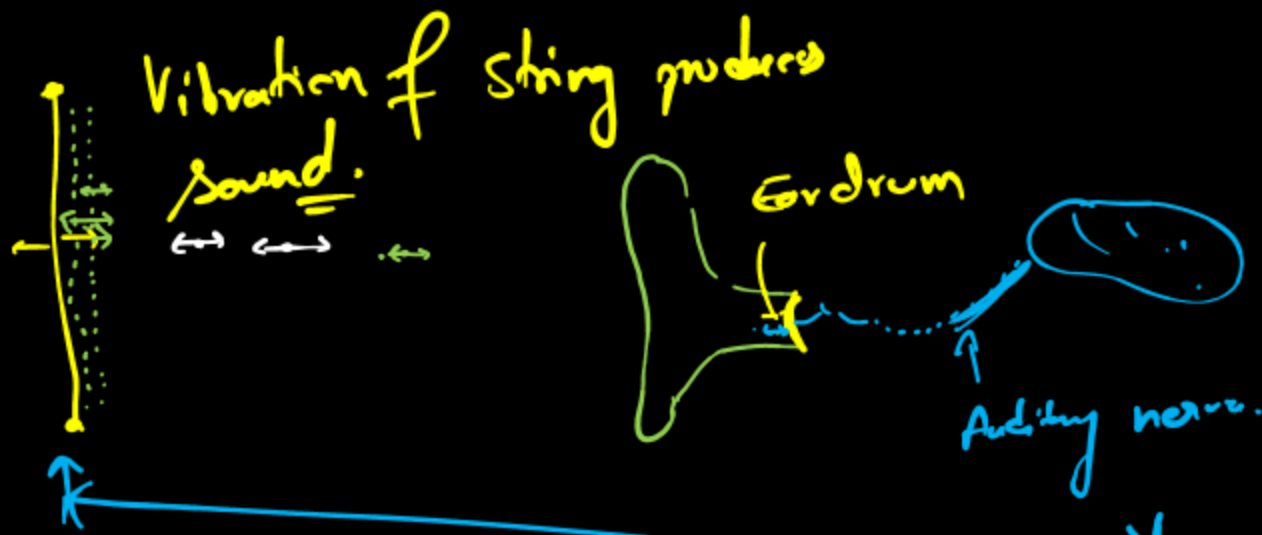
Sound /Light Waves

Sound

⇒ "Form of energy that produces the sensation of hearing in our ears".

* Sound is produced by vibrations

* Vibration travels from one place to other place in the form of wave (mechanical waves)



Experiments to demonstrate that sound is produced by vibration.

Exp 1: Stretch a string by holding one end between the teeth and other hand in one hand. Pluck it by other hand.

Exp 2: If the string of sitar (or guitar) is plucked, the string starts vibrating and its sound is heard.

On blowing a whistle, air inside whistle starts vibrating and a sound is heard.

* We can conclude that sound is produced when a body vibrates. As it stops vibration, the production of sound is ceases.

> A vibrating body is a source of sound

Sound is a form of energy

=> Mechanical energy is required to start vibration in a body.

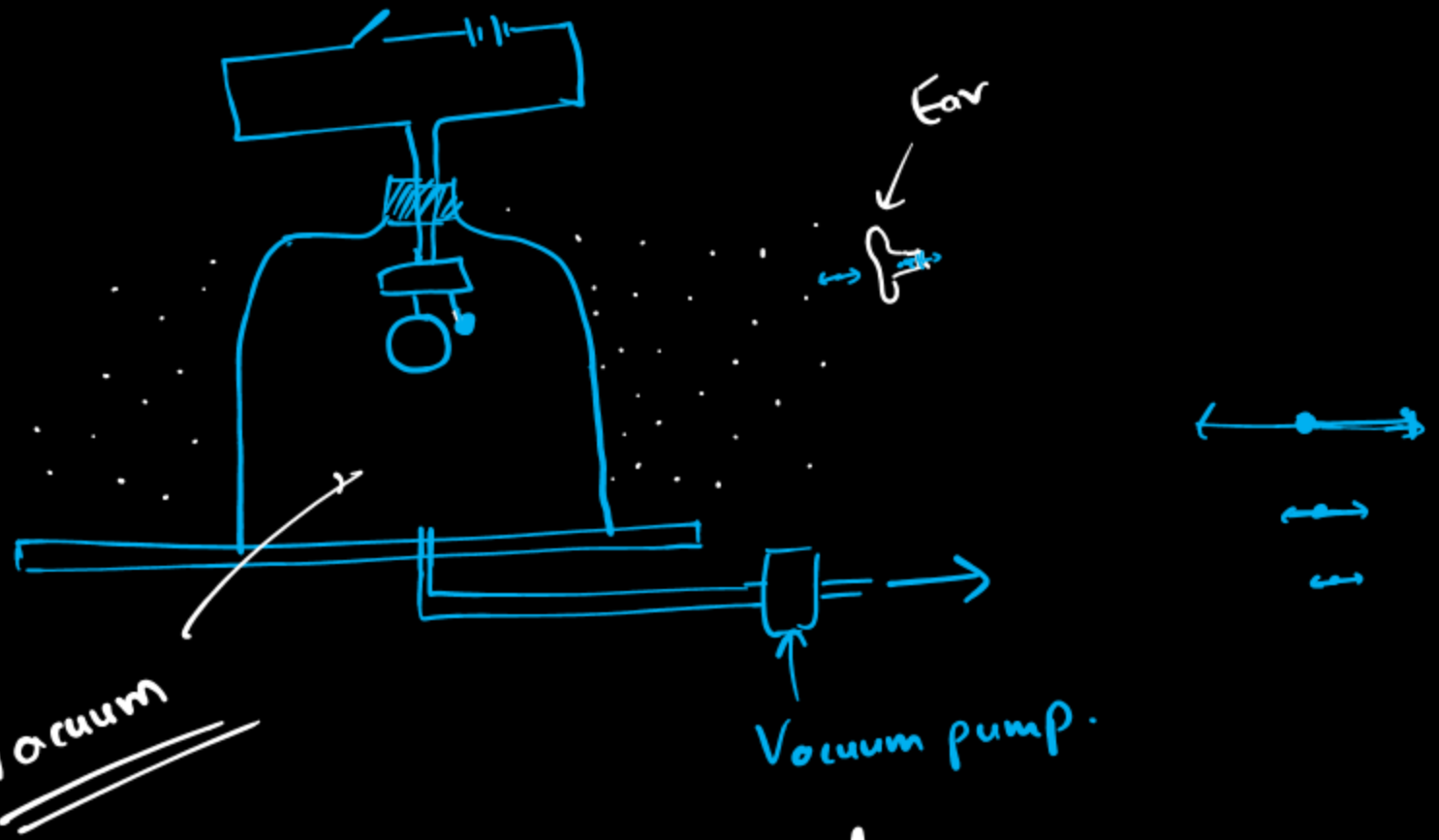
↳ (Sound is produced)

↳ Vibration of the body is transmitted in a medium in the form of waves from that point to the next and so on.

↳ The waves on reaching our ears, produce vibration in the ear-drum, which are perceived as sound by our brain.

Hence, Sound is a form of energy

Sound Propagation requires a material medium

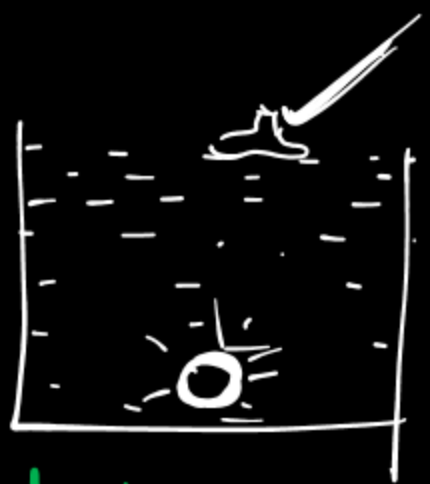


Bell-jar Experiment

↳ Proves that sound requires a material medium to propagate.

Material medium

- Gas (✓) — slowest
- Liquid (✓) — faster
- Solid (✓) — fastest



Speed of sound is different in various mediums.

Speed ⇒ Solid > Liquid > Gas

Fact Box.

Speed of Sound

- → in air = ~332 ms⁻¹
- → in water = 1450 ms⁻¹
- → in steel = 5100 ms⁻¹

⇒ A material medium is necessary for the propagation of sound from one place to other.

Properties of the medium

(i) The medium must be elastic (Vibration)
↳ particles should come back to initial position.

(ii) The medium should be frictionless.
So that there is no loss of energy in propagation.

(iii) The medium should have inertia (some mass)

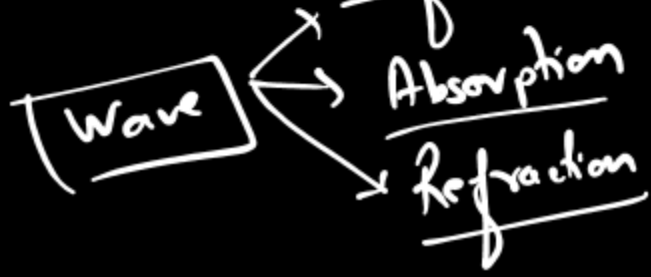
Photon (mass less particles)

⇒ Sound cannot travel in vacuum. (Light can travel in vacuum)

⇒ Sound can travel in gas, liquid, solid.

⇒ Solid surface can reflect sound waves. (eg. echo)

⇒ Soft and spongy object can absorb sound waves.



Propagation of sound in a medium.

