Properties ✓, Echo ✓, EM waves

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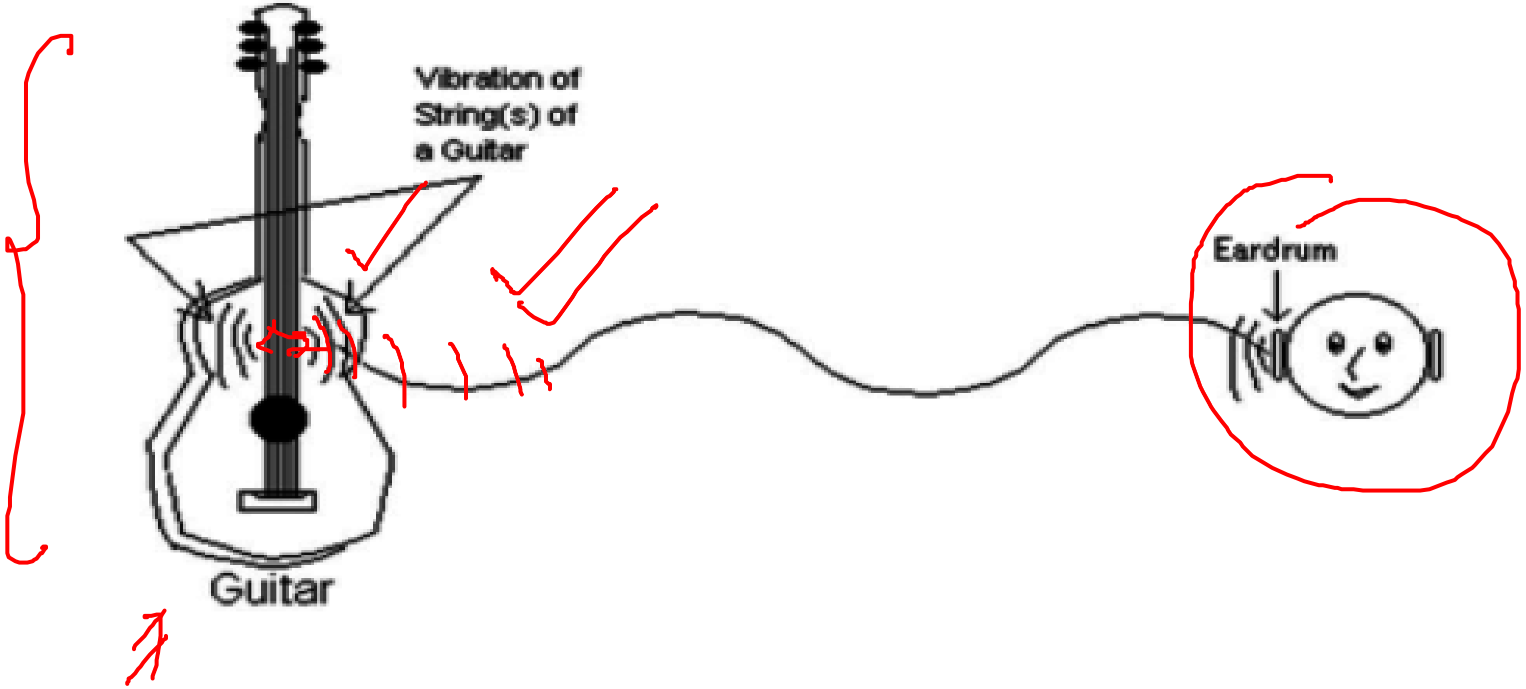
. Introduction to waves (mechanical waves)

A wave is a disturbance in a medium which moves from one point to another and carries energy without a net movement of particles.

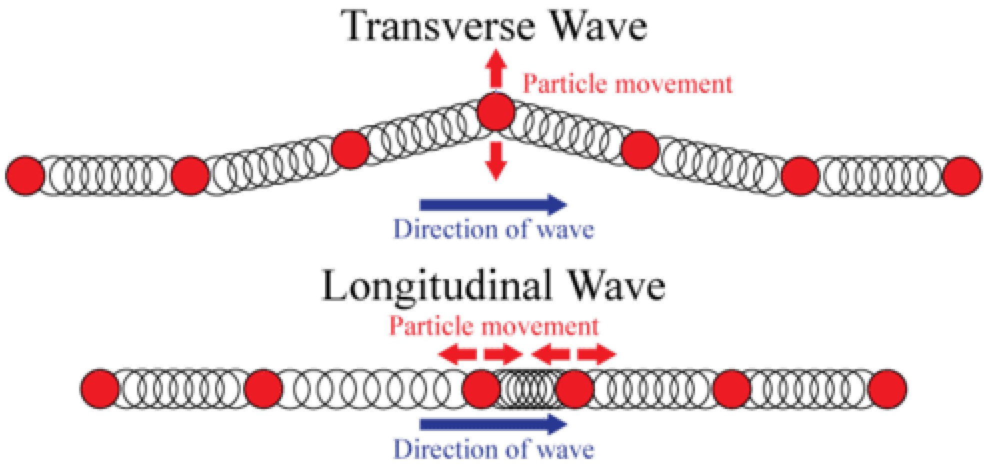
E.g: Rubber cork on the water that goes up and down when a rock falls in the water creates a ripple.



