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# PHY 116

GEN

Temperature & Heat measurement
Heat Capacity
Specific Heat & Latent heat
Calorimetry
GAS LAWS
Kinetic theory of gases.
Thermal Energy
Work done by expanding gases.
Laws of Thermodynamics
Liquefaction of gases
Heat transfer (Conduction, Convection, Radiation)
Longitudinal & transverse wave
Vibrations in solids
Sound waves in solids, liquids & gases
Pitch, intensity & sound quality
Doppler effect
Acoustics of buildings.
Ultrasonics.
Reflection & Refraction of light
Spherical mirrors
Thin & thick Lenses

Optical instrument
Wave nature of light.
Interference, diffraction, polarization & velocity of light.

Tents

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# Temperature & Heat Measurement

- Temperature is a phenomenon that occurs as a result of two bodies in contanct having different energies.
- Temperature is the degree of hotness or coldness of a body.
- Thermometric substances are substances whose physical properties change as the temperature change.

They are:

- All gases
- Platinium
- Radiant energy
- Thermocouples
- Mercury & Alcohol

## Thermometric property

- The properties of those substances that change with increase in ~~temperation~~ temperature

1) Volume of liquids
2) length of a solid
3) Pressure of a gas at constant volume
4) Volume of a gas at constant pressure
5) Electric resistance of a conductor

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$K.E = \frac{3}{2}RT = \frac{1}{2}mv^2$

## Features of temperature

- Temperature has a dimension of $\Theta$
- It is a measure of the average translational Kinetic energy of a molecule ie $\boxed{E = \frac{3}{2}RT}$ where $\frac{3}{2}R$ is a constant
- The temperature of a body can be raised without limit. It cannot be lowered without limit...

## System of measuring temperature

- Upper Fixed Point → boiling point (100°C) (1ATM)
- Lower Fixed point → ice point (0°C)

## Temperature Scales

there are 3;

1. Celcius °C
2. Kelvin K
3. Fahrenheit °F

- Fundamental interval is the difference between the upper & lower fixed point

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| Scale | LFP | UFP | FI |
|---|---|---|---|
| celcius (°c) | 0°c | 100°c | 100 |
| Kelvin (K) | 273.15K | 373.15K | 100 |
| Fahrenheit (°F) | 32°F | 212°F | 180 |

## Conversion of scales

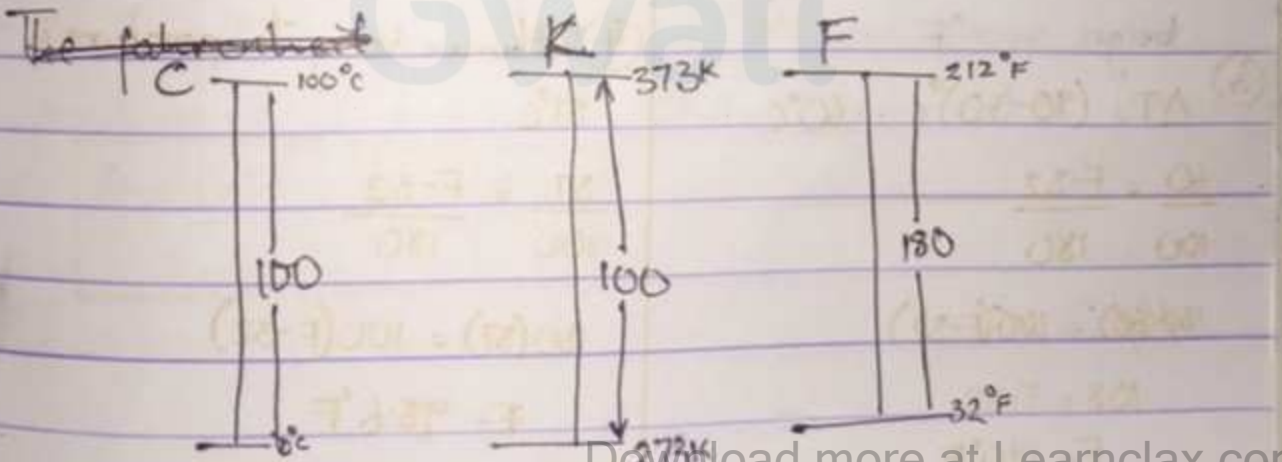
Temperature on one scale can be converted to another scale

$$\frac{\text{(Reading on any scale} - \text{LFP}}{\text{UFP} - \text{LFP}} = \text{constant for all scales}$$

$$= \frac{C-0}{100} = \frac{F-32}{180} = \frac{K-273}{100} = \frac{\theta-\theta_0}{n}$$

where (n) is the number of divisions between the ice point & steam point on the new scale

$\theta_0$ is the ice point.




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$$T_F = 32 + \frac{9}{5} T_C$$

$$\Delta T_C \equiv \Delta T = \frac{5}{9} \Delta T_F$$

Example

① Liquid nitrogen has a boiling point of $-195.81°C$ at atmospheric pressure, calculate this temperature in °F and K.

$$\frac{-195.81-0}{100} = \frac{K-273}{100}$$

$$100(K-273) = 100(-195.81)$$

$$K = 77.19K$$

$$\frac{-195.81}{100} = \frac{F-32}{180}$$

$$100(F-32) = 180(-195.81)$$

$$F = -320.458°F$$

② Express the temperature of 60°F to °C

$$\frac{C-0}{100} = \frac{60-32}{180} \; ; \; \frac{180C}{180} = \frac{100(60-32)}{180} = 15.6°C$$

③ The temperature of an iron piece is heated from 30°C to 90°C, find the $\Delta T$ in °F

④ Calculate the temperature of a normal human beign in °F

③ $\Delta T = (90-30)°C = 60°C$

$$\frac{60}{100} = \frac{F-32}{180}$$

$$180(60) = 100(F-32)$$

$$108 = F-32$$

$$F = 140°F$$

④ Human body temperature is 37°C

$$\frac{37}{100} = \frac{F-32}{180}$$

$$180(37) = 100(F-32)$$

$$F = 98.6°F$$

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# Important points in thermometers

- Let X denote a ~~thermometric~~ thermometric physical property and $X_0$, $X_{100}$ and $X_T$ be its values at 0°c, 100°c, and θ°c respectively. The temperature θ is given by $\frac{X_T - X_0}{X_{100} - X_0} \times \frac{100}{1}$

For the first case; Constant volume-gas thermometer

- The pressure of a gas at constant volume is the thermometric property

ie; $\theta = \frac{P_T - P_0}{P_{100} - P_0} \times \frac{100}{1}$

Case 2; Platinum resistance thermometer

- The resistance of a platinum wire is the thermometric property.

ie $\theta = \frac{R_T - R_0}{R_{100} - R_0} \times \frac{100}{1}$

Case 3; Mercury thermometer

- The length of the mercury column from some fixed point is taken as the thermometric property

ie $\theta = \frac{L_T - L_0}{L_{100} - L_0} \times \frac{100}{1}$

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## Case 4: Total Radiation ~~thermometer~~ Pyrometer (optical pyrometer)

- Used to measure very high temperatures above 2000K.

### The Principle (Working Principle)

- When a body is at very high temperature, It glows slightly & brightly and the total radiation emitted per second from a unit area is directly proportional to the fourth power of the absolute temperature $R \propto T^4$

### Advantages of Pyrometer

(1) The experimental body is not always kept in contact with it.

(2) It has no definite higher limit of temperature. (it measures above 2000K)

### Disadvantages of Pyrometer

(1) It cannot measure temperatures below 800°c because at 800°c, the emissions from that body is so low that it can't be measured directly.

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## Thermocouple

- It depends on the 'See beck effect'

See beck effect → Seebeck effect

- This is when two disimilar metals of different temperatures are joined and EMF is developed. The magnitude of the EMF developed as well as its direction of flow depends on the nature of the given pairs of wires, and also on the temperature difference between the two junctions

Example 1: A mercury thread has length of 12cm and 25cm at the ice and steam point respectively. Calculate the temperature when the mercury thread is 18cm.

use; $\theta = \frac{L_T - L_0}{L_{100} - L_0} \times \frac{100}{1}$

$L_T = 18cm$

$L_0 = 12cm$

$L_{100} = 25cm$

$\theta = \frac{18-12}{25-12} \times \frac{100}{}$

$\theta = \frac{6}{13} \times 100$

$\theta = 46.15^{\circ}C$

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# Calorimetry

- It is a branch of heat that studies the measurement of heat
- SI unit of heat is **Joules or Calories**

## Thermal Capacity

→ thermal capacity = $\frac{Q}{\Delta T}$

- the quantity of heat required to change the temperature of the body by 1K
  - It depends on the
    1. Nature of the body
    2. Mass of the body

## Specific heat Capacity

The heat required to change the temperature of a unit mass of a body by 1K

ie; $C = \frac{Q}{m\Delta T}$

## Molar heat capacity

Heat required to raise the temperature of 1mole of a gas by 1K

from specific heat capacity: $C = \frac{Q}{n\Delta T}$

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$C = \frac{MQ}{m\Delta T} = \frac{1}{\mu}\frac{Q}{\Delta T}$

M -> mass of a body (whole)
m -> mass of a unit mass

$C = \frac{Q}{m\Delta T}$

$\mu = \frac{m}{M}$

$$C = \frac{1}{\mu}\frac{Q}{\Delta T}$$

## Latent Heat

Heat absorbed or released when a body or substance changes from one state to another without change in temperature

-> It is an Isothermal process

## Latent Heat of Fusion

Heat energy required to change 1Kg of material from solid state to liquid state at its melting point

## Latent Heat of Vaporization

When a liquid body changes from vapour form to liquid form, the heat required to make the change is called Latent Heat of Vaporization

NB: Phenomenas

① It is more painful to get burnt by steam than by hot water because the internal energy of steam is more than that of boiling water.

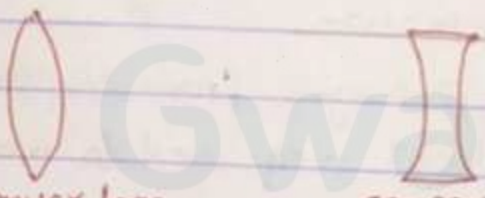
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# Triple Point of Water

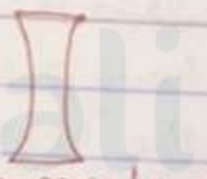
+ ~~It is the temperature~~
→ Single combination of temperature & pressure at which liquid water, gaseous water & solid water coexist in equilibrium. The triple point occurs at 0.01°c and the pressure is 4.58mmHg, and On the Kelvin scale, it is 273.16K.