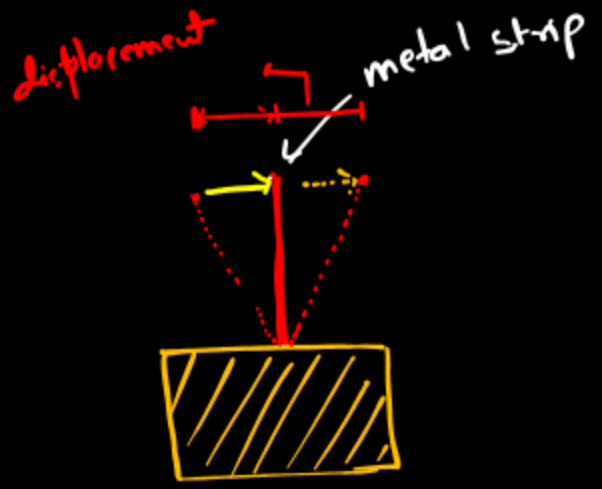
→ When the source of sound vibrates

↓

Creates a periodic disturbance in the medium near it.

↓

. The disturbance travels in the medium in the form of wave.

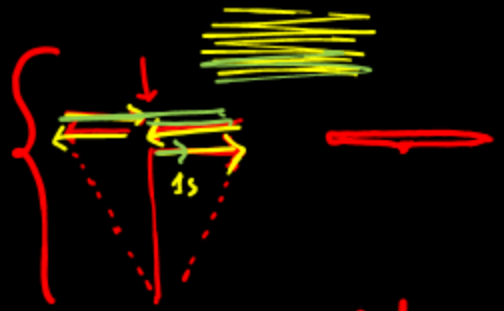


Mean position
or
Resting position

⇒ to and fro motion
⇒ Back and forth

} Oscillation

eg: motion of Pendulum



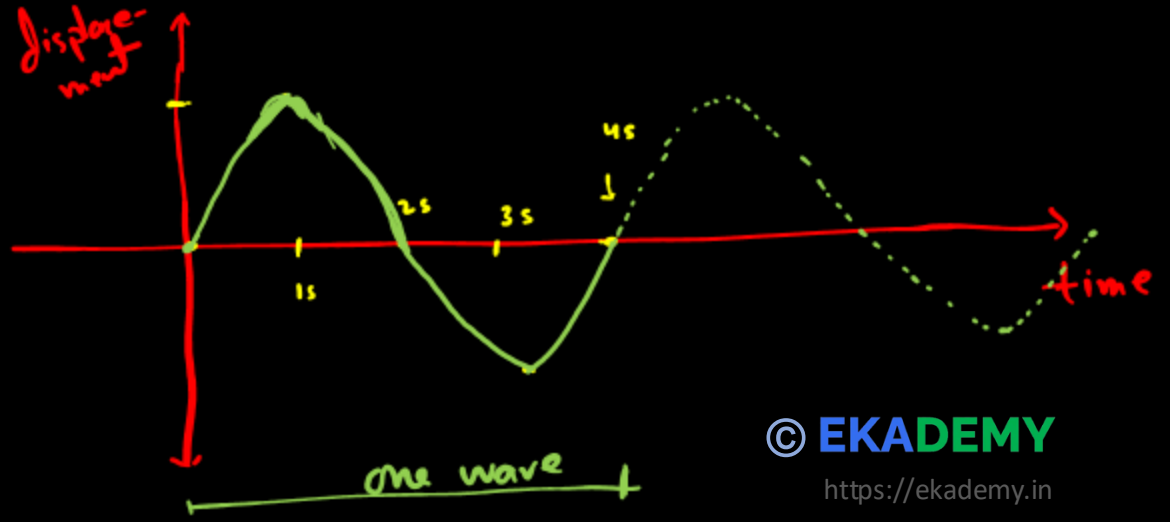
one complete Oscillation

↓

[one compression and one rarefaction]

↓ constitutes

one wave



Types of waves

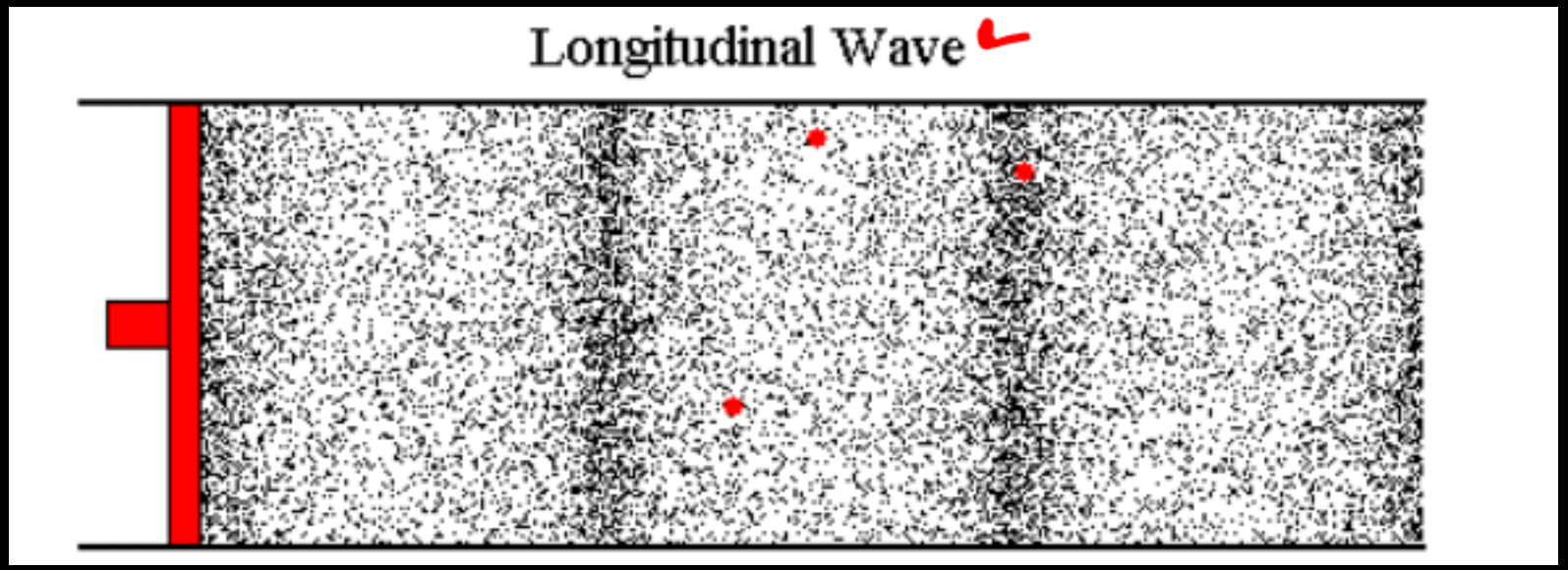
Longitudinal waves

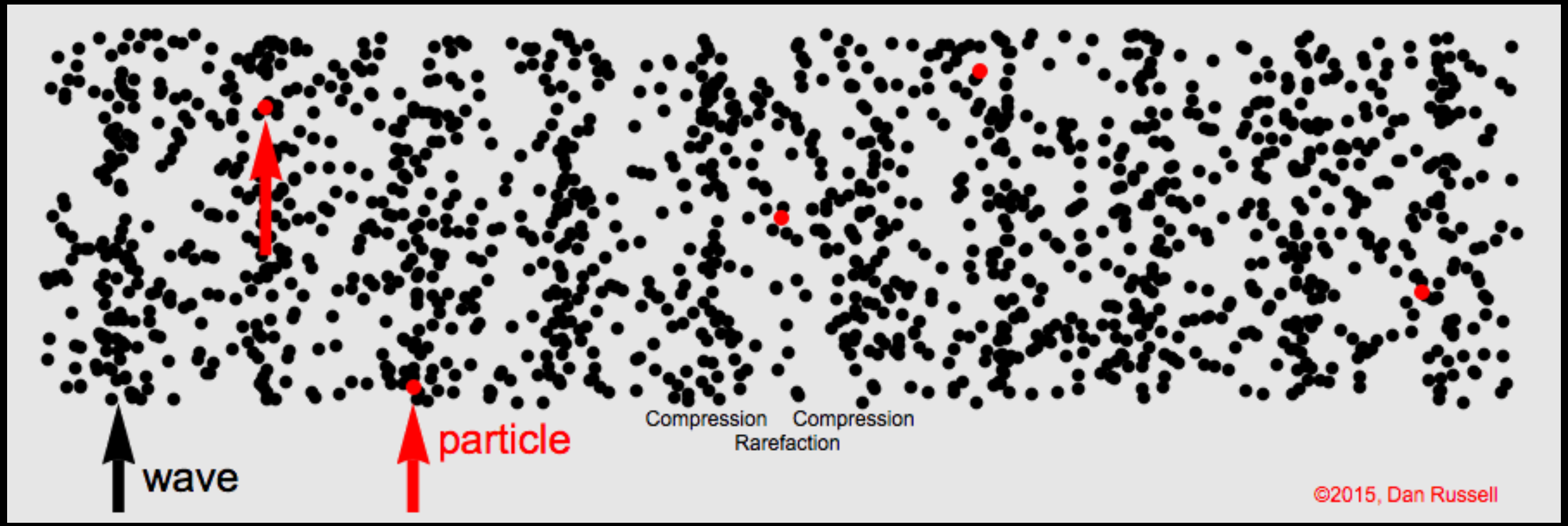
- Sound waves are Longitudinal waves
- The wave in which the particles of medium vibrate about their mean position parallel to the direction of propagation of wave.