- Particle motion of mechanical waves

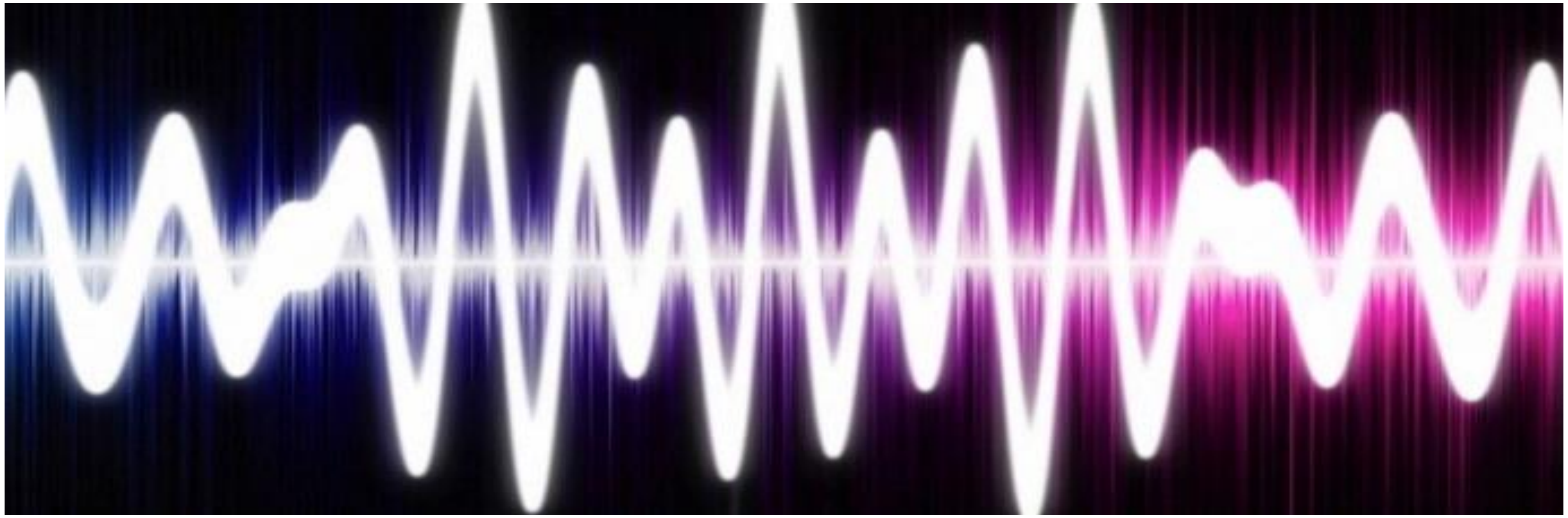
- (i) Transverse Waves
- Particle motion is perpendicular to the direction of wave motion. This type of wave is a mechanical wave.
- E.g: Light and Mexican wave in a stadium.

- (ii) Longitudinal waves
- Particles travel parallel to the direction successive compressions or elongation
- E.g: Sound waves in air.



Sound

- A vibration that propagates as an audible wave of pressure, through a medium such as a gas, liquid or solid.



- # Propagation Of Sound

Sound Needs A Medium To Travel

Sound Waves Are Longitudinal Waves

Speed Of Sound In Different Media

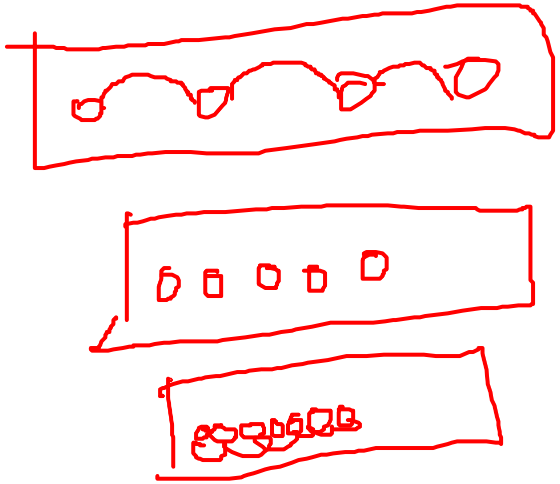
$C = 3 \times 10^8 \, m/s$

$v < C$

- # Reflection Of Sound

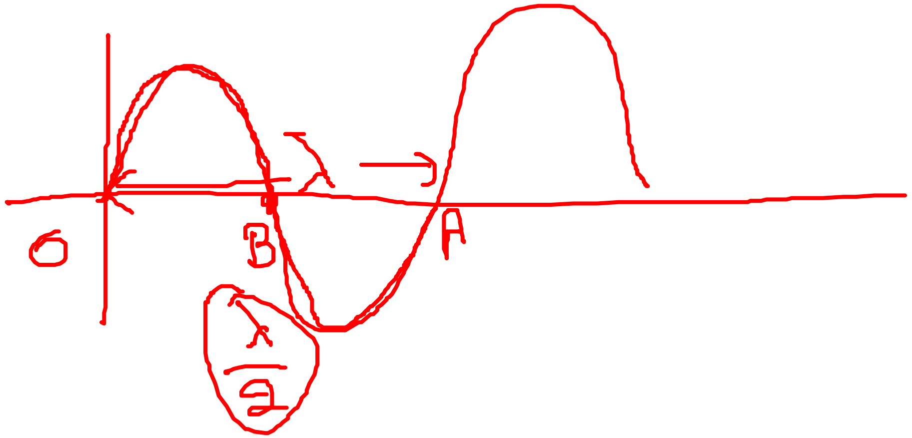
Echo

Reverberation



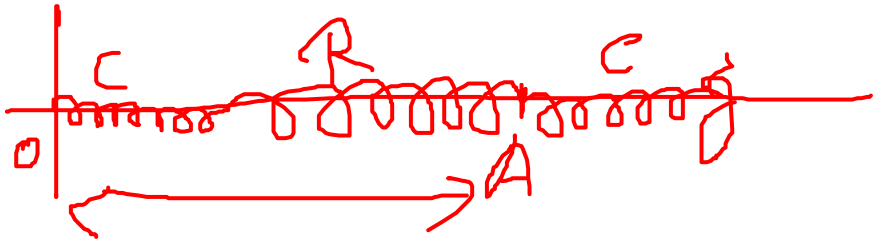
• Wavelength

The distance between two successive crests or troughs (or) successive compressions and rarefactions is called as wavelength (λ). The SI unit of wavelength is metre (m).



• Time period

Time taken by two consecutive compressions or rarefactions to cross a fixed point is called a Time period (T). The SI unit of time in seconds (s).



