a medium (a gas, solid or liquid) in which to travel.
- This is because when the vibration that causes the sound begins, the particles of the medium next to it are set in motion and they in turn bump into the neighbouring particles and that pattern continues. In this way the vibration passes along the substance. When moving particles reach the ears, they make the eardrum vibrate as they bump against it and the sound is heard.

### 2.2. The Speed of Sound

- Sound moves faster in liquids than in gases and fastest in solids.
- The speed of sound in air varies from place to place. It is approximately 340 m/s at 20°C.
- The speed of sound in a gas is affected by the *temperature* of the gas and by its *density*.
- The higher the density of the gas, the slower the speed of sound through it. For example, sound waves move slower in carbon dioxide than in air because it is much denser than air but sound will move much faster in hydrogen as it is less dense.
- Sound moves faster through hot air than through cold air.
- The table below gives the speed of sound in some media.

| Medium                   | Speed (m/s) |
|--------------------------|-------------|
| Air (at 0°C)             | 260         |
| Air (at 20°C)            | 340         |
| Air (at -50°C)           | 290         |
| Hydrogen (at 0°C)        | 1290        |
| Carbon Dioxide (at 20°C) | 280         |
| Water                    | 1480        |
| Glass                    | 5600        |
| Rock                     | 5400        |
| Steel                    | 6000        |

## 2.3. Reflection, Refraction and Resonance

### 2.3.1. Reflection

- All waves can be reflected and sound waves, although not as accurately as light obey the *Law of Reflection* which states  
*The angle of incidence = the angle of reflection*
- When sound energy strikes a medium, three things can happen to it
  - part of it is transmitted through the medium
  - part is absorbed by the medium and
  - the rest is reflected.
- Hard substances such as concrete walls reflect sound well but soft substances like carpets and soft furniture do not reflect sound so well, they actually absorb most of the sound energy.
- The following are phenomena which involve reflection of sound.

#### 1. Echoes

- An echo is formed by the reflection of sound off hard surfaces such as walls and cliffs.
- The distance from a cliff can be determined by clapping your hands and measuring how long it takes to hear the echo. Half this time will be the time takes for the sound to reach the cliff and the speed of sound in air is 340 m/s, the distance can be calculated using the formula : distance = speed x time.
- If the surface forming the echo is too close, we do not hear two distinct sounds. The listener must be at least 30m away from the surface for a sharp sound to have an echo.
- Closer than this, the original sound is only made to sound longer by the echo and this is known as *reverberation*.

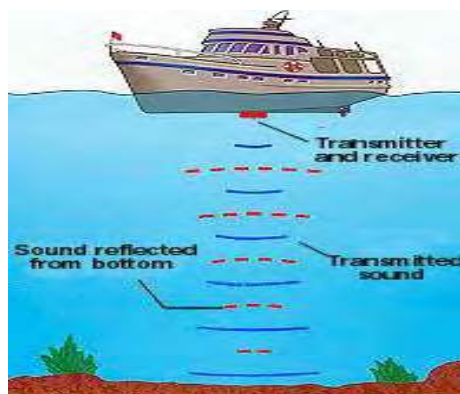
#### 2. Acoustics

- In a large room with no soft surfaces, sound will reflect many times before all the energy is absorbed.
- The echoes of the earlier sounds become mixed with the next sounds produced and the sound becomes unclear because there is too much reverberation.
- The *acoustics* of such a room are poor.
- In theatres and cinemas, the walls and ceilings are often lined with soft sound-absorbing material to help absorb these reflected sounds.
- If too much sound is absorbed however, the sound becomes softer and does not carry to all parts of the theatre.



- A correct balance between reflection and absorption results in a room with good acoustics and the sound can be heard clearly.

## 2. Sonar (Sound navigation and ranging)



- This was developed during World War II to trace submarines.
- Ultrasonic sound waves are transmitted by a special device attached to the hull of the ship. They are reflected by the submarine and are received by a special underwater microphone or detector.
- Since the speed of sound waves in sea-water is known, the time interval between the signal pulse and the echo can be used to calculate the distance between the submarine and the tracking ship.
- The tracking device is called an *echo-sounder*.