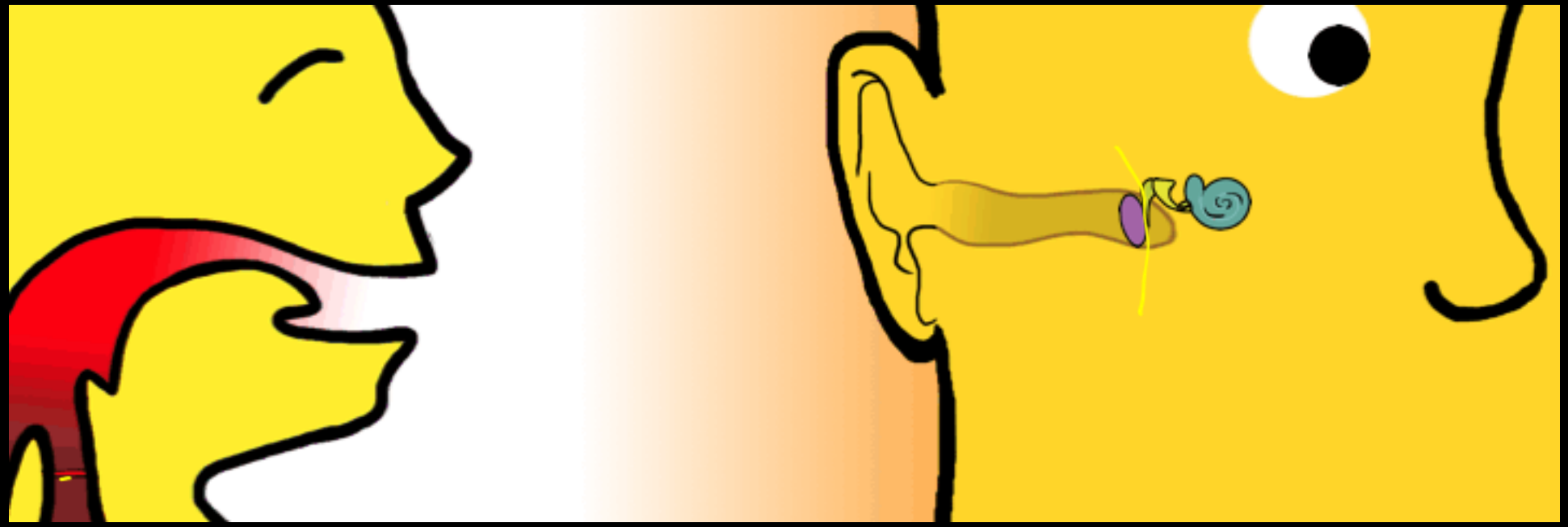
→ direction of propagation
↔ direction of vibration of particles

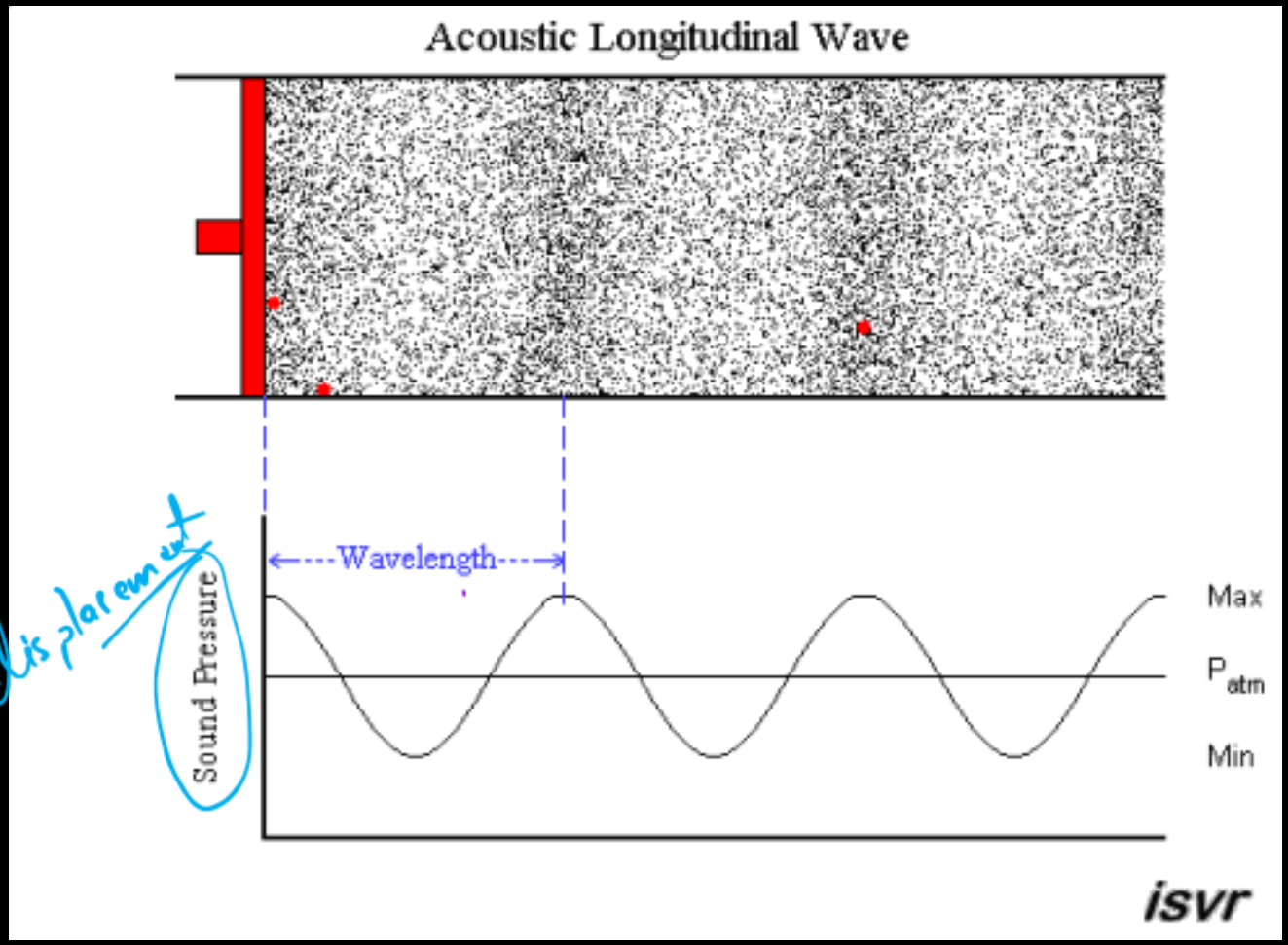
Transverse waves

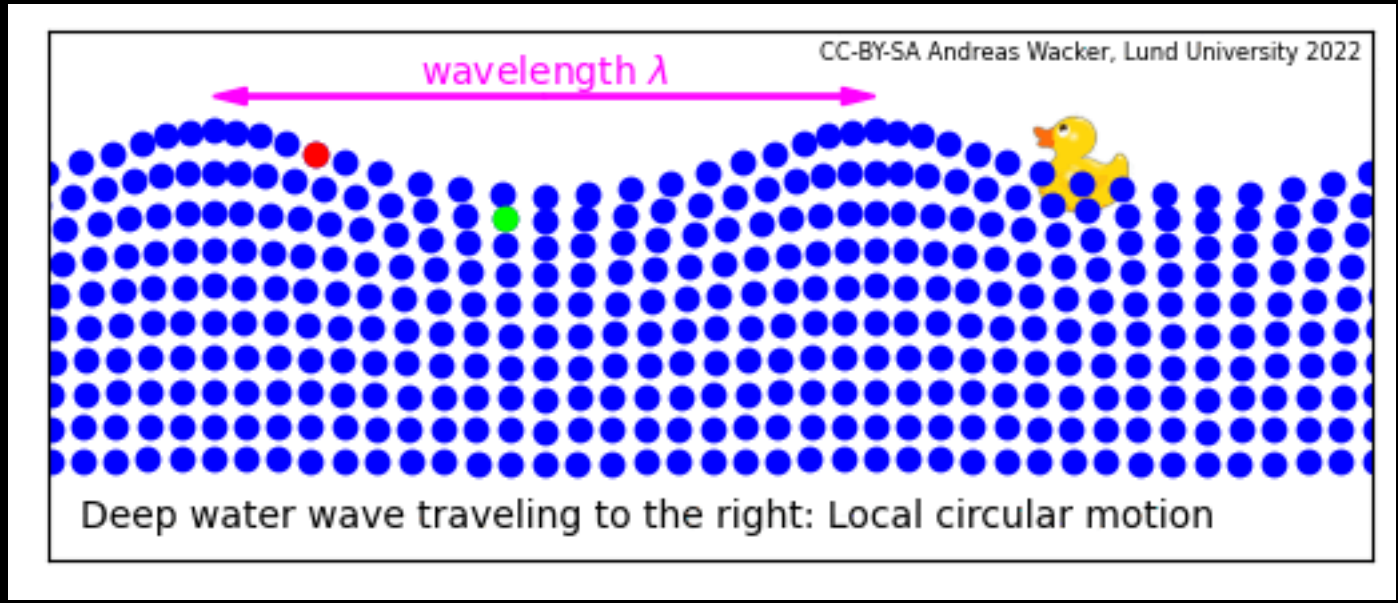
- Water waves.
- The wave in which the particles of medium vibrates about their mean position perpendicular to the direction of propagation of waves.