- **Amplitude**

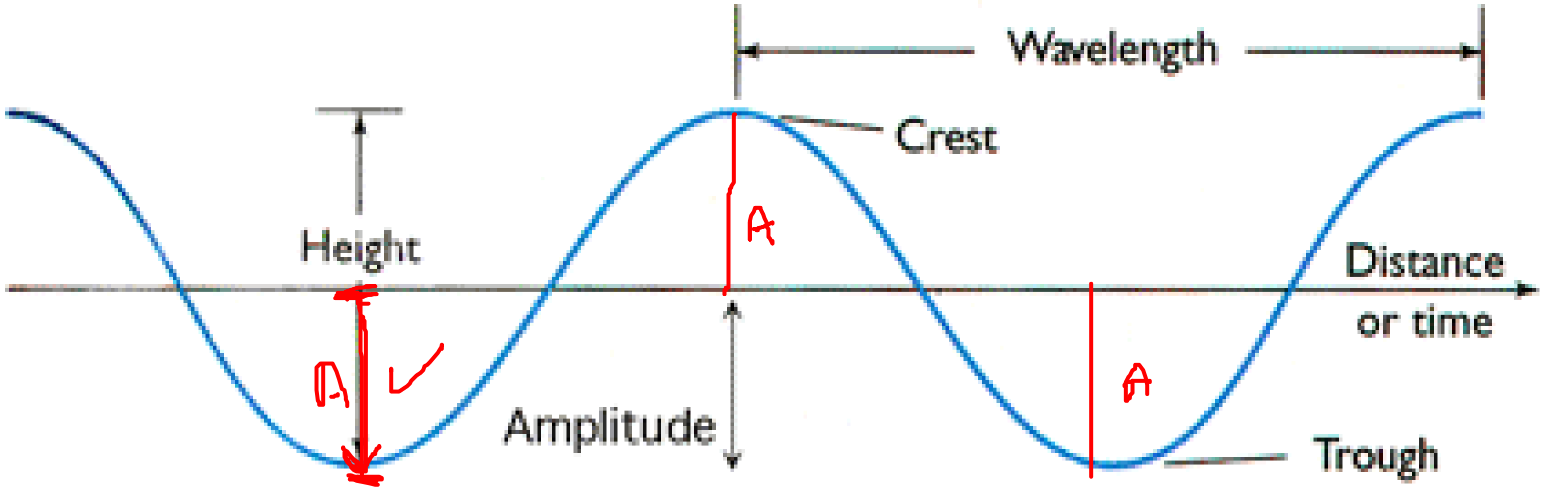
The magnitude of disturbance in a medium on either side of the mean value is called an amplitude (A).

- **Frequency**

The number of compressions or rarefactions per unit time is called frequency (ν). The SI unit of frequency is Hertz. The SI unit is Hertz (s^{-1})

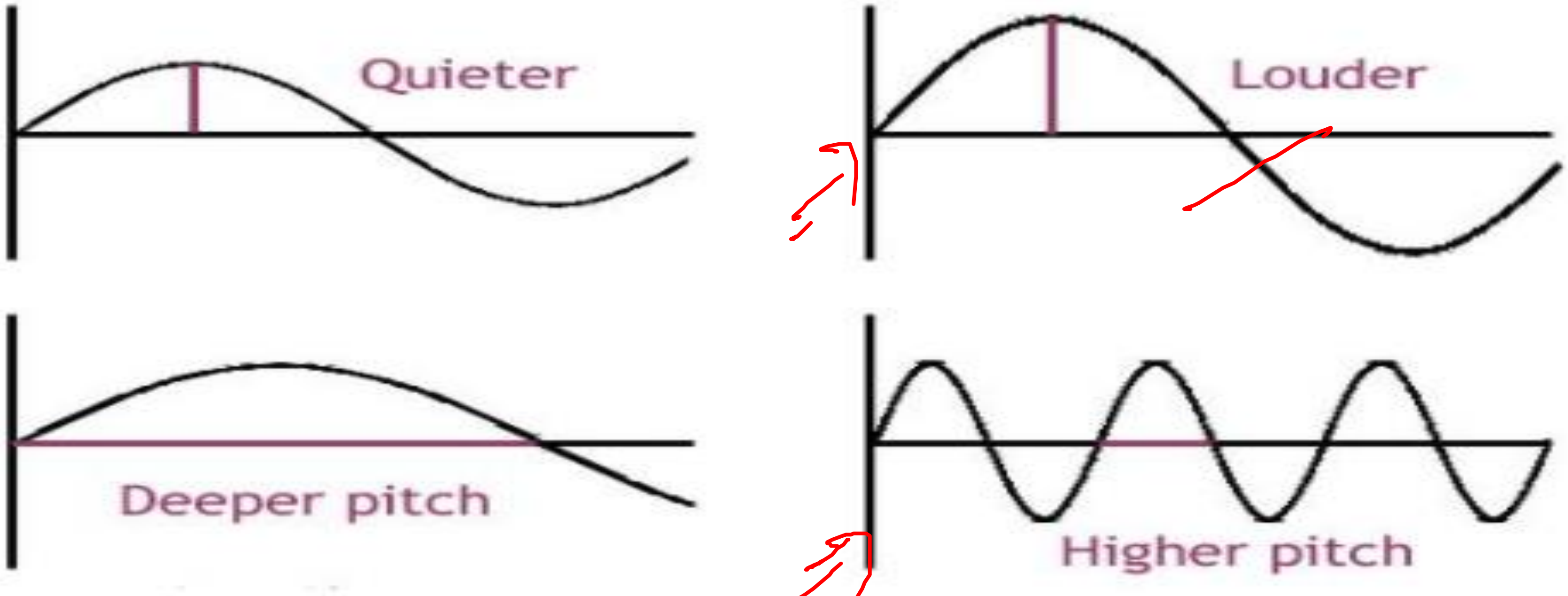
$$v = \frac{1}{T}$$

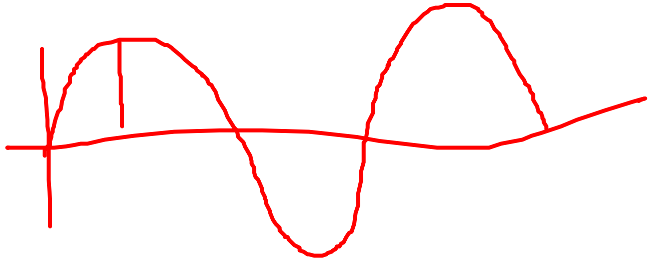
Speed (v), wavelength (λ) and frequency (ν) are related as $v=\lambda\nu$