# Optical Instruments 16/07/2019

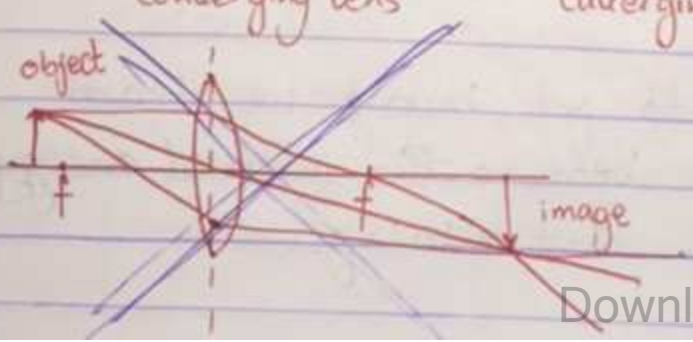
They are instruments that focus images on the eye ~~or the~~ (retina)
→ Microscope is an optical instruments
Telescope
Cameras
Concave and convex lenses



convex lens
converging lens

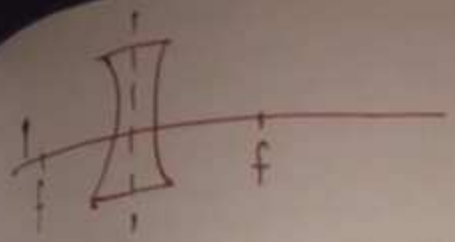


concave lens
diverging lens



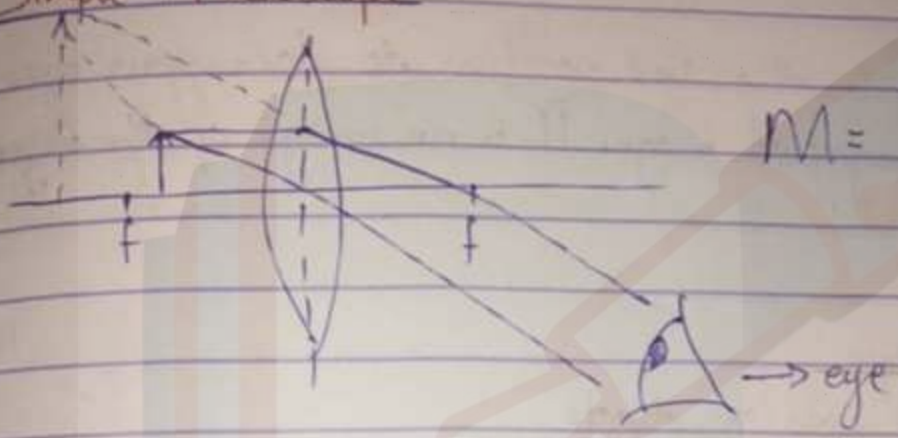

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

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## Simple Microscope

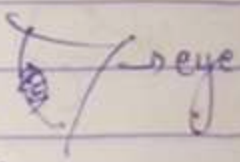


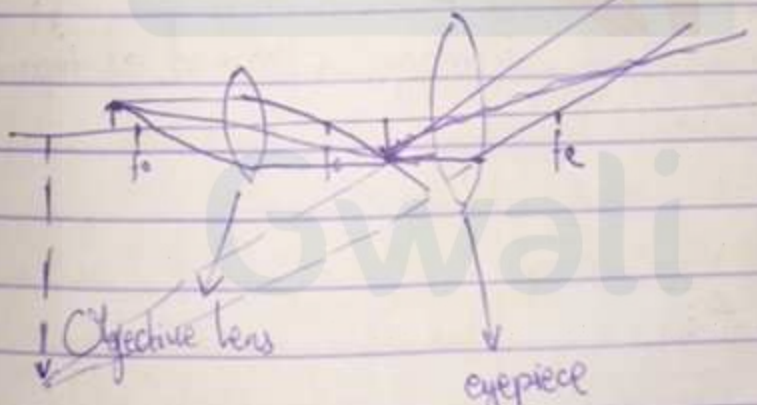

M =

## Compound Microscope

→ Works with 2 lenses

→ used to view very small objects.




$M = m_1 \times m_2$

$M_1$ is magnification of OL

$M_2$ is magnification of EP

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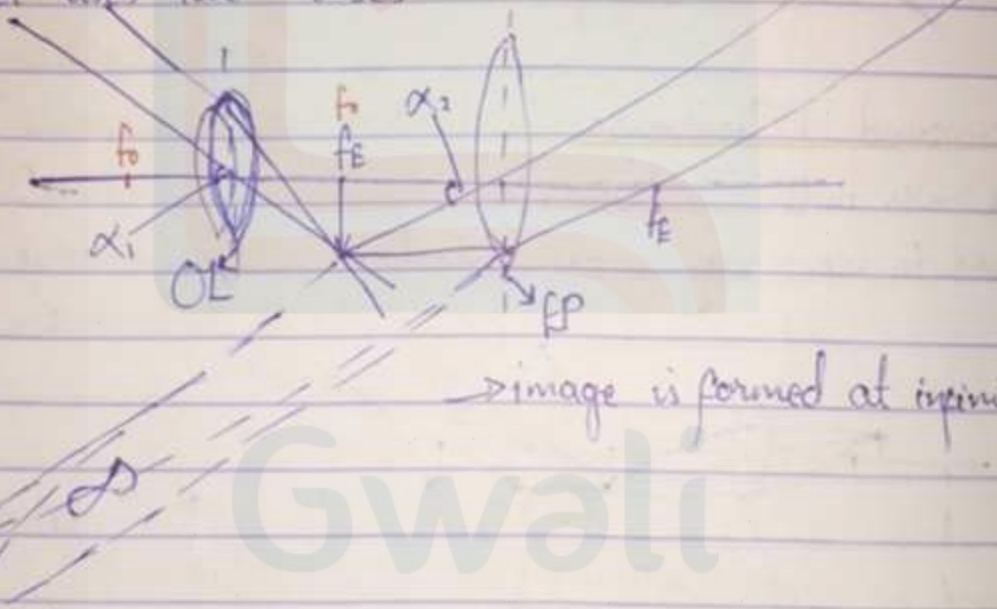
• the classification for compound microscope

Eye-ring is the best position to place your eyes to see the magnified image. It is an image of the objective lens.

## Telescope

→ Used to view far objects

→ It uses two lenses




→ image is formed at infinity

Normal adjustment:

Angular magnification: $M_\alpha = \alpha_2/\alpha_1$

where $\alpha_1$ is the angle which the object subtends at the eye or lens & $\alpha_2$ is the angle subtended by the image

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at the eye.

because the angles are very small.

$\tan\alpha_1 = \alpha_1$

$\alpha_1 = \frac{f}{f_e}$

$M\alpha = \frac{f_o}{f_e}$

A telescope with normal adjustment has an objective of $f_o = f_1$ & eyepiece of $f_e = f_2$ show that the eye-ring is located at a distance of $\frac{f_2(f_1+f_2)}{f_1}$ from the eyepiece

solution

$f_o = f_1$, $f_e = f_2$

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

u (object distance) $= f_1 + f_2$

v (image distance) $= ?$

$\frac{u}{f} = \frac{1}{f_2}$

distance between the objective and eyepiece in a telescope is $f_o + f_e$

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

$u = f_o + f_e$, $v = ?$, $f = f_e$

$\frac{1}{f_o+f_e} + \frac{1}{v} = \frac{1}{f_e}$

$\frac{1}{v} = \frac{1}{f_e} - \frac{1}{f_o+f_e}$

$\frac{1}{v} = \frac{f_o}{f_e(f_o+f_e)}$

$v = \frac{f_e(f_o+f_e)}{f_o} = \frac{f_2(f_1+f_2)}{f_1}$

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→ Read Up Cameras

→ Find out ① f number from camera

② speed of lens from camera

A photograph is taken with a lens of speed f/4 and an exposure time of 1/100 seconds. If the same picture is to be taken with an exposure of 1/50 seconds, what should be the speed of the lens?

Answer = f/5.6

$t \propto (\text{f-number})^2$

$\therefore \frac{t_1}{(f_1\text{-number})^2} = \frac{t_2}{(f_2\text{-number})^2}$

$\frac{1/100}{4^2} = \frac{1/50}{(f_2\text{-number})^2}$

$f_2\text{-number} = 5.65685$ | speed of lens = $f/5.65865$

Slide Projectors → Read Up

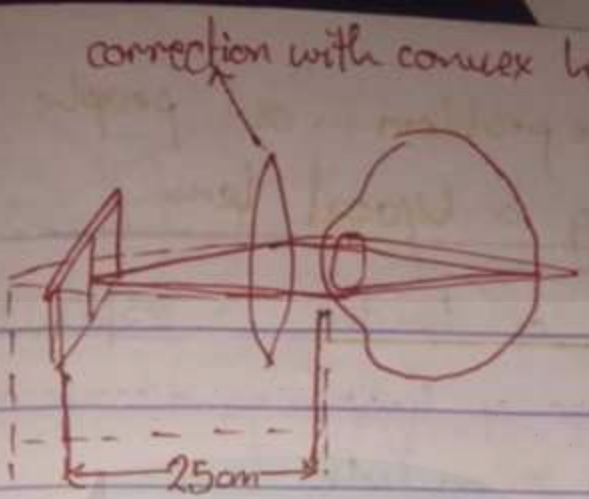
→ Accomodation is the ability of the eye to form images

→ Far points is the furthest distance one can see clearly. for normal people, their farpoint is at infinity

→ Near point is the closest that a normal person can see. It is at 25cm

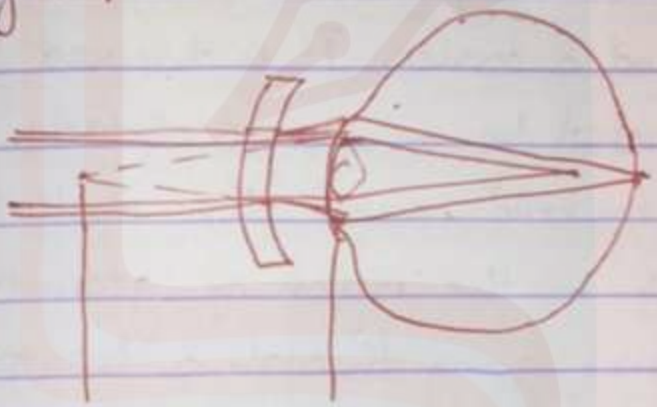
→ for longsighted people, their eye ball is too small

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Near point of a longsighted person is longer than the normal person

Short sighted



The near point of a man is 75cm from the eye, what type of lens should he use to be able to read a book held 25cm from his eyes *

solution

He is longsighted.