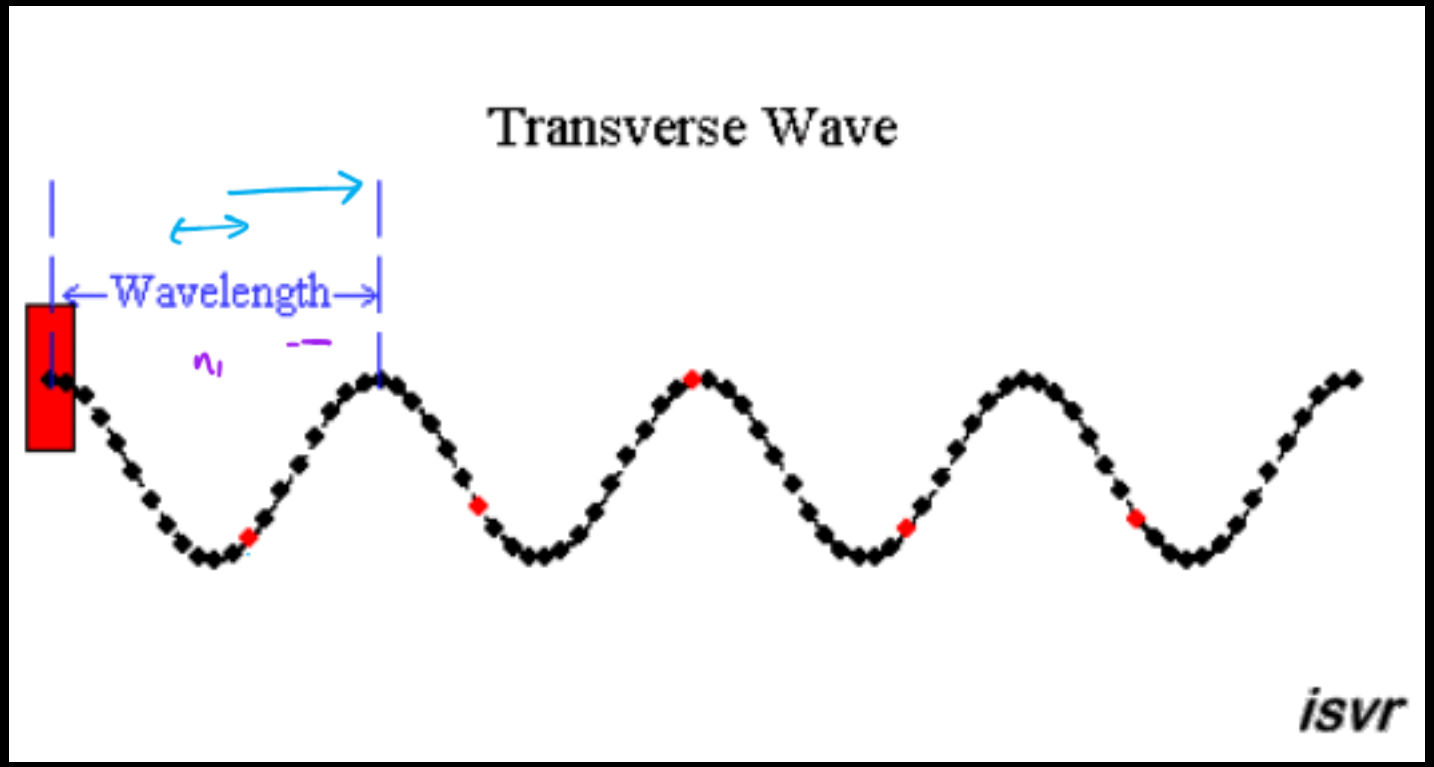


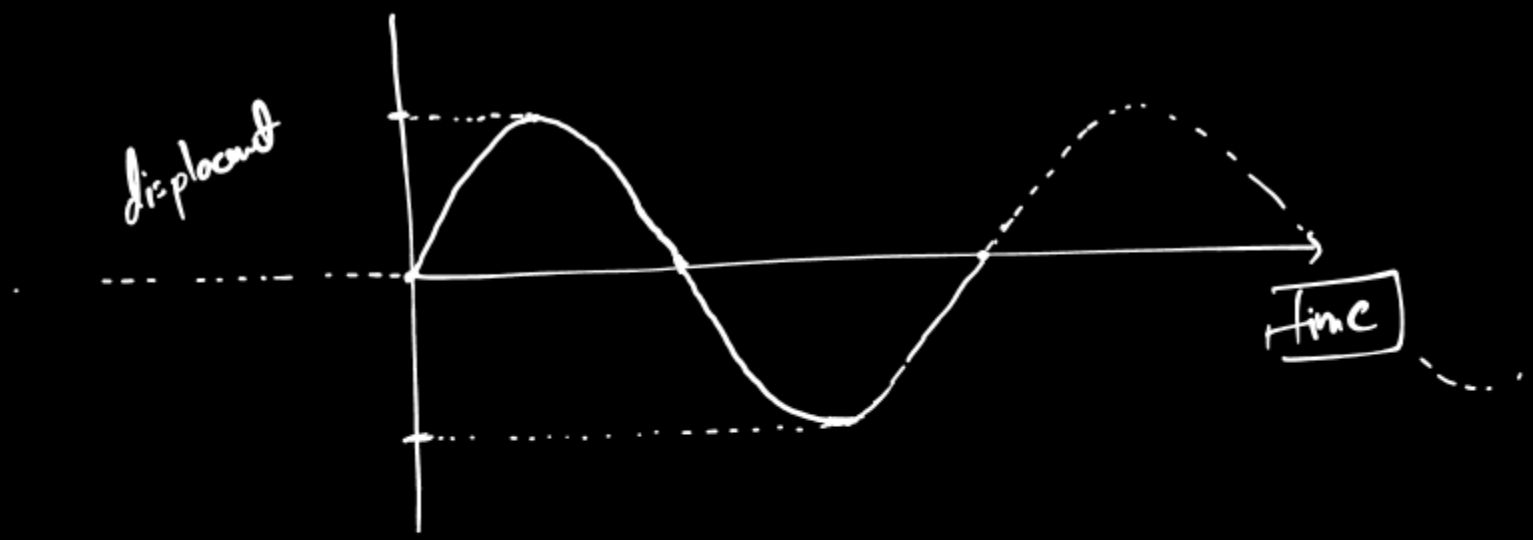






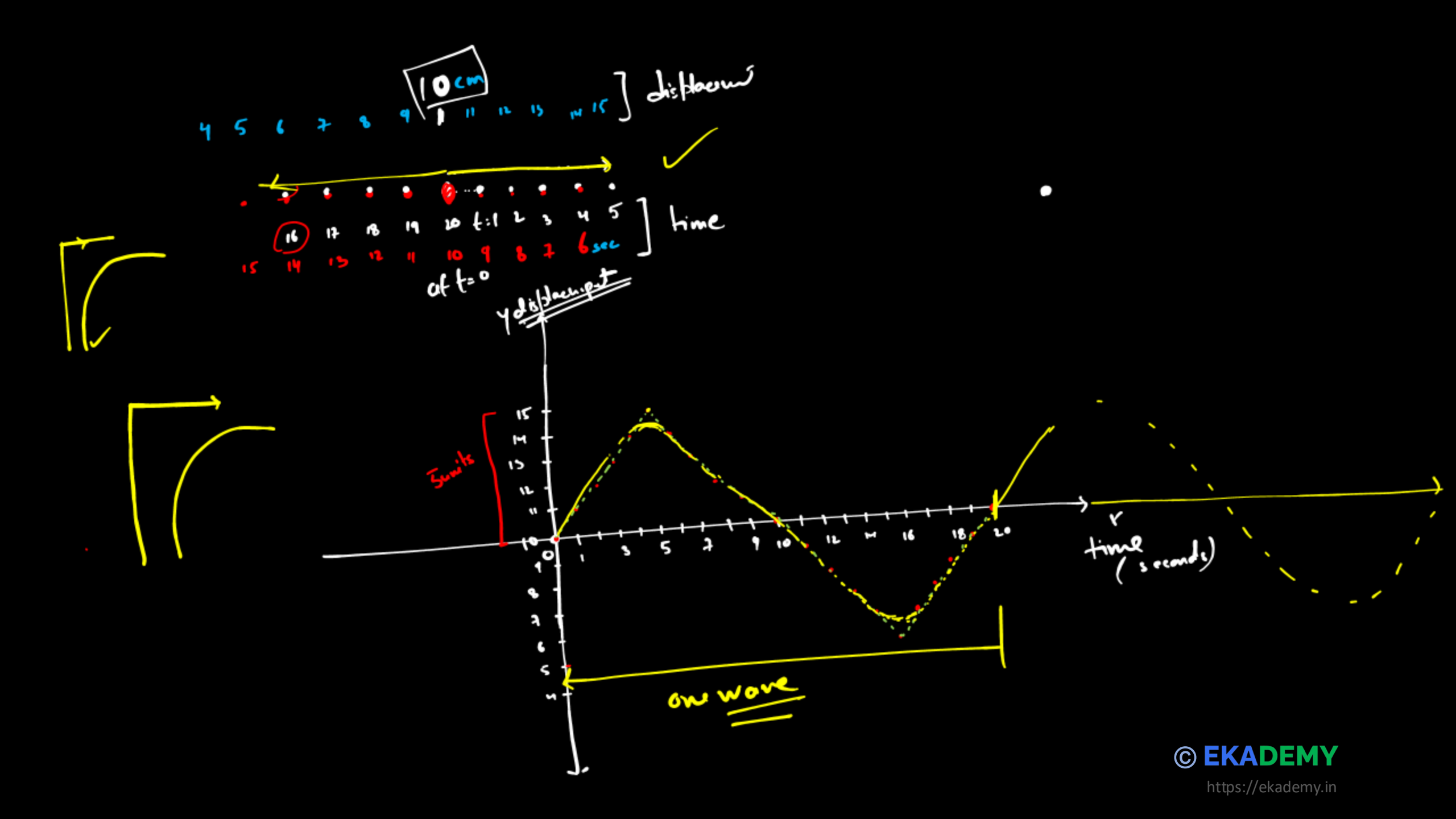






Vibration/oscillation

Vibration/oscillation



Characteristics of wave motion:

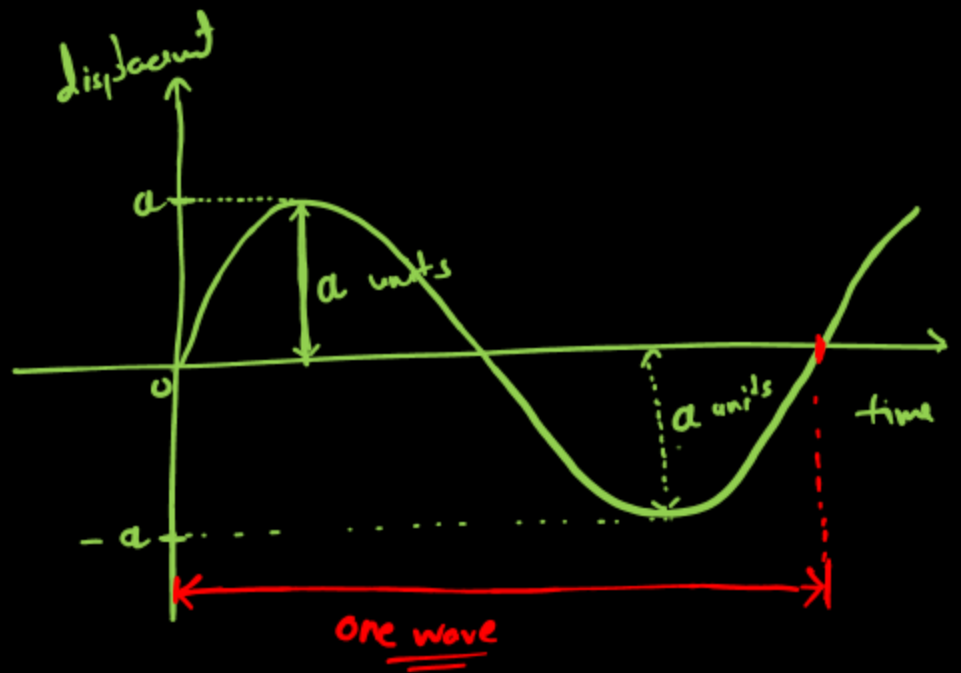
① A wave is produced by the periodic disturbance at a point in a medium

② During propagation of wave in a medium, the particles of medium vibrates about their mean positions and energy is transferred with a constant speed from one place of the medium to other place.

Waves are carriers of energy

- Mechanical waves (longitudinal, transverse)
- Electromagnetic wave (light)

Important terms related to wave motion



① **Amplitude (a):** The maximum displacement of the particle on either side from its mean position is called amplitude of the wave

Measured in (m) or (cm) or (mm)

SI unit is m

② **Time period (T):** The time taken by a particle of the medium to complete its one vibration is called time period of wave.

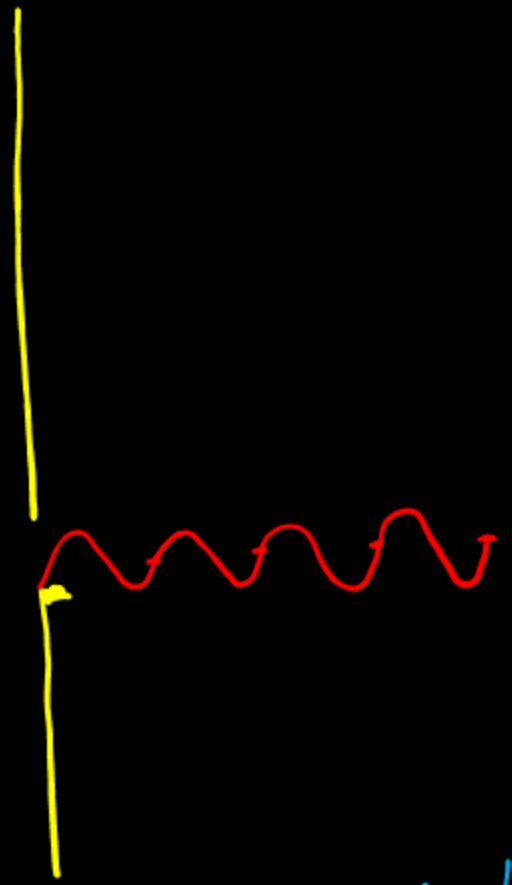
SI unit is second (s)

③ **Frequency** (f or n): The number of vibrations made by particle of a medium in one second. is called the frequency of wave.

- It is same as the number of waves passing through a point in one second.

S.I. unit of frequency is **hertz** (Hz)

1 Hz = 1 vibration per second



Q① Particle of a medium vibrates. 99 times in 3 seconds. Find the frequency of vibration of particle.

Sol:

3 seconds → 99 vibrations

1 seconds → $\frac{99}{3}$ vibration

= 33 vibration

∴ frequency = 33 vibrations/second

= 33 Hz

Q. An instrument produces sound such that 99 sound wave passes through a point in 3 seconds. Find the frequency of the sound wave in hertz.

Sol:

3 seconds $\longrightarrow$ 99 wave

1 second $\rightarrow$ $\frac{99}{3}$ waves

1 second $\Rightarrow$ 33 waves

frequency $\Rightarrow$ 33 waves per second

1 wave per second = 1 Hz

$\therefore$ 33 waves per second = 33 Hz

$\therefore$ frequency of the sound wave is 33 Hz.

Hertz = (per second)

* Frequence and time-period is related

10 waves (vibration) is produced in 5 seconds.

(T) Time period = $\frac{5}{10}$ second

= $\frac{1}{2}$ seconds.

(f) Frequency = 2 waves per second (= 2 Hz)

$$f = \frac{1}{T}$$ ✓

Time period ↑

⇒ 1 wave is produced in 'T' second

⇒ 1 wave in 10 seconds

$$f = \frac{1}{10}$$

$$f = \frac{1}{T \text{ (second)}}$$

or $$T = \frac{1}{f}$$

* Frequency of a wave depends on the frequency of vibration of its source. } Important

Speaker

Q. The time-period of a wave motion is 2 m. Find the frequency in hertz.

Sol: Given, $T = 2\ m = 120\ s$

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

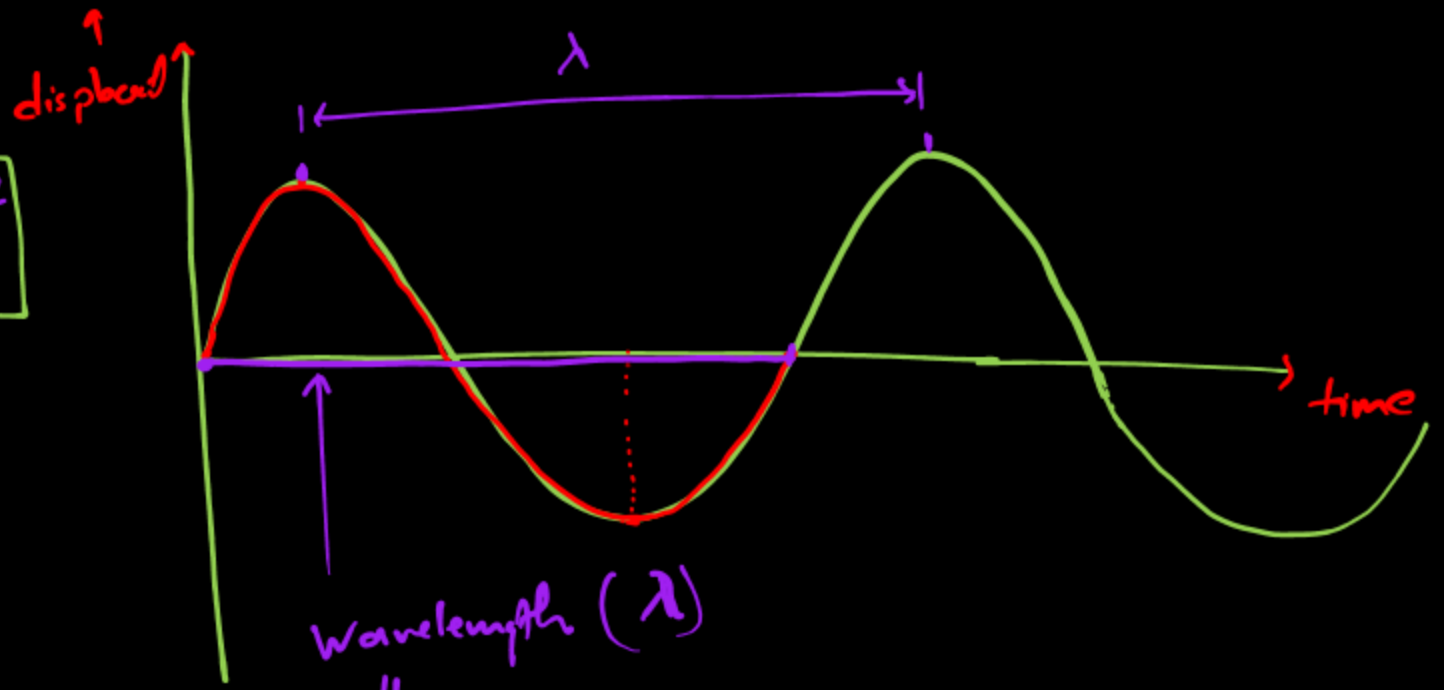
$$f = \frac{1}{120}\ \text{hertz (Hz)}$$

(4) Wavelength (λ)

↳ Lambda

[The distance travelled by the wave in one time-period (T).]

Length of one wave.



- In longitudinal waves (sound waves):
  distance between 2 consecutive compression or rarefaction is equal to one wavelength.
- In transverse waves (em wave, light)
  distance between 2 consecutive crest or trough is equal to one wavelength.

(5) Wave velocity

- Distance travelled by a wave in one second is called its wave velocity or wave speed.

- This is the speed with which energy is transferred from one place to another place by wave motion.

Imp: - Wave velocity is constant for a given medium.

SI unit ⇒ m/s (ms^{-1})

$S = \frac{\text{Distance (m)}}{\text{time (s)}}$

100 m is 10 sec.

10 sec → 100 m

1 sec → $\frac{100}{10} = 10$ m

10 m/s.