- **Pitch**

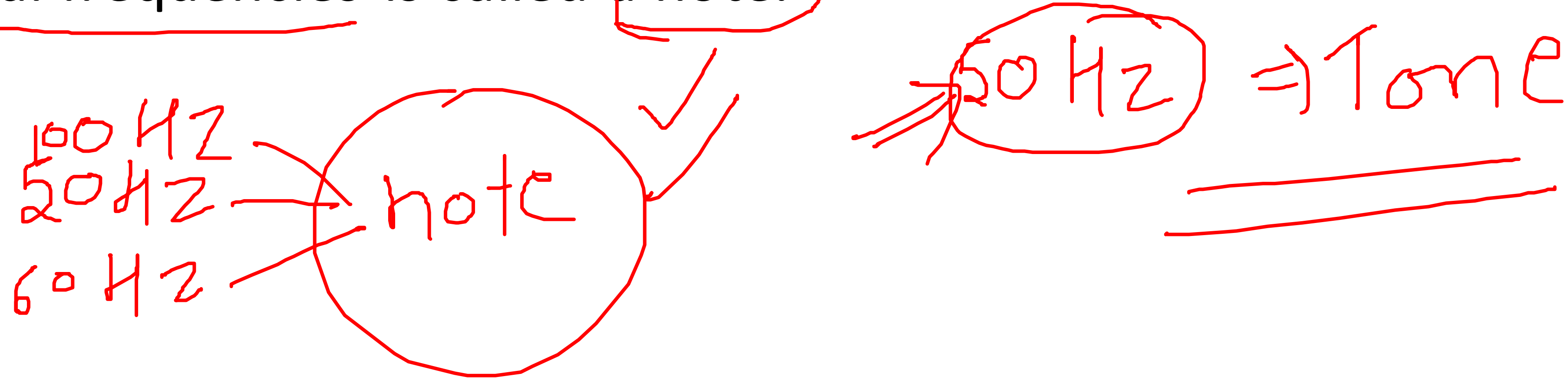
The number of compressions or rarefactions per unit time. Directly proportional to frequency.





- Higher force → higher amplitude → louder sound
- The amount of sound energy flowing per unit time through a unit area is called the intensity of sound.
- **Note and Tone**

A sound of a single frequency is called a tone. A sound produced with a mixture of several frequencies is called a note.



- **Speed of sound**
- Sound travels through different media with different speeds. Speed of sound depends on the properties of the medium: pressure, density and temperature
- **Speed of sound: Solids > Liquids > Gases**
- Speed of sound in air = 331 m/s at 0^0C and 344 m/s at 22° C
-

- **<u>Factors Affecting the Speed of Sound</u>**

- **<u>Density of the medium</u>**

When the medium is dense, the molecules in the medium are closely packed which means that the force required by the molecules to vibrate is more. Therefore, the speed of sound decreases as the density of the medium increases.

- **<u>Temperature of the medium</u>**

The temperature of the medium and the sound waves are directly proportional to each other. Therefore, as the temperature increases, the speed of sound increases.

- **<u>Speed of Sound in Solid</u>**

Speed of sound in solid is 6000 meters per second while the speed of sound in steel is equal to 5100 meters per second.

Another interesting fact about the speed of the sound is that sound travels 35 times faster in diamonds than in the air.

- **Speed of Sound in Water**

The speed of sound in water is 1480 metres per second.

It is also interesting to know that the speed may vary between 1450 to 1498 meters per second in distilled water whereas

the speed is 1531 metres per second in seawater when the temperature is between 20°C to 25°C.

- **Speed of Sound in Gas**

We should remember that the speed of sound is independent of the density of the medium when it enters a liquid or solid.

Since gases expand to fill the given space, density is quite uniform irrespective of the type of gas.

This clearly isn’t the case with solids and liquids.

Table 12.1: Speed of sound in different media at 25 °C

State	Substance	Speed in m/s
Solids	Aluminium	6420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass (Flint)	3980
Liquids	Water (Sea)	1531
	Water (distilled)	1498
	Ethanol	1207
	Methanol	1103
Gases	Hydrogen	1284
	Helium	965
	Air	346
	Oxygen	316
	Sulphur dioxide	213

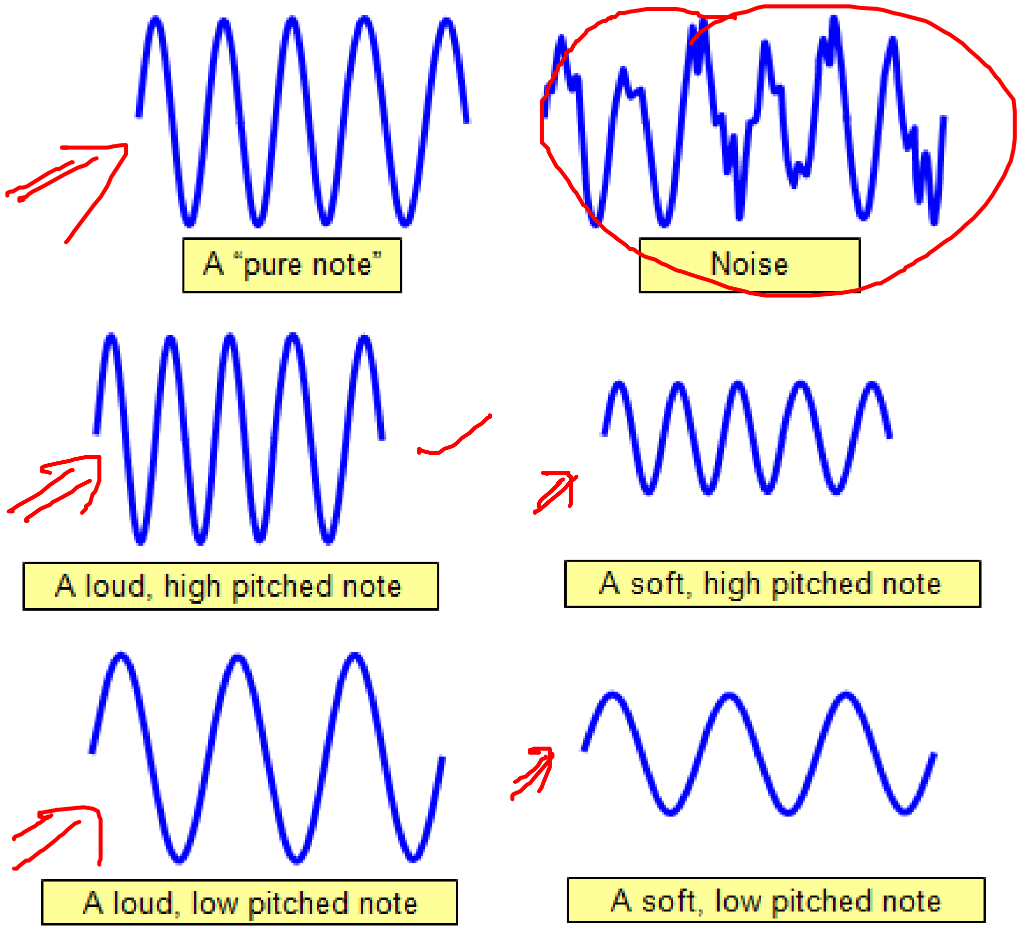
- **Echo**
- The phenomenon where a sound produced is heard again due to reflection is called an echo.
  E.g: Clapping or shouting near a tall building or a mountain.