We will need a convex lens

$u = 25cm$, $V = -75cm$ → because its a virtual image

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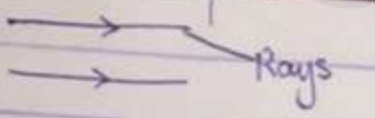
Presbyopia → Eye problem in old people
It is solved using a bifocal lens.

## Wave nature of light: 23/07/19

- Before wave nature of light was discovered, it was considered as just a particle
- Diffraction is the slight bending of light as it passes around the edge of an object.

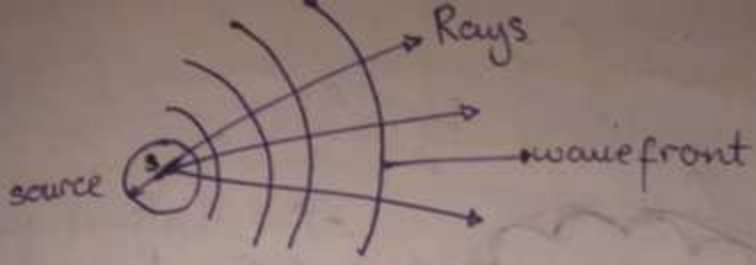
- In 1802, Thomas Young showed experimentally that light could bend round a corner. It is observed that when a wave is obstructed by an opaque obstacle, the incident waves appear to bend round the obstacle and form fringe patterns in the region of geometrical shadow.
- Similarly, waves going through a transparent hole in an opaque object are spread out in the region of geometrical shadow. This deviation from the rectilinear propagation is an ~~inco~~ incontrovertible evidence of the wave nature of light.

### Wavefronts and Rays

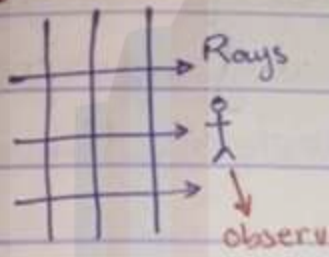



→ A wave is a disturbance in a medium that trasfers energy around the medium without displacing particles in the medium.

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- A Ray is the direction of the energy travel of the wave.




⚠ At far distances, wavefronts look vertical to an observer

- The surface of the sphere at a time 't' is called the wavefront. Every point on the wavefront vibrates in step or in phase with every other point on it.

NB: A ray of light going through a point is perpendicular to the wavefront at that point

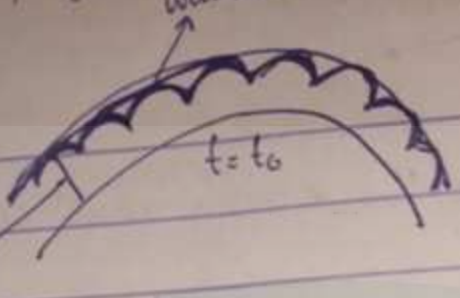
## Huygen's Principle

This states that every point on a wavefront becomes a new or secondary center of disturbance which serves as the source of spherical secondary wavelets of the same frequency as the primary wave; the new wavefront is the surface which touches all the wavelets from the secondary sources.

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$S = Ct$ → time
distance ↓ speed of light

$S = C\Delta t$



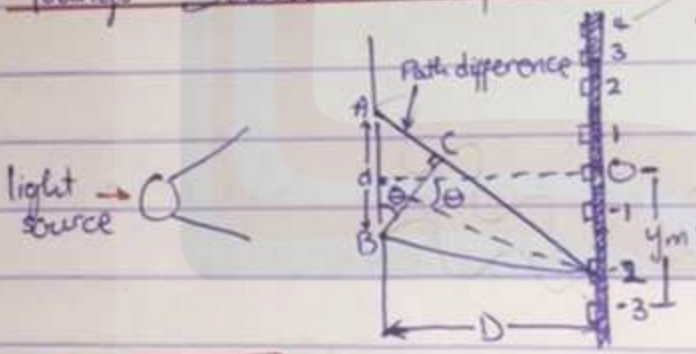

-the distance used to draw the wavelet is $S = C\Delta t$

• to get the next wavefront, a series of wavelets are drawn from points on the preceding wavefront. When a line is drawn that meets all the wavelets that is the next wavefront.

start

## Interference of Light.

### Young's Double-slit experiment




• Path difference determines whether there'll be a bright spot or a dark spot.

• If path difference is 0, there will be a bright spot and vice versa

• Bright spot is constructive interference. Dark spot is destructive interference

$\sin\theta = \frac{AC}{d}$

$AC = d\sin\theta$

↓ Path difference

for constructive interference ; $AC = n\lambda = d\sin\theta$

where $\lambda$ is wavelength

n is $0, \pm1, \pm2, \pm3, \ldots$ (order)

d is distance between the slits

→ the reason for adding n is because the values depend on which fringe we are observing.

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$m = n$

$$AC = (m - \tfrac{1}{2})\lambda = d\sin\theta$$
$$m = 1, 2, 3, \cdots$$

→ for destructive interference (dark fringes)

- If the path difference is an integer number of wavelengths, the waves will arive in phase and add having a maximum intensity or constructive interference.

- If the path difference equals an odd number of half wavelength, the waves arive out of phase and cancel having a minimum intensity or destructive interference.

→ To know the exact position of a bright spot

$$\tan\theta = \frac{y_m}{D}$$

$$y_m = D\tan\theta$$

- NOTE: the subscript m is dependent on the order, (ie $y_1, y_2, y_3$) it can be used interchangeably with n, but should be consistent to avoid confusions

but $\sin\theta = \tan\theta$ (because $\theta$ is very small)

$$y_m = D\sin\theta$$

$$y_m = \frac{D n \lambda}{d}$$ → position for a bright fringe/spot

Assignment

In young's experiment, 2 slits spaced 0·2mm apart are a distance of 1·6m from a screen. If the 5th bright fringe is located 25mm from the central fringe, find the wavelength of the light used.

Ans = $6.25 \times 10^{-7}$ m

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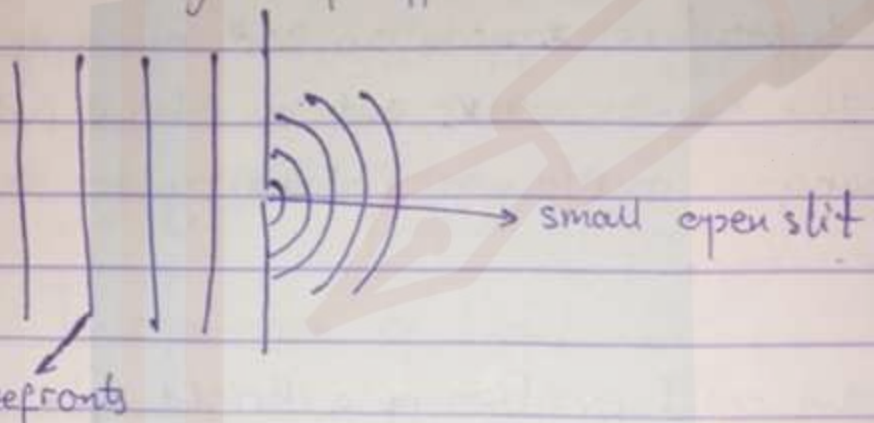
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# Diffraction of Light

Diffraction is the process by which a beam of light or other system of waves is spread out as a result of passing through a narrow aperture or across an edge.

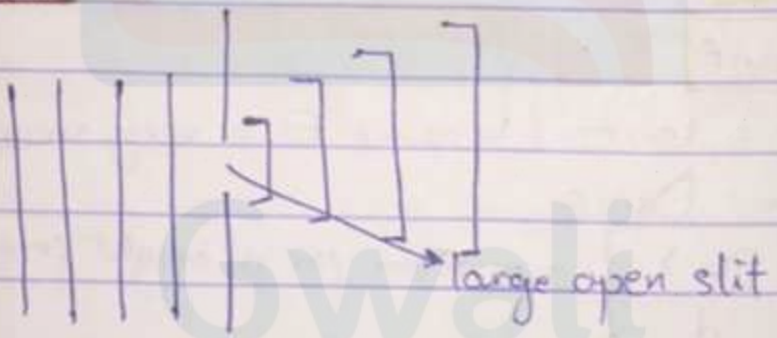
There are two types of diffraction:

(1)




Spherical waves after diffraction is called Fresnel diffraction

(2)

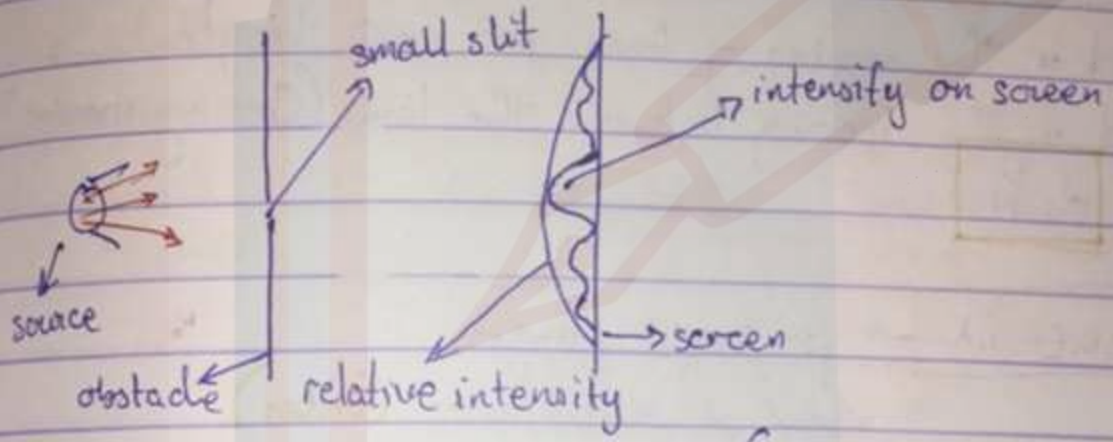



This is reffered to as Fraunhofer diffraction

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→ Diffraction is the bending of light/waves around corners or or obstacles. It occurs ~~in accors~~ in accordance with Hygen's principle and is an interference phenomenon.

∴ If the obstacle in the light beam is a single narrow slit, a pattern of fringes will be formed on a screen placed behind the slit.