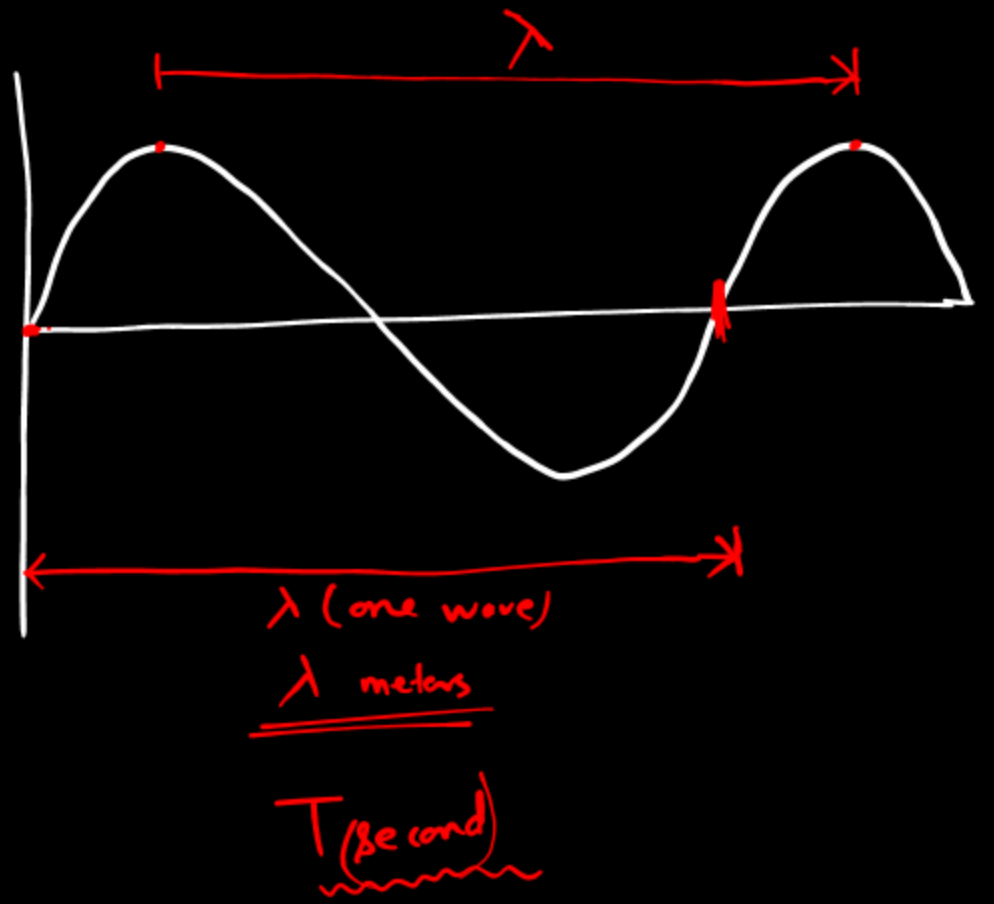
Relation between the wavelength (λ), wave velocity (V), Frequency (f) and Time period (T):

Let velocity of wave = V m/s

Time period = T seconds.

frequency = f hertz

wavelength = λ metres



$$\text{Wave velocity} = \frac{\text{Distance travelled by wave}}{\text{Time.}}$$

$$= \frac{\text{Wavelength}}{\text{Time period}}$$

$$V = \frac{\lambda}{T} \quad \text{or} \quad \lambda = V \cdot T$$

$\because \quad T = \frac{1}{f}$

$\therefore \quad \boxed{\lambda = \frac{v}{f}}$

$\boxed{v = \lambda \cdot f}$

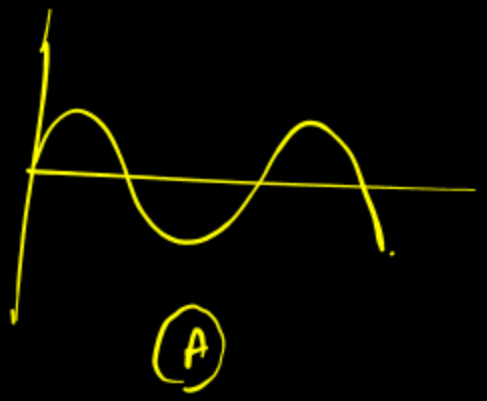
Wave velocity = frequency x Wavelength

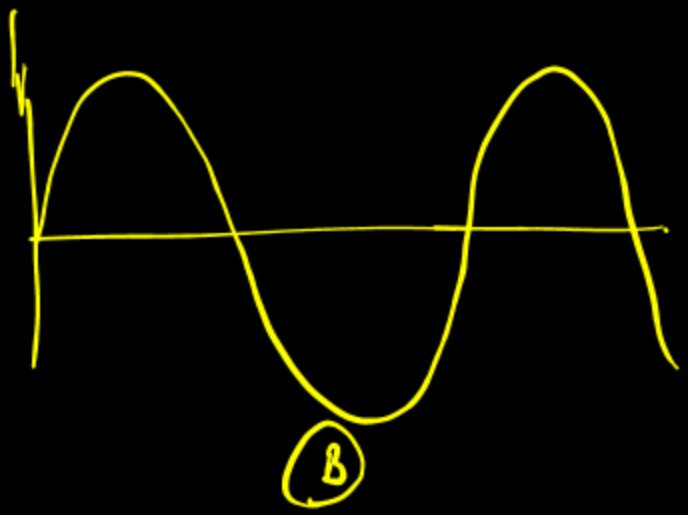
Features of Sound :

(i) **Loudness** : depends on the amplitude of wave (direct relation)

(ii) **Pitch** : depends on frequency of the sound wave (direct relation)

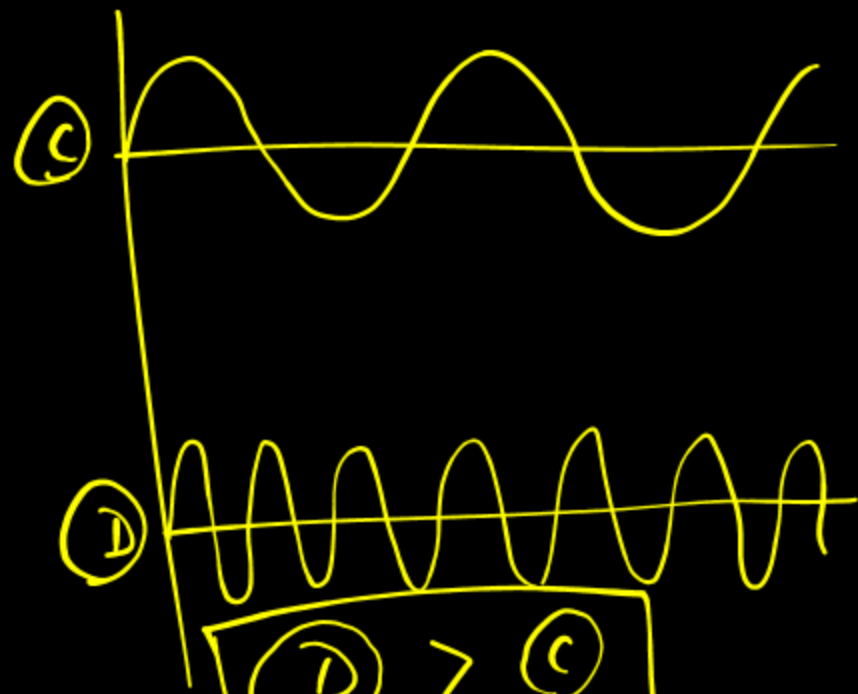
eg:





B > A

Loudness



D > C

~~Frequency~~ Pitch

Speed of sound in different

Speed of Sound waves vary with medium.

↳ depends on the density of the medium.

↳ directly proportioned.

Speed of Sound $\overset{\text{directly proportional to the}}{\propto}$ density of the medium

* Speed of sound is maximum in solids and minimum in gases.

- Speed of sound in air : ~330 ms^{-1} (m/s)
- Speed of light in air : 3×10^8 ms^{-1} (metres per second)
  - ms^{-1} → m/s

→ * Speed of light is a million times more than speed of sound in air.

⇒ Hence, ① on thunder storms light is seen much earlier than the sound of thunder.

Infra sonic, Sonic and Ultra sonic frequency:

Human ears

↓

can only detect sound waves that has its frequency in the range of:

20 Hz to 20,000 Hz

Audible range of frequency.

Sonic range

below 20 Hz → Infrasonic

↓

Infra sound

above 20 000 Hz or 20 kHz → Ultrasonic

↓

Ultra sound

Bat: 10 Hz - 100 kHz

Dolphin: 200 Hz - 150 kHz

* Higher the frequency, higher will be the energy of the wave

Ultrasounds and its application

→ Sound with frequency more than 20000 Hz.

Properties of Ultra sound

- The energy carried by Ultrasound is very high.
- It can travel along a well defined straight path.

Applications of ultrasound.

① Medical application → Ultrasonography (or Ultrasound):

→ Surgery

(2) In SONAR, (Sound navigation and ranging)

↓

to detect / find distance of object deep underwater

H.W.

- Explain the above two applications
- Find more applications of ultrasounds
- What is the difference between ultrasonic and supersonic?

Light Waves

→ An electromagnetic wave. (em waves)

→ EM waves can also travel in vacuum.

→ EM waves made up of electric and magnetic field.

→ • Reflection of waves
  • Absorption of waves.

} Properties associated with waves.

Echo :

↳ Reflection of sound waves.

- To avoid echo we use sound proofing / sound absorbing materials on the walls.
  - ↳ Spong.
  - ↳ Wood
  - ↳ Books
  - ↳ Carpet
  - ↳ Curtains
- These materials can absorb sound waves.

- There are materials that can absorb light waves.
- Every material / matter has property of absorbing and reflecting light waves.

↓

gives specific colour to that material.