- To hear distinct echo sound, the time interval between original and reflected sound must be at least 0.1s.
- Minimum distance for obstruction or reflective surface to hear an echo should be 17.2 m.

20Hz - 20000Hz

- <u>Audible and inaudible sounds</u> 20kHz
- Audible range = 20Hz to 20kHz known as the Sonic range.
- Below 20 Hz (inaudible) → infrasonic range
- Above 20 kHz (inaudible) → Ultrasonic range

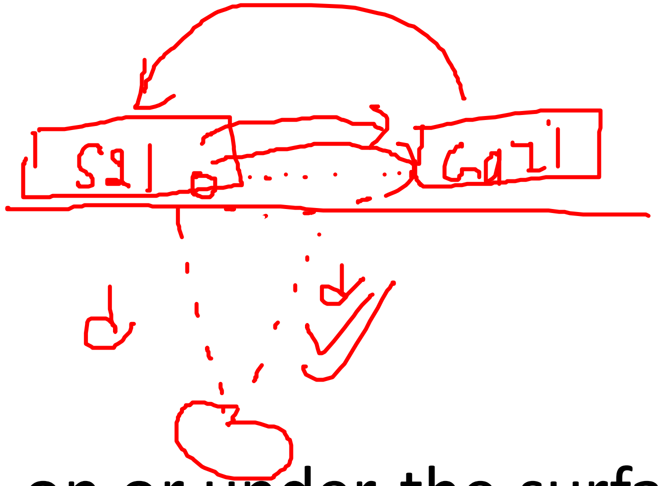
- **Noise and music**
- – Sounds with the same pitch and loudness can be distinguished based on the quality. Music is pleasant to the ears while noise is not.
- – Unpleasant sounds are called as noise.



Ultrasonic sounds

- Ultrasonic sounds are high-frequency sound having a frequency greater than 20kHz (inaudible range).

- **Applications of Ultrasound**



- (i) Scanning images of human organs
  (ii) Detecting cracks in metal blocks
  (iii) Cleaning parts that are hard to reach
  (iv) Navigating, communicating or detecting objects on or under the surface of the water (SONAR).

- **2d=v×t.** This method is called echo-location or echo ranging.

- **Reverberation**
- Persistence of sound because of multiple reflections is called reverberation.
- Examples: Auditorium and a big hall.
- E.g: Fibreboard and rough plaster.

- **DOPPLER EFFECT**
- According to Doppler's effect, whenever there is a relative motion between a source of sound and listener, the apparent frequency of sound heard by the listener is different from the actual frequency of sound emitted by the source

- Example: If one is standing on a street corner and an ambulance approaches with its siren blaring, the sound of the siren steadily gains in pitch as it comes closer and then, as it passes, the pitch suddenly lowers.
- . Apparent frequency,

$$v' = \frac{V - V_L}{V - V_S} \times v$$

Special Cases :