∴ The slit has to be very small (it should be the wavelength of light)

→ Note that;

1. There is a broad central maximum with little or no secondary maximum or minimum
2. There is no difference between the diffraction pattern & the interference pattern
3. There is a peaked central maximum with equal number of maxima and minima on both sides.
4. The intensity of the secondary maxima decreases progressively away from the central maximum

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→ In diffraction, dark fringes are located using $d\sin\theta = n\lambda$ → this is inverse of what is in interference

## Diffraction Grating



N → Newtons constant

N is the number of lines per unit length

d is the spacing between the lines (Grating spacing)

$d = \frac{1}{N}$

$d\sin\theta = n\lambda$ → for bright fringes

where $n = 0, 1, 2, 3, \ldots$ (order)

→ A diffraction grating consists of multiple parallel, equidistant slits in an opaque screen. As in a double-slit experiment, the grating equation is $d\sin\theta = n\lambda$

d is the distance between the centers of any two adjacent slits, $\theta$ is the angle through which the light is diffracted.

n is the diffraction order

$\lambda$ is the wavelength of the light/wave form

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Transverse wave definition!

Example

A slit of width d is illuminated by white light. For what value of d will the first minimum for red light ($\lambda = 6,500$ ~~Angstrong~~ (A°) Angstrom) fall at $\theta = 30°$

1 angstrom = $1 \times 10^{-10}$ metre

solution

$d\sin\theta = n\lambda$

$d = \frac{n\lambda}{\sin\theta}$ ; $d = \frac{n(6500)}{0.5}$ where $n = 1$, because we are considering red light and its order is 1 in white light

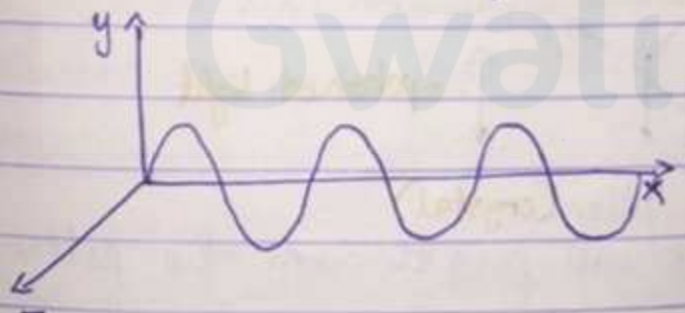
$d = 13,000\,A°$

$d = 13,000 \times 10^{-10}\,m$

$d = 1.3 \times 10^{-6}\,m = 1.3\,\mu m$

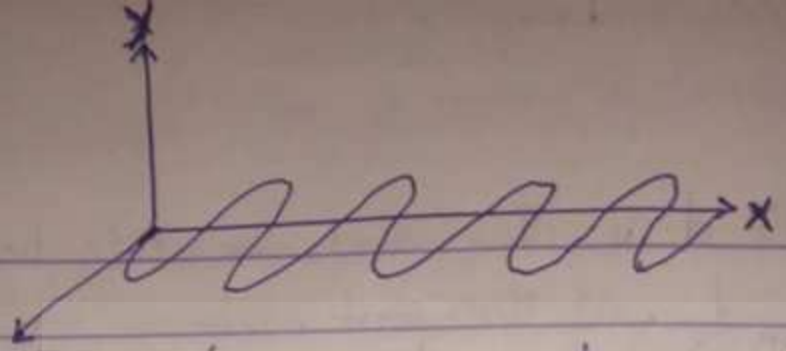
Polarization

A wave is said to be linearly polarized if the vibration of particles of the medium in a transverse wave remains parallel to a fixed line in space.




It is linearly polarized in the y-direction

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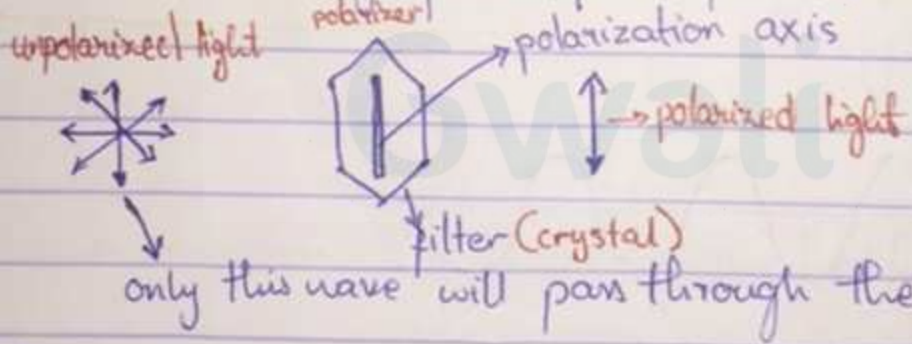

It is linearly polarized in x-direction

Read up; unpolarized waves.

There are four basic phenomena that can produce polarized light namely;

1. Polarization using filters / absorption
2. Polarization by reflection
3. Polarization by scattering
4. Polarization by birefringence

## Polarization by filters / absorption



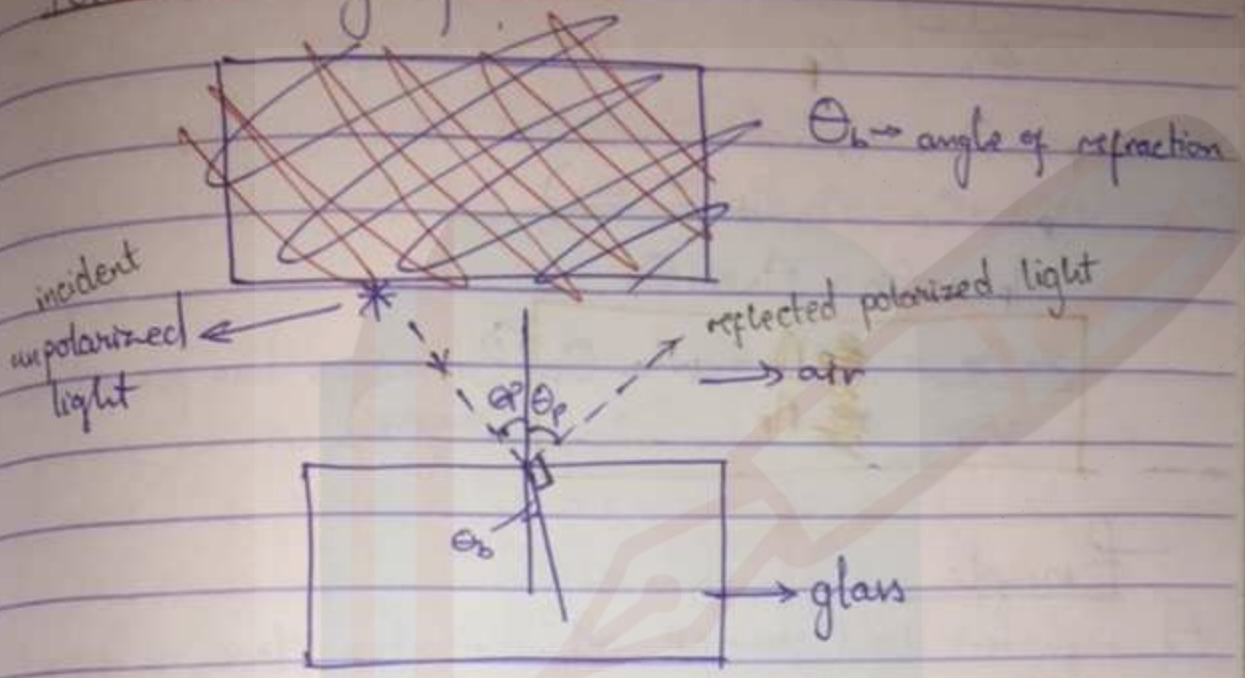

Several crystals absorb and transmit differently depending on the polarization of the light

→ the polarization axis are formed by hydrocarbons

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This side - BurnaBoy ft YG

## Polarization by reflection




→ tangential rays will be reflected as polarized light
→ At $\theta_p$, the angle of polarization and reflected ray are those tangential to plane of incidence
→ At polarization angle, the light for which the electric field ~~is~~ lies in the plane of incidence is not reflected at all but is completely refracted
→ Reflected rays are those that are polarized tangential to the plane of incidence

- In 1812, Sir David Brewster discovered that at the polarization angle ($\theta_p$) the reflected ray and the refracted ray are perpendicular to each other

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$n$ → refractive index

so we can say $\theta_p + \theta_b = 90^\circ$

$$\frac{\sin\theta_p}{\sin\theta_b} = \frac{n_b}{n_p}$$

$$n_p \sin\theta_p = n_b \sin\theta_b$$

$$n_p \sin\theta_p = n_b \sin(90-\theta_p)$$

$$n_p \sin\theta_p = n_b \cos\theta_p$$

$$\frac{\sin\theta_p}{\cos\theta_p} = \frac{n_b}{n_p} \Rightarrow \tan\theta_p$$ (Brewsters law for polarizing angle)

## Example.

A reflected light from an oil concrete floor of refractive index 1.45 appears to be fully polarized. Find the angle of the incident line.

$n_p = 1.45$

$$\tan\theta = \frac{1.45}{1}$$

$$\tan\theta = 1.45$$

$$\theta = \tan^{-1}(1.45)$$

$$\theta = 55.41^\circ$$

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30/7/19

Know this !!!
$f_o$ → frequency of observer
$f_s$ → frequency of source
$V$ → speed of sound
$V_s$ → speed of source
$V_o$ → speed of observer

$$f_o = f_s\left[\frac{V \pm V_o}{V \pm V_s}\right]$$

# Doppler Effect

- The apparent alteration in the frequency of sound when there is a relative velocity between the source of the sound and the observer is called Doppler effect

The apparent frequency ($f'$) when; ~~the source is~~

(1) ~~when~~ the source is moving towards a stationary observer is given by $f_o' = \frac{V}{V - U_s} \cdot f_s$

where: $V$ is the velocity of the sound
$U_s$ is the velocity of the source
$f$ is the original frequency

NB: An apparent increase in frequency is observed.

(2) the source ~~exceeds~~ recedes from a stationary observer, an apparent decrease in the frequency is observed such that $f_o' = \frac{V}{V + U_s} \cdot f_s$

(3) the observer approaches a stationary source with velocity $U_o$, an apparent increase is observed such that $f_o' = \frac{V + U_o}{V} \cdot f_s$

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④ the observer moves away from a stationary source, an apparent decrease in frequency is observed such that $f_o' = \frac{V - U_o}{V} \cdot f_s$

⑤ the movement of both the observer and the source in the same direction but with different velocities will result to either an increase or decrease in the frequency depending on the velocities of the source & the observer such that $f_o' = \frac{V - U_o}{V - U_s} \cdot f_s$

⑥ the source and the observer are moving in opposite direction, there is an apparent increase in frequency given as $f_o' = \frac{V + U_o}{V \mp U_s} \cdot f_s$

→ the velocity and direction of wind relative to that of a source of sound can also bring about doppler effect. such that the effect of wind is represented by replacing the wave velocity V with $V + U_w$ ($U_w$ is the velocity of wind) when the wind is in the direction of the observer and $V - U_w$ when the wind is in the opposite direction of the observer.