Reflection of light

Sunlight

↓

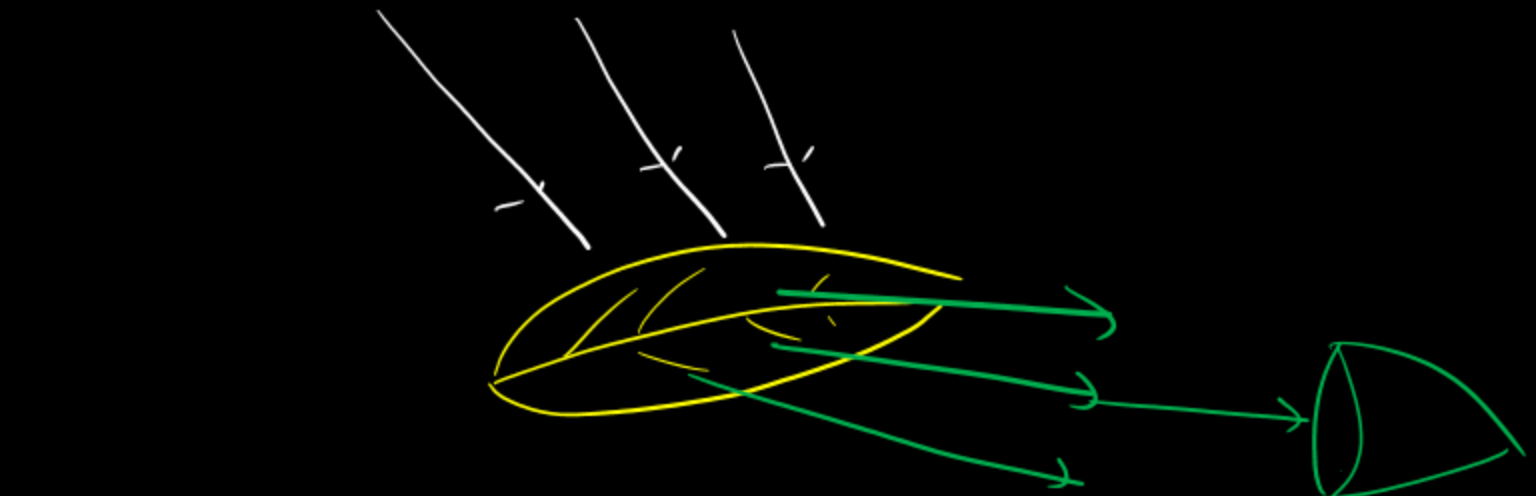
Visible light from the sunlight

↓

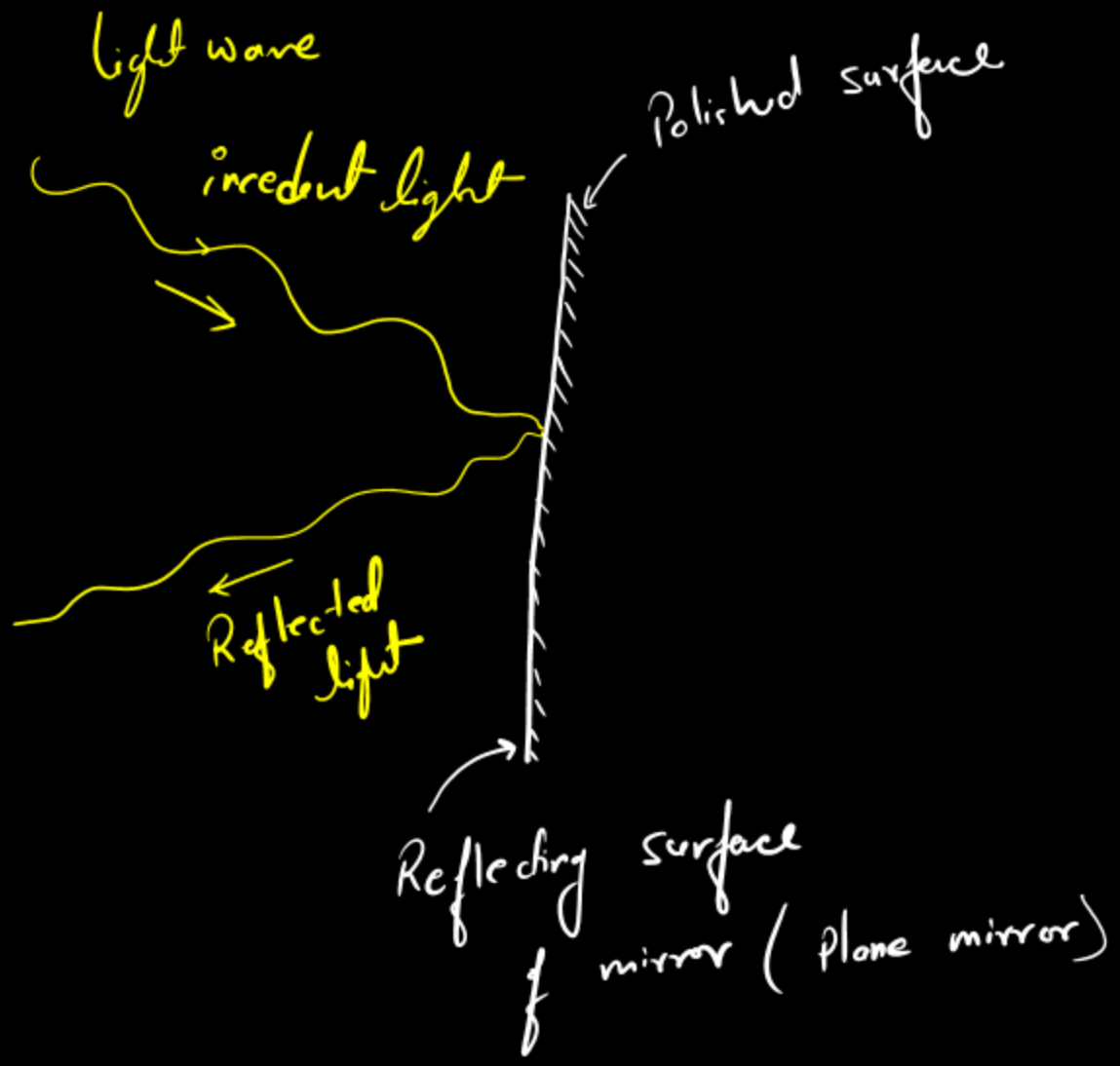
white in colour

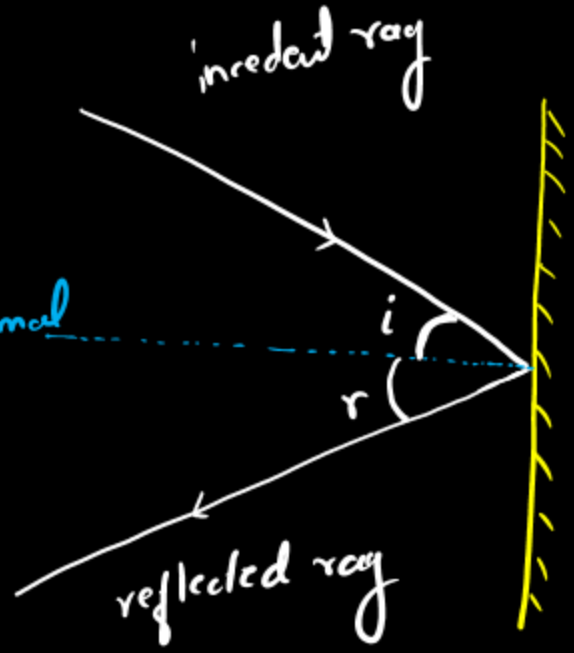
↓

has Seven colour → VIBGYOR



Reflection of light





(An imaginary line perpendicular to the surface of mirror.) Normal

$i \Rightarrow$ angle of incedent (angle between incedent ray and normal)

$r \Rightarrow$ angle of reflection (angle between reflected ray & normal)

Laws of reflection :

(i) angle of incedence is always equals to the angle of reflection.