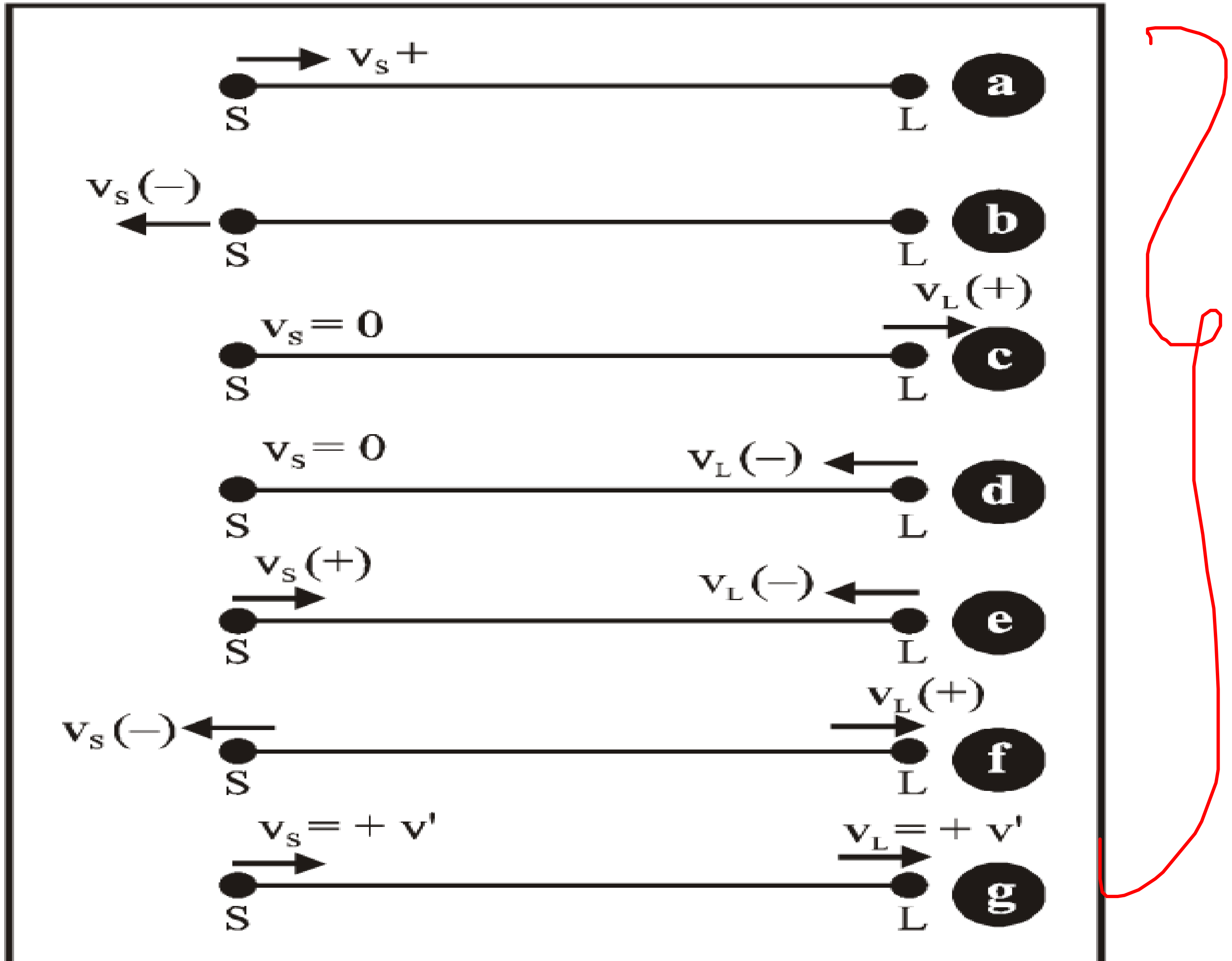
(a) If the source is moving towards the listener but the listener is at rest, then v_s is positive and $v_L = 0$ (figure a). Therefore,

$$\nu' = \frac{v}{v - v_s} \times \nu$$ i.e. $\nu' > \nu$

(b) If the source is moving away from the listener, but the listener is at rest, then v_s is negative and $v_L = 0$ (figure b). Therefore,

$$\nu' = \frac{v}{v - (-v_s)} \nu = \frac{v}{v + v_s} \nu$$ i.e. $\nu' < \nu$

(c) If the source is at rest and listener is moving away from the source, the $v_s = 0$ and v_L is positive (figure c). Therefore,



$$\boxed{\nu' = \frac{(v - v_L)}{v}\nu} \quad \text{i.e. } \nu' < \nu$$

(d) If the source is at rest and listener is moving towards the source, then $v_s = 0$ and v_L is negative (figure d). Therefore,

$$\boxed{\nu' = \frac{v-(-v_L)}{v}\nu = \frac{v+v_L}{v}\nu}$$ i.e. $\nu' > \nu$

(e) If the source and listener are approaching each other, then v_s is positive and v_L is negative (figure e). Therefore,

$$\boxed{\nu' = \frac{v-(-v_L)}{v-v_s}\nu = \left(\frac{v+v_L}{v-v_s}\right)\nu}$$ i.e. $\nu' > \nu$

(f) If the source and listener are moving away from each other, then v_s is negative and v_L is positive, (figure f). Therefore,

$$\boxed{\nu' = \frac{v-v_L}{v-(-v_s)}\nu = \frac{v-v_L}{v+v_s}\nu}$$ i.e. $\nu' < \nu$

(g) If the source and listener are both in motion in the same direction and with same velocity, then $v_s = v_L = v'$ (say) (figure g). Therefore,

(g) If the source and listener are both in motion in the same direction and with same velocity, then $v_s = v_L = v'$ (say) (figure g). Therefore,

$$\boxed{\nu' = \frac{(v - v')}{(v - v')}\nu} \quad \text{i.e. } \nu' = \nu$$

It means, there is no change in the frequency of sound heard by the listerner.

Apparent wavelength heard by the observer is

$$\lambda' = \frac{\nu - \nu_s}{\nu}$$

7. CHARACTERISTICS OF SOUND

- **Loudness** of sound is also called level of intensity of sound.

  In decibel the loudness of a sound of intensity I is given by $L = 10 \log_{10} \left(\frac{I}{I_0}\right)$. $(I_0 = 10^{-12}\ w/m^2)$

- **Pitch** : It is pitch depends on frequency, higher the frequency higher will be the pitch and shriller will be the sound.

ELECTRO MAGNETIC WAVES

Electromagnetic Waves

- **Displacement Current**

While charging a capacitor, Maxwell found an inconsistency in the Ampere’s law. Maxwell suggested the existence of an additional current, called displacement current, to remove this inconsistency.

This displacement current is due to the time-varying electric field and is given by $i_d = \varepsilon_0 (d\phi_E/dt)$ and acts as a source of the magnetic field in exactly the same way as conduction current.

Maxwell's Equations

1. $\oint \mathbf{E} \cdot d\mathbf{A} = Q / \varepsilon_0$ (Gauss's Law for electricity)