## 4. Ultrasound

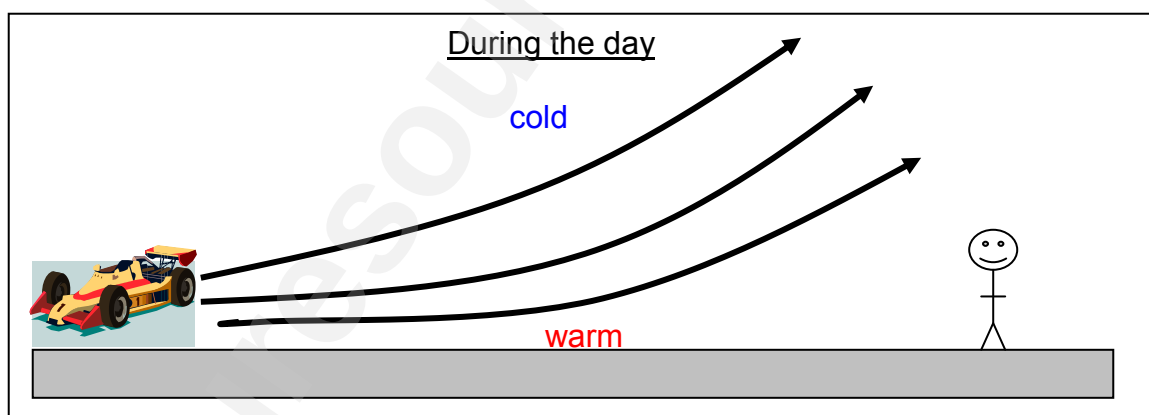
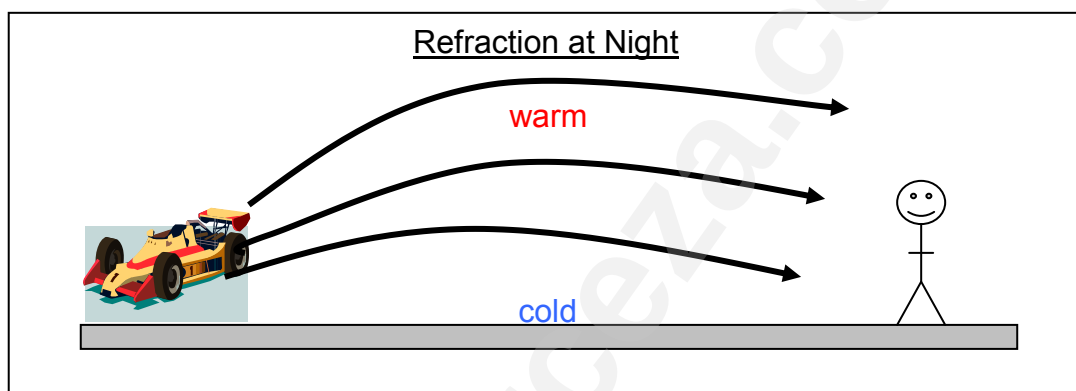
- Sounds that have a higher frequency than the upper limit of normal range (20 – 20 000 Hz) of human hearing are called *ultrasounds*.
- Human beings cannot hear ultrasounds, but animals can.
- Dogs can hear frequencies of up to 50 000Hz and bats can hear frequencies of up to 120 000Hz.
- Bats use ultrasounds to catch their prey.
  - Most bats navigate in darkness by means of a built-in sonar device. It makes a very high-pitched sound (which humans cannot hear) and hears the echo from nearby objects. In this way it locates the positions of the objects, including flying insects and flies.
  - If a bat's mouth is kept closed and its ears plugged it is unable to navigate successfully, it will fly into objects that are in the way.
- Ultrasounds are used also in medicine and industry.
- Ultrasounds can help doctors form pictures of organs inside a human body.
- They are also used to examine unborn babies in their mother's womb. An ultrasound transmitter is moved over the mother's body and a detector picks up sound waves reflected from different layers inside the body. The signals are then processed by a computer, which projects an image of the baby onto the screen. This helps the doctors to see whether the baby is developing normally.
- They are also used as a treatment for kidney stones. Kidney stones are small, hard objects that form inside the kidneys and are very painful. By directing the ultrasound

at the kidney stones, the sound vibration breaks the stones up and they can pass painlessly out of the body.

- In industry, ultrasound scanning is used to detect cracks in metals. Aircraft and railway lines are checked in this way.

### 2.3.2. Refraction

- Speeding up or slowing down of waves as they enter a new medium causes refraction. The bending that sound waves undergo in layers of air of different temperatures is called refraction.
- An example of this is the fact that you can hear the barking of a dog or the music from a radio clearly over a long distance on a cool night but not so well on a hot day.



- On a cold day or at night the air near the ground is cooler than the air higher up. This slows down the sound waves near the ground and makes waves that would have passed over you to bend and reach you by refraction.
- On a hot day, the layer of air near the ground is hotter than the air above the ground and the speed of sound near the ground is increased. Sound waves that start horizontally are bent upwards. Therefore beyond a certain distance from the source, you cannot hear the sound.

### 2.3.3. Resonance

- Resonance occurs when a system vibrates at its natural frequency as a result of the impulses that it receives from another vibrating source at the same frequency.
- A suspension bridge has its own natural frequency. When some other source transfers impulses of the same frequency to such a bridge, the bridge's vibrations can be increased quite considerably. These can be so strong that the bridge collapses.
- For example, the collapse of the Tacoma Bridge in America. On that particular day, the wind transferred impulses to the bridge which matched the frequency of the bridge. Because of resonance, the bridge eventually vibrated so strongly that it collapsed.

**SECTION D: HOMEWORK**

**QUESTION 1 – 1 minute**

1. Write the wave equation using symbols. (1)

**QUESTION 2 – 2 minutes**

2. What is the unit for each of the quantities in the wave equation? (3)

**QUESTION 3 – 9 minutes**

3. Longitudinal waves in a spring have a wavelength of 50mm. The vibrator making them is vibrating at 5 oscillations per second.
- 3.1. Calculate the speed of the waves. (3)
- 3.2. Calculate the period of the wave. (3)
- 3.3. How far will a compression in this wave move in 4s? (3)

**QUESTION 4 – 6 minutes**

4. A vibration of period 0,2s is used to generate longitudinal waves in a spring.
- 4.1. If the wave travels at 1,2m/s in the spring, calculate the wavelength of the wave. (5)
- 4.2. If the frequency of the vibration were to double, what effect would this have on the period of the vibration? (1)
- 4.3. What effect would it have on the wavelength if the speed remains the same? (1)

**QUESTION 5 – 3 minutes**

5. Name the two properties of a gas that affect the speed of sound and how each property affects it. (4)

**QUESTION 6 – 3 minutes**

6. In which of the following gases will sound travel fastest: *air, carbon dioxide or hydrogen*? Explain your answer. (4)

**QUESTION 7 – 2 minutes**

7. When the speed of sound is measured on a very hot day, is it faster or slower than the speed of sound measured on a cold day. Explain.

**QUESTION 8 – 4 minutes**

8. A small boat at sea is in danger of sinking. The captain fires an emergency flare. A passenger on a nearby ship sees the flare explode, and five seconds later hears the explosion.
- 8.1. Explain the delay between seeing the smoke and hearing the explosion. (2)
- 8.2. How far is the troubled boat from the ship? (3)