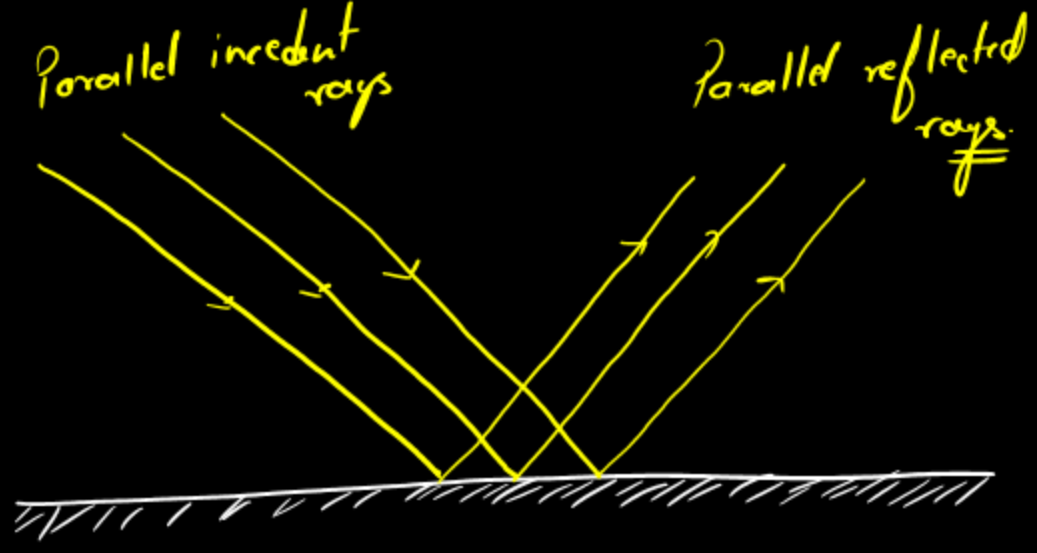
$$\boxed{\angle i = \angle r}$$

Types of Reflection

- Regular reflection
- Irregular reflection

Regular Reflection

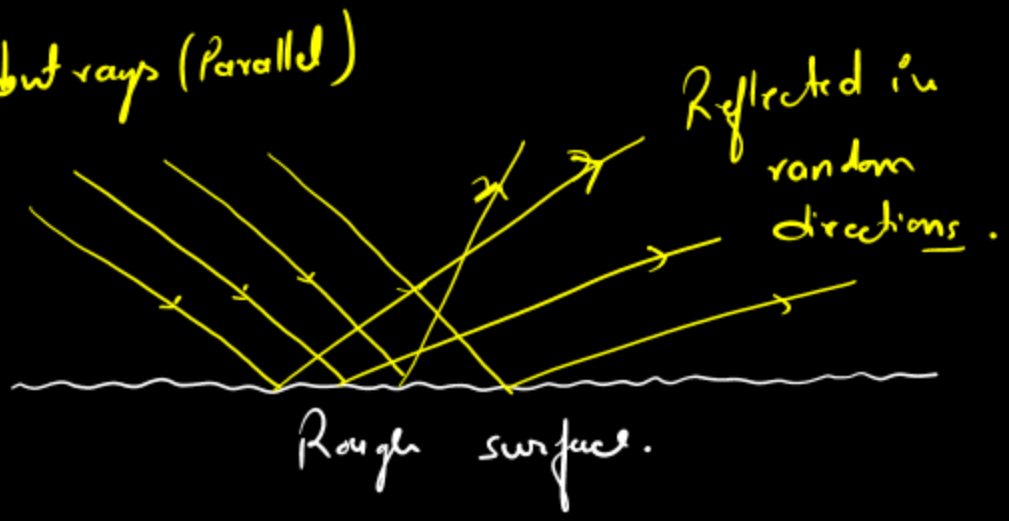
=> Regular reflection occurs when a beam/rays of light falls on a smooth and polished surface.



Irregular Reflection

⇒ Occurs when a beam of light falls on a rough surface

⇒ Laws of reflection are still followed in irregular reflection



Light as wave

↳ Electromagnetic waves

→ Sun emits electromagnetic waves.

↓

→ Kind of Mixture of electric and magnetic wave (field)

⇒ EM wave

↳ waves are associated with wavelengths, frequency, timeperiod, wave velocity, etc.

Sun → emits em waves of different wavelengths (λ) | frequency (f).

$$f \propto \frac{1}{\lambda}$$

Energy of wave

↳ determined by the frequency of that wave.

$$\text{Energy} \propto \text{frequency} \propto \frac{1}{\text{wavelength}}$$

$f \uparrow \Rightarrow E \uparrow$

Single em waves is ~~the~~ made up of many waves of various frequencies/wavelengths.

Spectrum of sunlight.

Named based on their frequency/wavelength.

Spectrum of EM waves (Sunlight)

frequency is decreasing / Wavelength increasing →

Gamma Rays

(Highest freqy)

Highest Energy

→ Small regulated dose of gamma rays is used against cancerous cell.

X-Rays

↓

X-ray image of internal organs of body like bone to detect fractures.

Ultra Violet Rays (UV Rays)

↓

- Used to Sterilize Surgical equipment.
- Kill germs present in water.

Visible light

VIBGYOR

↑ Violet ↑ Red

InfraRed rays

↓

TV Remote

- Carrier of heat energy
- → Night vision camera.

Microwave

↓

ovens

Radio wave

↓

Lowest f.

Lowest E.

↓

Used in wireless Communication

Visible light

↳ Consists of a range of emWaves having different frequencies / wavelengths

wavelength ⇒ 400 nm to 700 nm

↳ Visible light is white in colour. (white light)

1 nanometer (nm) = 10^{-9} meters

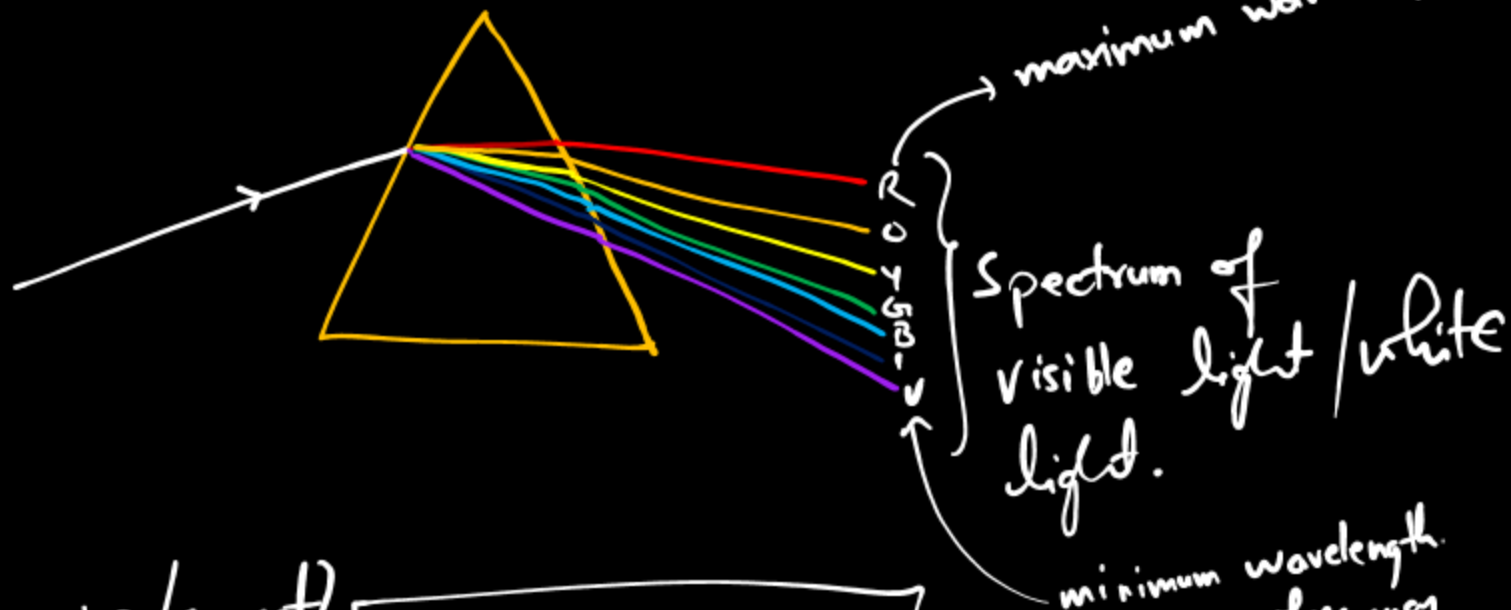
0.000000001 m

1 nm

is made up of 7 prominent colours (wavelength)

called Spectrum of visible light (white light).

- We can see 7 colours of white light, when it passes through a prism.



[Q. Why sky is Blue?

Q. Why sun is Red during sunrise/sunset?

Newton's Disk

Rainbow formation:

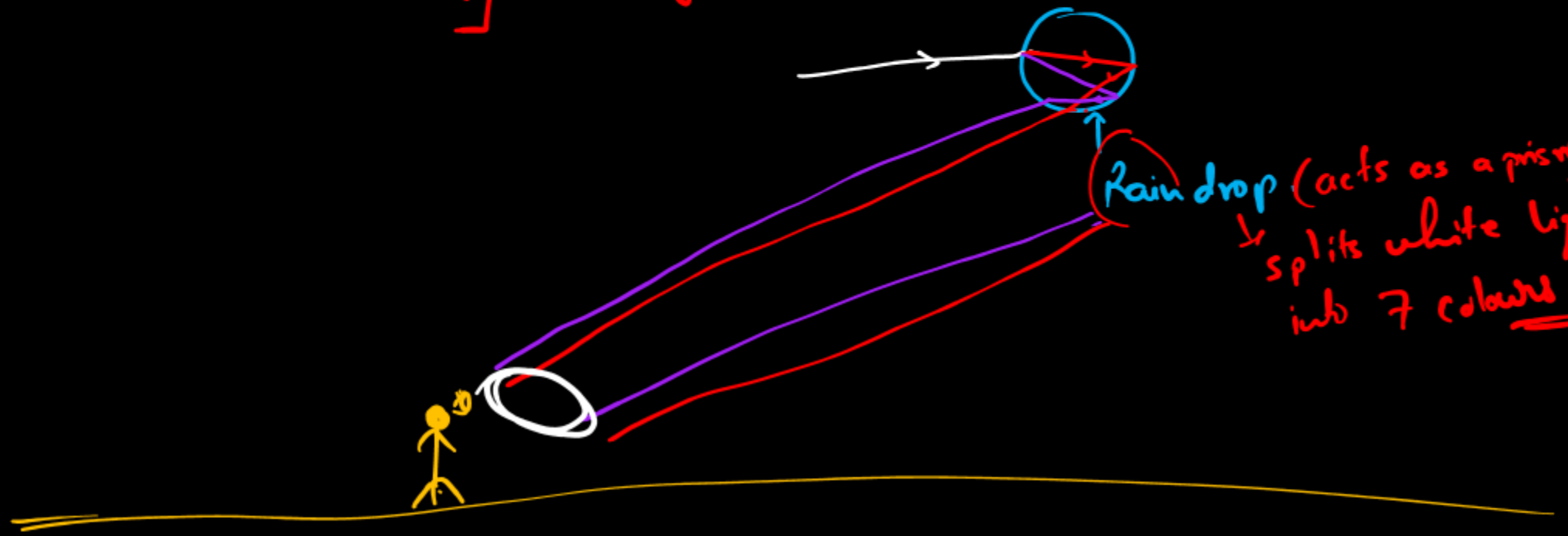
- Rain drops / droplets in atmosphere.
- Sun should be behind viewer and low in sky.
- Angle of incidence should be $\sim 42^\circ$ ||

Primary Rainbow

Internal Reflection

Secondary Rainbow

Sun



Raindrop (acts as a prism)
↓
splits white light into 7 colours.

End of the Chapter