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Examples

# EXAM QUESTIONS !!!

① A police sirene has a frequency of 800Hz. If the velocity of sound in air is 344m/s, determine the frequencies heard by drivers of vehicles at 14m/s
(i) towards the sirene
(ii) away from the sirene

HINT:

(i) $f' = \frac{V + U_o}{V} \cdot f$ (ii) $f' = \frac{V - U_o}{V} \cdot f$

Hint: $f_o = f_s \left[\frac{V \pm V_o}{V \mp V_s}\right]$

(a) $f_o = 800\left[\frac{344+14}{344}\right]$ (b) $f_o = 800\left[\frac{344-14}{344}\right]$

$f_o = 832.56Hz$ $f_o = 767.44Hz$

② Find the velocity of the source of sound along the line joining the source to a stationary observer if as a result of the motion, the frequency of the note heard is
(a) increased in the ratio of 18:15
(b) decreased in the ratio of 15:18 with reference to the true frequency
• Take the velocity of sound in air to be 345m/s

$V_o = 0$, $V_s = ?$, $f$

NB: Read up what happens when the source is moving at an angle to the line joining the source and the observer

(a) $18f_s = 15f_s\left[\frac{345}{345 - V_s}\right]$ (b) $15f_s = 18f_s\left[\frac{345}{345+V_s}\right]$

$V_s = 57.5 m/s$ $V_s = 69 m/s$

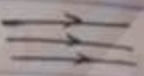
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start

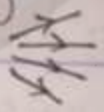
# Reflection and Refraction of Light

A bundle of rays proceeding from a source in a particular direction is called a beam.

There are 3 categories of beams

(a) Parallel; rays are parallel to eachother 

(b) Converging beams; rays are approaching eachother 

(c) Diverging beams; rays are seperating 

- Geometric optics deals with rays (rectilinear propagation of light) while physical ~~optics~~ optics considers light as a wave motion.

Laws of reflection and refraction

1. Incident, Normal ray, reflected and refracted ray meet at a point.
2. angle of incidence = angle of reflection
3. Snells law; $\frac{\sin\theta_a}{\sin\theta_b} = \frac{n_b}{n_a}$ ; $\boxed{n_a \sin\theta_b = n_b \sin\theta_a}$ Law of refraction

⚠

Note that refractive index ($n$) is the ratio of the speed of light ($c$) in vacuum to the speed of light ($v$) in the medium or material ie $n = \frac{c}{v}$

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Advert space

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## Two types of reflection

→ Regular reflection } READ UP
→ Diffused reflection }

## ~~Conca~~ Types of mirrors

- ~~Concave / Diverging mirror~~
- Concave / Converging mirror
- Convex / Diverging mirror

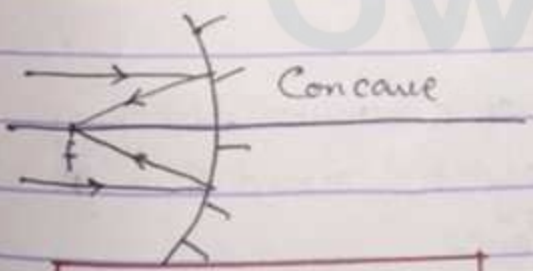
### Concave

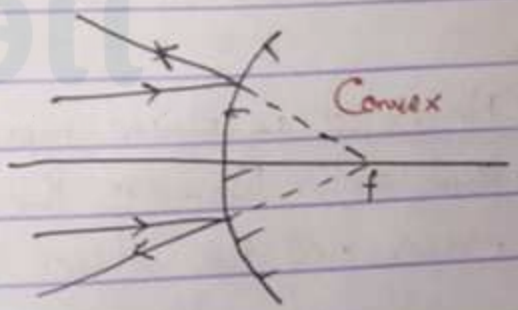
- they converge a beam of parallel rays to a real focus.

→ for concave mirrors, f is positive because it is real

### Convex

- they diverge a beam of parallel light rays from a virtual focus




magnification $m = \frac{v}{u}$

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Read Up - definition of terms in textbook
- image formation by concave & convex lenses

mirror equation; $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Note that we use the convention that real is positive and virtual is negative while using the mirror equation. Therefore; (i) R (radius of curvature) and f are positive for converging mirrors and negative for diverging mirrors

NB; $f = \frac{R}{2}$

(ii) u (object distance) is positive for objects in front of mirrors

(iii) v (image distance) is negative for virtual images and positive for real images

Examples

① A tree stands 1m from a concave mirror with radius of curvature 20cm find
(i) the position of image (ii) the magnification
(iii) the nature of the image

② An object is placed infront of a convex mirror of focal length 10cm if the image is formed 8cm from the mirror, find the object distance

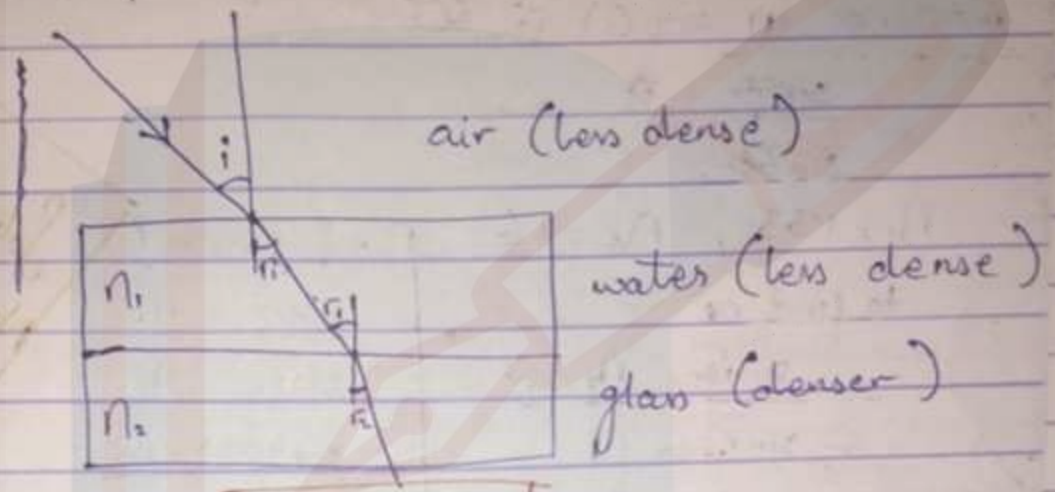
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# Optical Invariant

2/08/19

Note that Snells law is $\frac{\sin i}{\sin r} = \frac{n_e}{n_a}$.

Considering two parallel sided media as shown below




from snells law; $\frac{\sin r_1}{\sin r_2} = \frac{n_2}{n_1}$

$n_1 \sin r_1 = n_2 \sin r_2$

- Therefore the refractive index of the first medium multiplied by sine of angle made by the ray in the first medium with the normal is equal to the refractive index of the ~~first~~ second medium multiplied by sine of angle made by the ray in the second medium with the normal.
- Therefore, for refraction through several media, $n \sin\theta$ is equal to a constant ($n \sin\theta = \text{constant}$)
  $\theta$ is angle of refraction → This is known as Optical Invariance

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## Example

In the figure above, the first medium is water with refractive index = 1.33 and the second medium is glass with $n = 1.6$. Calculate the angle $r_2$ if the angle of incidence in air ($i$) is 60°

~~sin 60~~ #
~~sin 60~~

$n_1 = 1.33$, $n_2 = 1.6$, $r_1 = ?$, $r_2 = ?$

to find $r_1$

$$\frac{\sin i_{air}}{\sin r_{water}} = \frac{n_2}{n_1}$$

$$\frac{\sin 60}{\sin r} = \frac{1.33}{1}$$

$$\sin r = \frac{0.866}{1.33}$$

$$r = \sin^{-1}(0.6511)$$

$$r = 40.63°$$

$$\therefore \frac{\sin r_1}{\sin r_2} = \frac{n_2}{n_1}$$

$$\frac{\sin 40.63}{\sin r_2} = \frac{1.6}{1.33}$$

$$\sin r_2 = \frac{(1.33)(0.654)}{1.6}$$

$$r_2 = \sin^{-1}(0.5413)$$

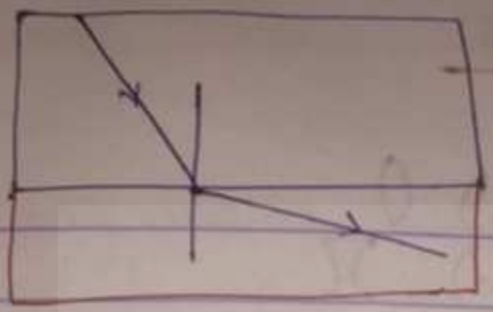
$$r_2 = 32.77°$$

Solve Yourself
n Tobe
No go say
solve am

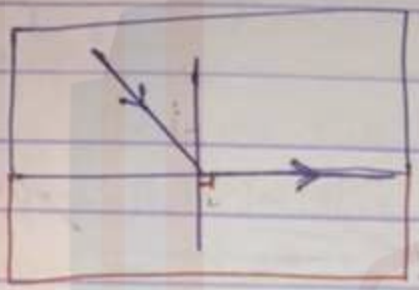
## Total Internal Reflection

If light travels from an optical denser medium, to a less dense medium, the angle of ~~refraction~~ incidence for which the refracted ray emerges tangent to the surface is called the critical angle. As the angle of incidence increases beyond the critical angle, total interval reflection occurs such that there is no refracted ray and all the light is reflected.