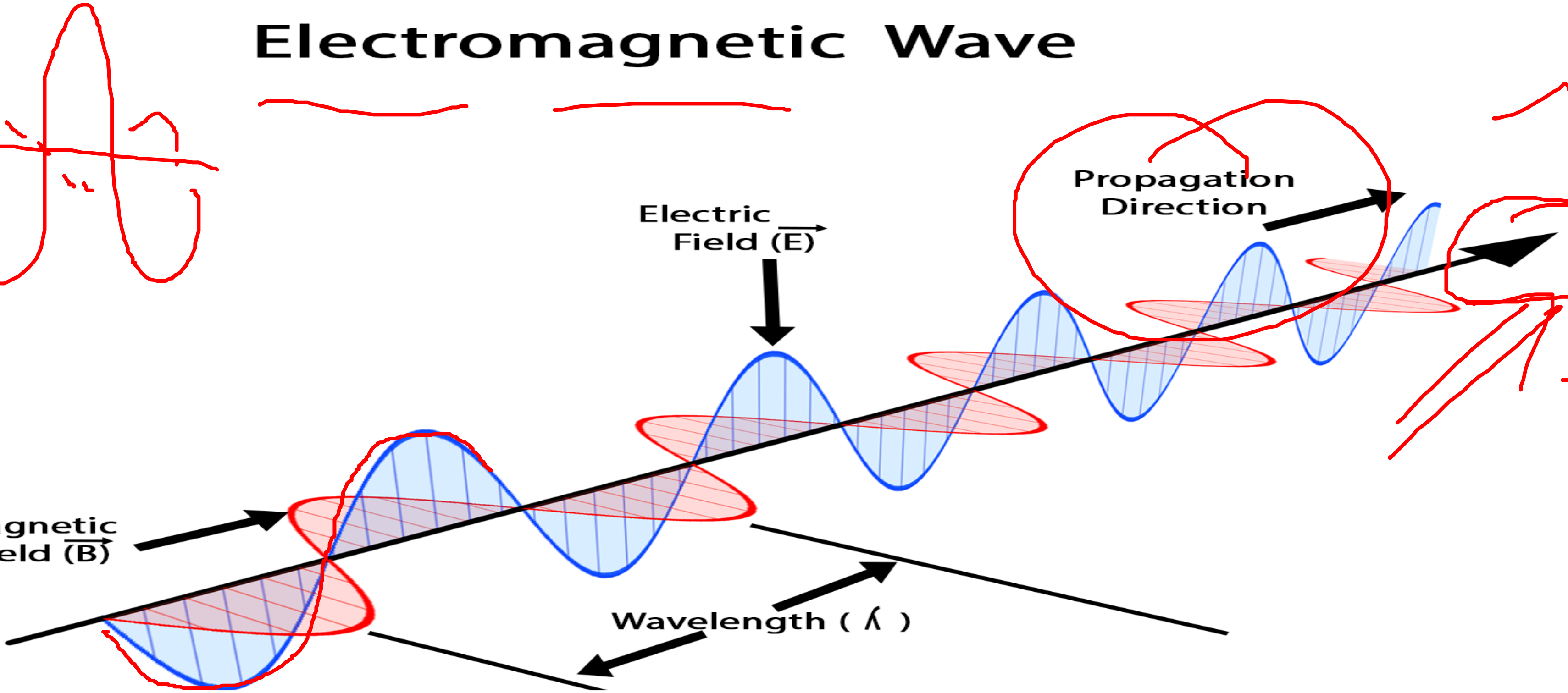
2. $\oint \mathbf{B} \cdot d\mathbf{A} = 0$ (Gauss's Law for magnetism)

3. $\oint \mathbf{E} \cdot d\mathbf{l} = \dfrac{-d\Phi_B}{dt}$ (Faraday's Law)

4. $\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 i_c + \mu_0 \varepsilon_0 \dfrac{d\Phi_E}{dt}$ (Ampere – Maxwell Law)

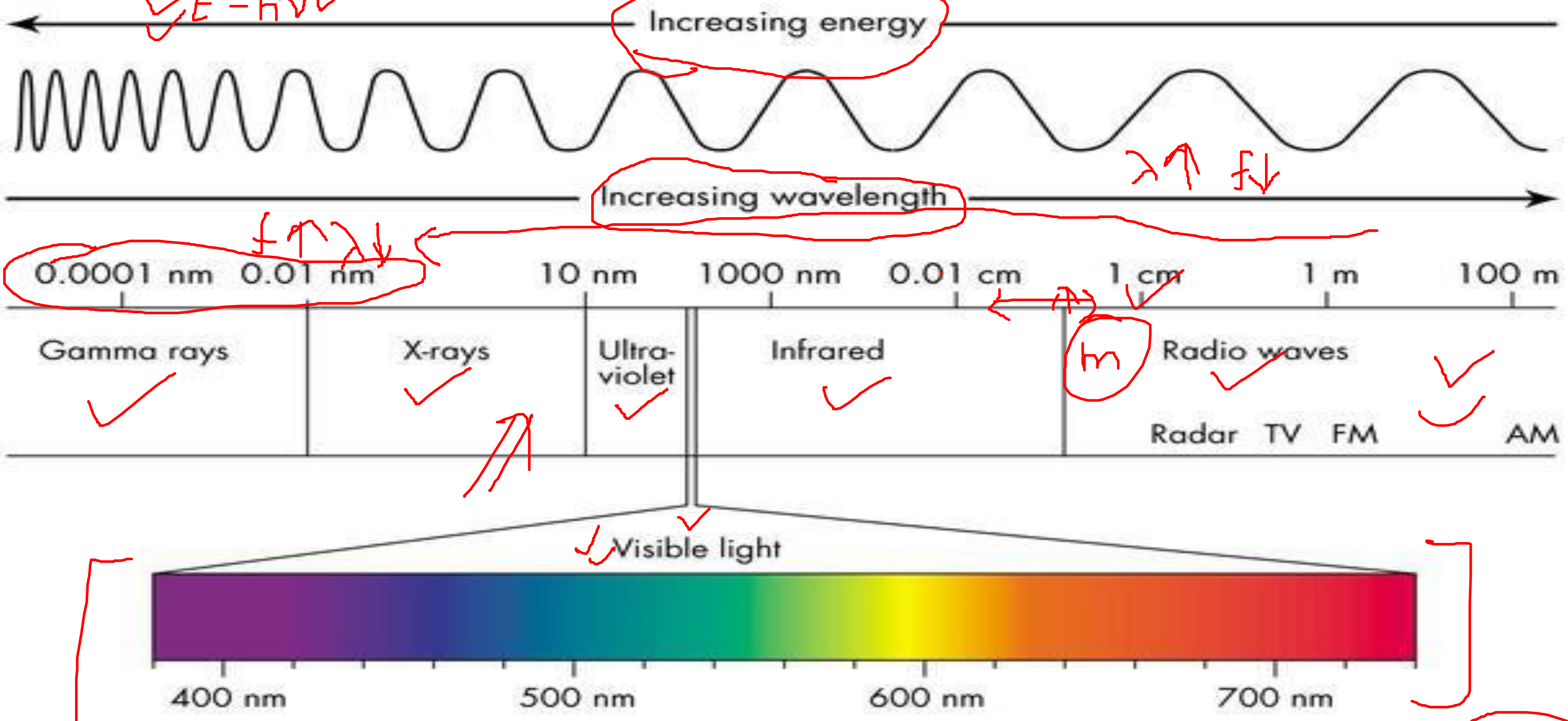
- **Electromagnetic Waves**

Electromagnetic waves are those waves in which there are sinusoidal variations of electric and magnetic field vectors at right angles to each other as well as at right angles to the direction of wave propagation.