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At critical angle:




NOTE

- At critical angle there is no refraction
- Beyond the critical angle, there is total internal reflection

→ from snells law; $\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$

when i is critical angle ($i_c$) $\frac{\sin 90}{\sin i_c} = \frac{n_2}{n_1}$

at ic $n_1 = n_2 \sin i_c$ ∴ $\sin i_c = \frac{n_1}{n_2}$

Given that the refractive index of glass is 1.5 calculate its critical angle

$\sin i_c = \frac{1}{1.5}$

$i_c = \sin^{-1}\left(\frac{1}{1.5}\right)$

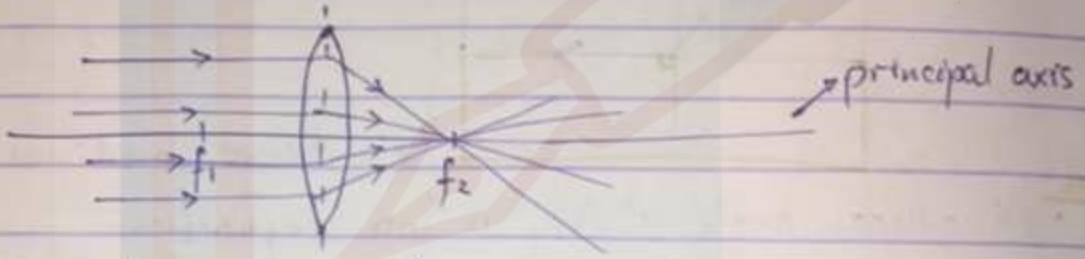
$i_c = 41.81°$

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# Types of thin lenses

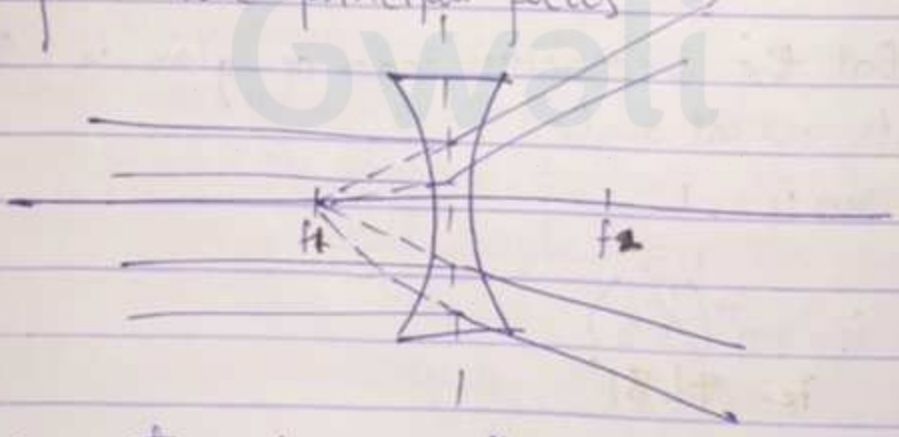
① Convex (Converging lens) O
② Concave (Diverging lens) )(

Convex lenses → they converge a the beam of parallel rays to a principal focus ($f_2$)




∴ $f_2$ is real because the rays actually pass through it. So when solving using our lens equation, $f$ is positive

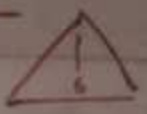
Concave lenses → they are thicker at the edges than at the middle, they diverge a beam of parallel rays from the principal focus




∴ $f$ is negative because the rays do not pass through $f_2$ and are virtual.

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# Image Formation in Thin lenses



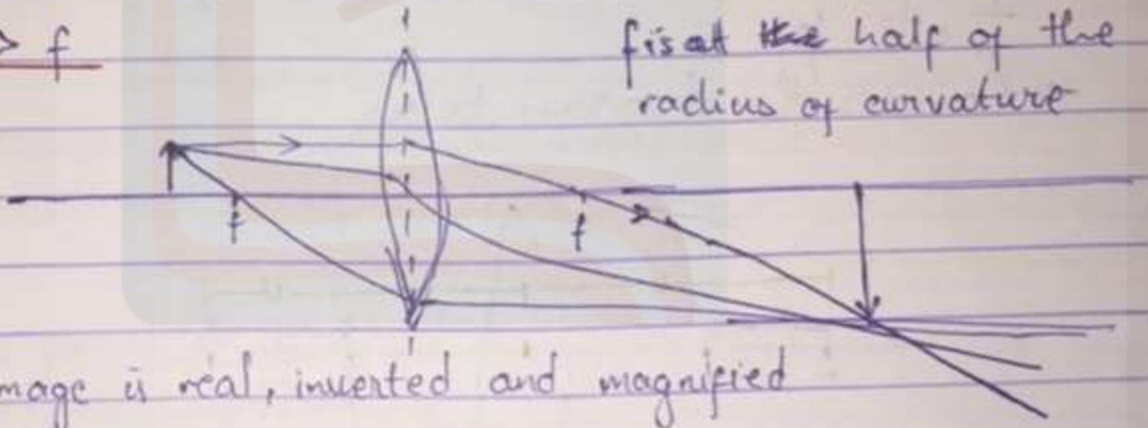
① Any ray parallel to the principal axis is refracted to pass through the corresponding focal point.

② Any ray through the center of the lens is undeviated

③ Any ray through the near focal point will emerge parallel to the principal axis after refraction by the lens

if $u > f$

f is at half of the radius of curvature




the image is real, inverted and magnified

if $u < f$

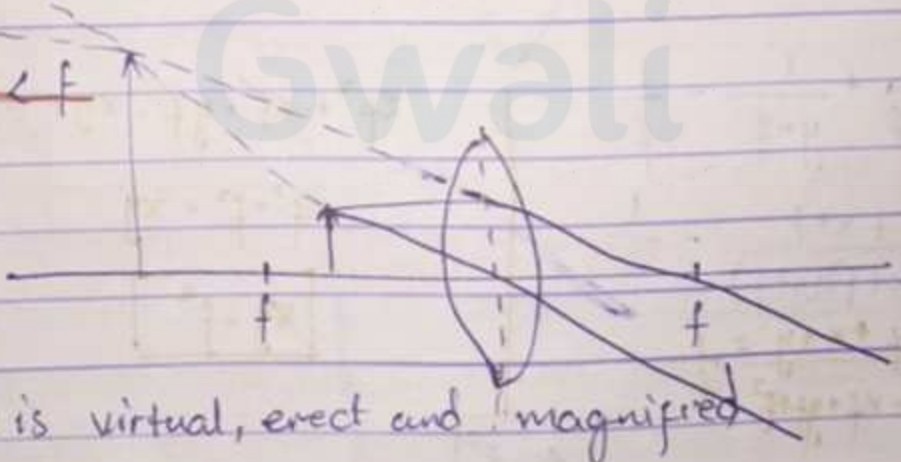



image is virtual, erect and magnified

Gwali
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## Concave lens

if $u > f$

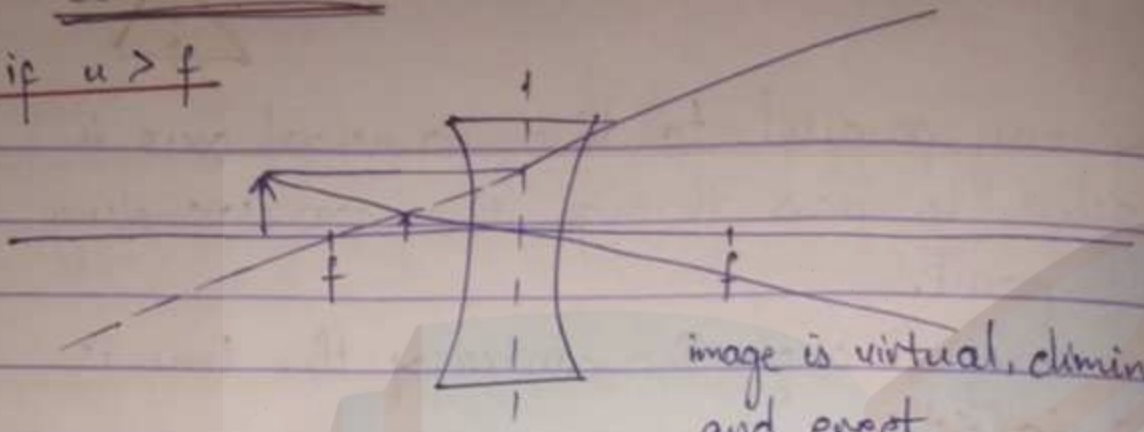



image is virtual, diminished and erect

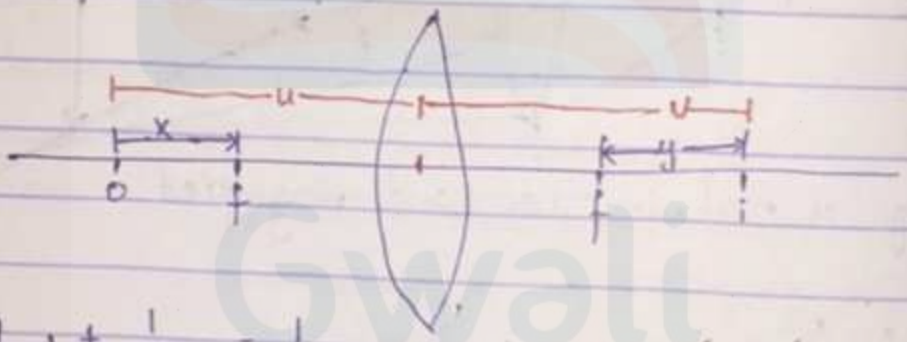
- find out what kind of image is formed at different object distances wrt focal point ?

## Newtons relation

It can be derived from the lens equation

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

→ Consider the diagram below




$\therefore \frac{1}{x+f} + \frac{1}{y+f} = \frac{1}{f}$

$\frac{y+f+x+f}{(x+f)(y+f)} = \frac{1}{f}$

$\frac{2f+x+y}{xy+xf+yf+f^2} = \frac{1}{f}$

$2f^2 + \cancel{xf} + \cancel{yf} = xy + \cancel{xf} + \cancel{yf} + f^2$

$2f^2 - f^2 = xy$

$\boxed{xy = f^2}$

$\boxed{xy = f^2}$

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this shows that as object approaches the lens (ie 'x' is decreasing) the image recedes from the lens (y increasing)

6/08/2019

## Waves

→ A wave is a disturbance which travels from one point to another transferring energy through its line of propagation on its medium.

Mechanisms for waves to occur;

1) There must be vibration of a medium
2) There must be transfer of energy

## Forms of Waves

- When the wave repeats, it is a periodic wave.
- When it is non-repeatable, it is a non-periodic wave.

## Classification of Waves by;

(1) Mode of production.
(2) Mode of propagation.

(1) **Mode of Production**; We have longitudinal and transverse waves. Transverse waves travel perpendicularly to their line of propagation e.g electromagnetic waves, ripples on the surface of water. Longitudinal waves travel parallel to their propagation e.g. wave generated from tuning fork, sound waves

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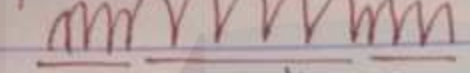


Advert space

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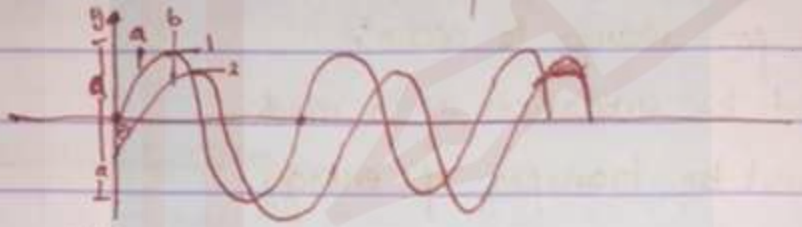
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- Longitudinal waves are characterized by compression and ~~epraction~~ reafaction




## Wave Parameters

① Displacement is the distance from the point of rest at any point on the wave




② Cycle: A wave is said to cover one cycle when it undergoes maximum up and down displacement and returns to its original position.

③ Period: It is the time taken for a wave to complete one cycle. It is measured seconds (s)

④ Frequency is the number of waves completed in 1 second. It is measured in Hz (Hertz). Mathematically, $\boxed{f = \frac{1}{T}}$ — ①

⑤ Wavelength is the horizontal distance covered by the wave in one cycle. Represented with ($\lambda$). It is the distance between

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successive

two ~~sussesive~~ crests or ~~the~~ troughs

⑥ Phase ($\phi$) is the angular distance between a wave of zero (0) displacement and that of non-zero displacement. It is given as $\phi = \frac{2\pi x}{\lambda}$ ——— ②

⑦ Velocity is the distance travelled by the wave in one second. Given by $v = f\lambda$ $(ms^{-1})$

→ Based on Propagation we have - Progressive waves
- Standing waves

① Progressive waves: particles of the medium vibrate about their mean position with the same amplitude and frequency but with changing phase.

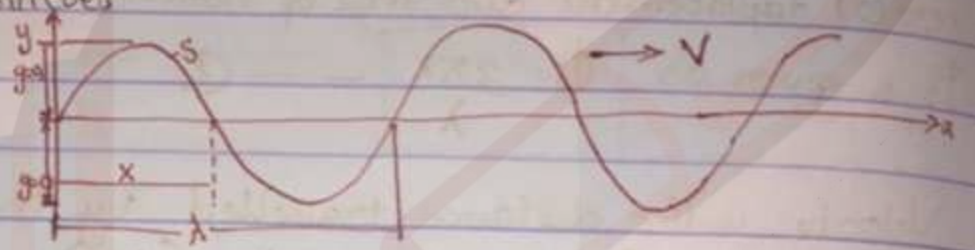
② Stationary waves are produced by superposition of two progressive waves travelling in opposite direction in the same medium.



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# Progressive Wave Equation

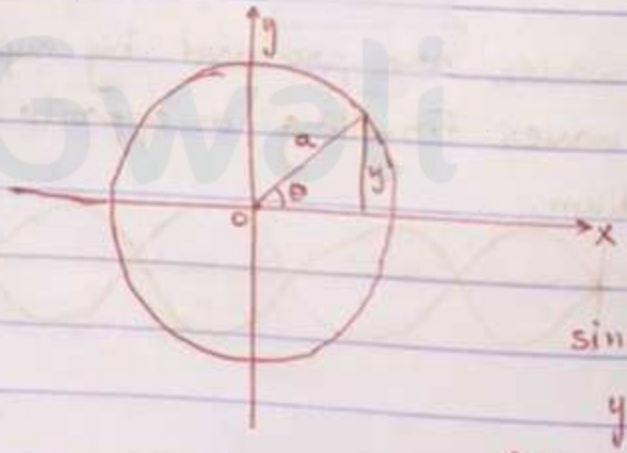
Energy is transfered outwards from the source in a progressive wave. We can use equations to represent the vibration of the particles




This figure represents progressive wave moving with velocity V in the positive direction when there is an oscillation in S.H.M at the source O.

. The oscillation varies between y=0 and y=a. "y=a" is the point of maximum displacement while "y=0" is the point of minimum displacement.

NB: Amplitude is the point of maximum displacement from the mid position.




$$\sin\theta = \frac{y}{a}$$

$$y = a\sin\theta$$

But, $\omega = \frac{\theta}{t}$

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$\theta = \omega t$ (angular frequency is the measure of $\theta$ with time(t))

$\therefore \boxed{y = a\sin\omega t}$ → wave equation

~~If point x in~~

~~If the particale at point x in the previous diagram~~

In a situation whereby the particle of point S in the distance x from the mean position, the oscillation lags at that distance with a phase difference of $\phi$ (phi)

$y = a\sin\omega t$

$y = a\sin\omega t - \phi$

$y = a\sin(\omega t - \frac{2\pi x}{\lambda})$

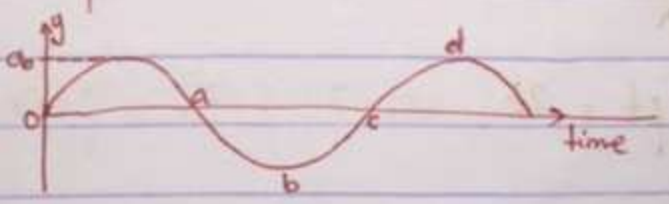
$y = a\sin(2\pi f t - \frac{2\pi x}{\lambda})$

$\boxed{\phi = \frac{2\pi x}{\lambda}, \quad \omega = 2\pi f, \quad f = \frac{1}{T}}$ → Note the following

If the progressive wave moves in a negative direction, we will have positive, as opposed to negative in positive direction. (ie $y = a\sin\left(2\pi f t + \frac{2\pi x}{\lambda}\right)$)

Example 1

A wave motion has the equation $a = A_0\sin(\omega t - Kx)$, the graph below shows how the displacement a varies with time. Which of the label points shows a displacement equal to that at the point $x = \pi/2K$ at $t = 0$




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## Solution

$a = a_0 \sin(\omega t - Kx)$

$a = a_0 \sin\left(0 - K\left(\frac{\pi}{2K}\right)\right)$ → because $t = 0$

$a = a_0 \sin\left(0 - \frac{\pi}{2}\right)$ Note: $\sin \pi/2 = 1$

$a = -a_0 \sin\frac{\pi}{2} = -a_0$

∴ the answer is (b)

## Example 2

The equation for a transverse wave moving along a string is given as $y = 2.0 \sin(0.02x + 2t)$ where $x$ and $y$ are in cm and $t$ is in seconds

Calculate; ① Amplitude

② Wavelength

③ Frequency

④ Speed

⑤ Maximum transverse speed for a particle on the string

⑥ The direction of wave propagation

## Solutions

① Amplitude = 2.0

② Wavelength; $\frac{2\pi x}{\lambda} = 0.02x$ ; $\frac{2\pi}{\lambda} = 0.02$ ; $\lambda = \frac{2\pi}{0.02} = 314.16\text{cm}$

③ frequency ; $2\pi ft = 2t$ ; $2\pi f = 2$ ; $f = \frac{2}{2\pi}$ ; $f = 0.318\ Hz$

④ speed ; $v = f\lambda$ ; $= 0.318 \times 314.16 = 100\ cm/s$

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(5) $V_{max} = \omega \times A$ | $\omega = 2\pi f = 1.998$

$V_{max} = \omega A = 3.996$

(6) Propagation is negative direction

Example 3

Write an equation representing a wave moving in the positive x-direction having an amplitude of 0.60 m, frequency of 500Hz and speed of 100 m/s

· solution

$A = 0.60m$ . $v = 100m/s$

$f = 500Hz$

$y = A\sin(\omega t - \phi)$

$y = A_0 \sin(2\pi ft - \frac{2\pi x}{\lambda})$

$y = A_0 \sin(2\pi ft - \frac{2\pi fx}{v})$

$y = 0.6 \sin(2 \times \pi \times 500 \times t - \frac{2 \times \pi \times 500 \times x}{100})$

$y = 0.6 \sin(3141.6t - 31.416x)$

What is the phase difference between a point at a distance S from the source and the source itself for a progressive wave given by $y = a \sin 2\pi\left(\frac{t}{T} - \frac{1x}{\lambda}\right)$

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# Properties of Waves

① **Reflection**: Its brought about by the change in direction of the wavefront at the interface between two media.
Law of Reflection ⋎ states that the angle of incidence is equal to the angle of reflection.

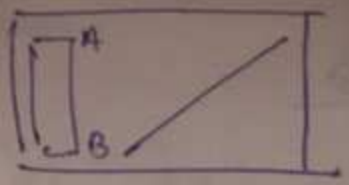
② **Refraction**: It is the bending of a wave when it moves from a denser to les dense medium or from a ~~slow~~ less dense to a denser medium. This is caused by the change in speed and wavelength ~~of~~ of the wave when it moves from one medium to another

$$\frac{\sin i}{\sin r} = \frac{V_1}{V_2} = \frac{f\lambda_1}{f\lambda_2}$$ Snells law

## Example

A bar vibrating with a frequency of 10Hz produces ripples in a ripple tank. the wave moves with a speed of 24m/s until it reaches a shallow region when it becomes 12m/s. The boundary xy of region is at 45° to the incident plane ray. Find the wavelength of the ripples before and after crossing the boundary
Find the direction of propagation..

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$$\lambda_1 = \frac{V_1}{f} = \frac{24}{10} = 2.4m$$

$$\lambda_2 = \frac{V_2}{f} = \frac{12}{10} = 1.2m$$

$$\frac{\sin i}{\sin r} = \frac{V_1}{V_2}$$

$$\frac{\sin 45}{\sin r} = \frac{24}{12}$$

$$\sin r = \frac{\sin 45}{2}$$

$$\sin r = \frac{\frac{\sqrt{2}}{2} \times \frac{1}{2}}{} = \frac{\sqrt{2}}{4}$$

$$= 0.3536$$

③ Diffractions is the ability of a wave to expand when it crosses a narrow aperture.

④ Interference: before two waves will interfere, they must be coherent (same frequency, same phase)

we have; - constructive interference

- destructive interference

$y_1 = a\sin \omega t$ and $y_2 = a\sin(\omega t + \phi)$

$y = y_1 + y_2 = a\sin \omega t + a\sin(\omega t + \phi)$

$$\sin A + \sin B = 2\sin\frac{(A+B)}{2}\cos\frac{(A-B)}{2}$$

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$$\therefore 2a \sin \frac{\omega t + \omega t + \phi}{2}$$

$$2a \sin \frac{2\omega t + \phi}{2} \cos\left(\frac{-\phi}{2}\right)$$

$$2a \sin \omega t + \frac{\phi}{2} \cos \frac{\phi}{2}$$

$$2a \cos \frac{\phi}{2} \sin \omega t + \frac{\phi}{2}$$

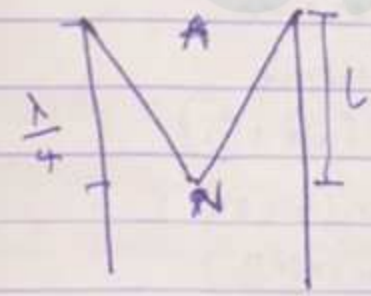
## Sound Waves

Sound is a form of energy that is transmitted in fluids (liquids and gases)

→ Energy transfered in solids & liquid is by intermolecular forces & collision but in gases is just by intermolecular forces that is why velocity of sounds in solids is greater than in liquids & liquids is greater than gases.
(solid > liquids > gases)

→ Reflection of sounds causes echoes.
Echoes are used in oil exploration, medical diagnosis etc...