- The speed *c* of the electromagnetic wave in vacuum is related to *μ* and *ε* (the free space permeability and permittivity constants) as follows:

$$c = 1/\sqrt{\mu_o \varepsilon_o}$$



{7 Types}

400 – 700 nm

Different Types of Electromagnetic Waves

- **Radio waves**

Radio waves are produced by the accelerated motion of charges in conducting wires.

They are used in radio and television communication systems.

They are generally in the frequency range from 500 kHz to about 1000 MHz.

$$\lambda = 1 m$$

- **Microwaves**

Microwaves (short-wavelength radio waves), with frequencies in the gigahertz (GHz) range.

They are produced by special vacuum tubes (called klystrons, magnetrons and Gunn diodes).

Due to their short wavelengths, they are suitable for the radar systems used in aircraft navigation.

- **Infrared waves**

Infrared waves are sometimes referred to as heat waves.

Infrared waves are produced by hot bodies and molecules.

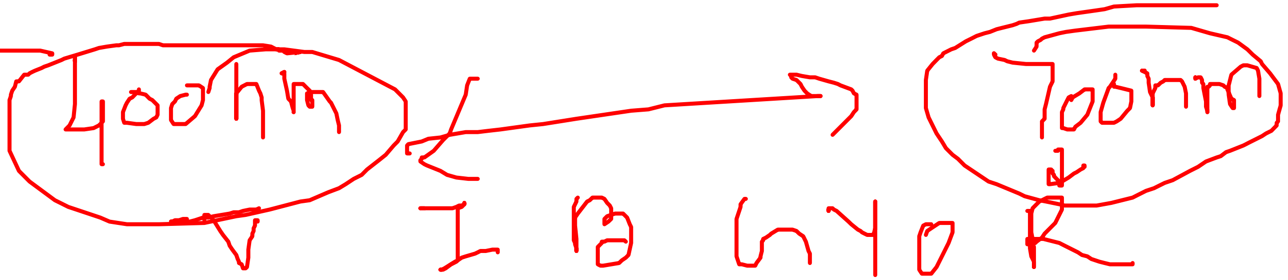
Infrared radiation plays an important role in maintaining the earth's warmth or average temperature through the greenhouse effect.

- **Visible rays**

It is the part of the spectrum that is detected by the human eye.

It runs from about 4×10^{14} Hz to about 7×10^{14} Hz or a wavelength range of about 700 – 400 nm.

Visible light emitted or reflected from objects around us provides us information about the world.



- **Ultraviolet rays**

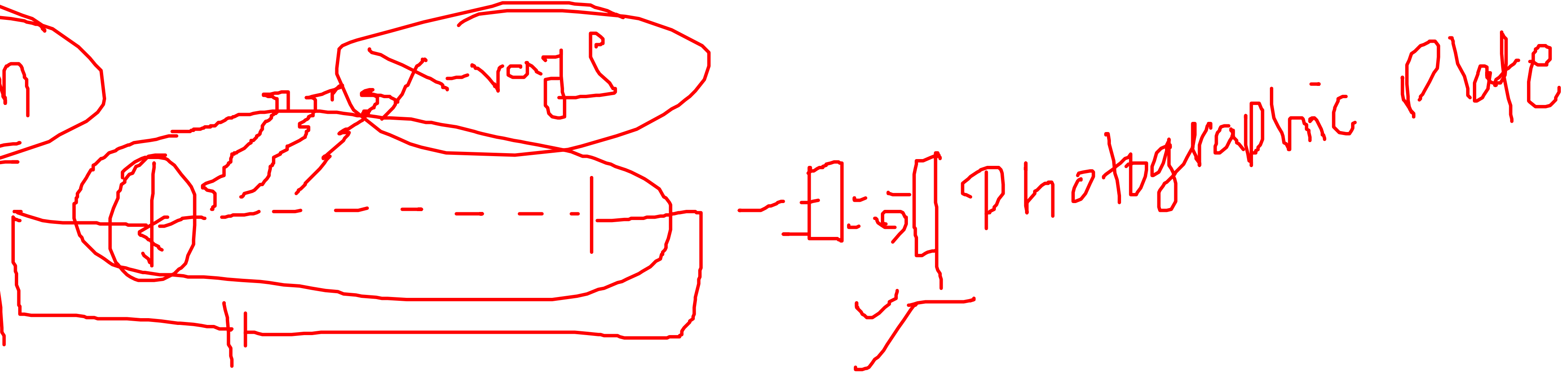
It covers wavelengths ranging from about 4×10^{-7} m (400 nm) down to 6×10^{-10} m (0.6 nm).

Ultraviolet (UV) radiation is produced by special lamps and very hot bodies.

The sun is an important source of ultraviolet light.

Ultraviolet radiations can be focused into very narrow beams for high precision applications such as LASIK (Laser assisted in situkeratomileusis) eye surgery.

Ultraviolet lamps are used to kill germs in water purifiers



- **X-rays**

It covers wavelengths from about 10^{-8} m (10 nm) down to 10^{-13} m (10–4 nm).

One common way to generate X-rays is to bombard a metal target by high energy electrons.

X-rays are used as a diagnostic tool in medicine and as a treatment for certain forms of cancer.

- **<u>Gamma rays</u>**

The wavelengths of Gamma rays are from about 10^{-10} m to less than 10^{-14} m.

Gamma rays are produced in nuclear reactions and also emitted by radioactive nuclei.

They are used in medicine to destroy cancer cells.

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