## Reflection in Air Columns




$\frac{\lambda}{4} = L$

for a closed tube;

$$f_{n-1} = \frac{V(2n-1)}{4L}$$

V velocity

L length

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~~for an open tube~~: 16th August, 2019

fundamental frequency is the lowest frequency that is attainable.

$f_0 = f_{1-1} = \frac{V(2-1)}{4l} = \frac{V}{4l}$ → fundamental frequency

$f_1 = f_{2-1} = \frac{V(4-1)}{4l} = \frac{3V}{4l}$ → first overtone

$f_2 = f_{3-1} = \frac{V(6-1)}{4l} = \frac{5V}{4l}$ → second overtone

∴ we have $f_0, 3f_0, 5f_0, 7f_0$ ; for a closed tube

since $f = \frac{V}{\lambda}$ ; because $\frac{\lambda}{4} = l$

$f = \frac{V}{4l}$ $\lambda = 4l$

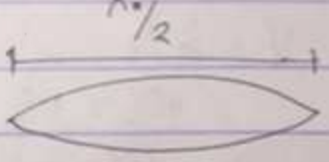
for open tube;

$f_{n-1} = \frac{V}{\lambda_{n-1}}$

$f_0 = f_{1-1} = \frac{V}{\lambda_{1-1}} = \frac{V}{\lambda_0}$

$f_1 = f_{2-1} = \frac{V}{\lambda_1}$

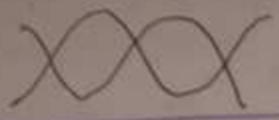
$f_2 = f_{3-1} = \frac{V}{\lambda_2}$




$l = \frac{\lambda_0}{2}$

$\therefore \lambda_0 = 2l$

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for open tube: $f_0, 2f_0, 3f_0, 4f_0$

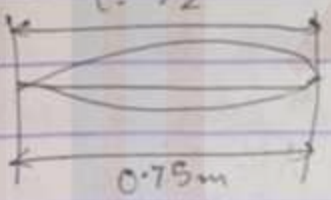
Example

The lowest resonant frequency for a guitar string of length 0.75m is 400Hz. find the speed of a transverse wave on the string.

solution

$l = 0.75m, \quad f_0 = 400Hz$

$V = f\lambda \qquad l = \lambda_0/2$




$l = \frac{\lambda_0}{2}$

$\lambda_0 = 2 \times l = 2 \times 0.75$

$\lambda_0 = 1.5m$

$V = f_0 \lambda_0$

$= 400 \times 1.5$

$= 600 m/s$

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$V = \sqrt{\frac{T}{u}}$ T is tension

$2lf_0 = \sqrt{\frac{T}{u}}$ $u \rightarrow$ mass per unit length

$$\boxed{f_0 = \frac{1}{2l}\sqrt{\frac{T}{u}}}$$

Example

Calculate the tension on the string of length 1.8m, when a note of fundamental frequency 10Hz is played given that the mass per unit length is 2.

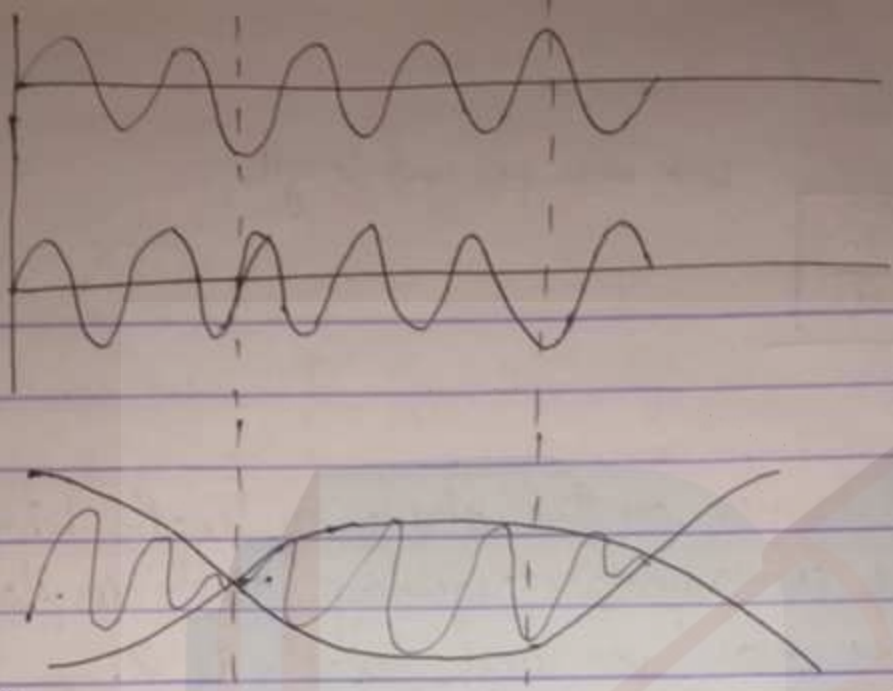
$l = 1.8m$ $f_0 = 10Hz$ $u = 2$ ; $(2lf_0)^2 = \left(\sqrt{\frac{T}{u}}\right)^2$ ; $(2(1.8)(10))^2 = \frac{T}{2}$ ;

$36 = \frac{T}{2}$ ; $T = 72N$

Resonance occurs when the frequency of external vibrating force acting on a system is equal to the fundamental frequency of that system.

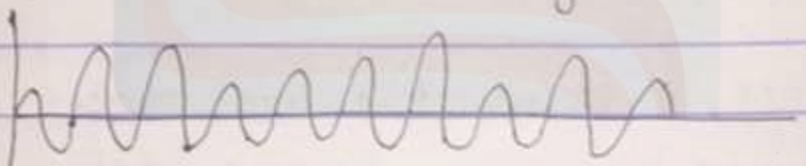
- For interference to occur; the two sources must be coherent. periodic
- Beat is the variation in intensity of sound which is heard when two notes of almost the same frequency are played simultaneously. loudness
- Beat frequency difference is the difference between the frequency of the first beat and that of the second beat.

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Example

A microphone and a cathode ray oscillator with a calibrated time base are used to display the wavefront produced by two audio frequency signal generator. When the time base is set so that 1 complete swing takes 50 ms (milli seconds) a steady trace is shown




Estimate ① the period of the wave motion
② the beat frequency
③ frequency of the two signal generators

② $10T = 50 \times 10^{-3}$

$T = \frac{50 \times 10^{-3}}{10} = 5 \times 10^{-3}$

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(2) $50 \times 10$

$T = \frac{1}{2} \times 50 \times 10^{-3} = 2.5 \times 10^{-2}\,s$

$f = \frac{1}{2.5 \times 10^{-2}} = 40\,Hz$

(3) 解: $F_1 - F_2 = 40Hz$

$\frac{1}{T} = \frac{1}{5 \times 10^{-3}} = \frac{1}{2} F_1 + F_2$

$F_1 - F_2 + F_1 + F_2 = 40 + 400$

$2F_1 = 440 \quad F_1 = 220Hz$

$F_2 = 180Hz$

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Thermodynamics
Heat current
Heat resistance
Refrigerator

PMMM
carnon cycle - Gyplied epping
auto cycle
PV-diagrams

→ show that $\gamma = 3\alpha$

→ derive the equation of thermal stress

① $\alpha = \frac{\Delta L}{L_0 \Delta T}$ $\quad \gamma = \frac{\Delta V}{V_0 \Delta T} \rightarrow V = V_0 + \gamma V_0 \Delta T$

$L = L_0 + \alpha L_0 \Delta T$

$V = L^3$

$V = L_0^3 + 3\alpha L_0^3 \Delta T$

$= V_0 + 3\alpha V_0 \Delta T$

chapter 17
18
19 - an
20 - an

Every class test

② $\frac{\Delta L}{L_0} = \alpha \Delta T$

$Y = \frac{F/A}{(\Delta Le)/L}$

$\frac{\Delta Le}{L} = \frac{F}{AY}$

$\left(\frac{\Delta L}{L_0}\right) + \frac{(\Delta Le)}{L} = 0$

$\frac{F}{AY} + \alpha \Delta T = 0$

$\boxed{\frac{F}{A} = -\alpha Y \Delta T}$ → equation of thermal stress

③ $\xi \xrightarrow{Q} \xi = mC\Delta T$

$\frac{d\xi}{dt} = \frac{KA(T_H - T_C)}{L}$

$P = A e \sigma T^4$

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Calculate the pressure exerted on the wall of a container by a gas molecule

$\frac{\Delta P}{t} = F$ ans: $\frac{F}{A} = P = \frac{N m V_x^2}{V}$

change in momentum / time = Force

why is latent heat of fusion always greater than latent heat of vaporization

Read PVt- diagram

$TV^{\gamma-1}$ = constant

Bro. just read chapter 17 to 20

Characteristics of Sound

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# Characteristics of Sound

1. Intensity: Sound energy per second incident on a unit area at right angle to the source of the sound. Measured in Watts per $m^2$. It is directly proportional to the amplitude and inversely proportional to the square of the distance between the sound source and the sound detector. It is measured in decibel.

$$I = \frac{\text{Power}}{\text{Area}} = \frac{W}{m^2} = \frac{a}{r^2}$$

$$\text{Obel} = 1.0 \times 10^{-12}\ W/m^2$$

Obel is the threshold of humming (the least sound that the ear can hear).

2. Loudness: This depends on the intensity and the sensitivity of the detector.

3. Pressure: The minimum change in pressure that the ear can detect is the threshold of hearing and the maximum is the threshold of pain. The threshold of hearing is 20$\mu$Pa while the threshold of pain is 20Pa

* It is measured in micropascal

4. Pitch: The sensation a sound produces in a listener's ear. It depends on frequency.

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5. Quality: Helps to distinguish between two notes of the same frequency from two different instruments. It depends on overtones

## Production of Sound

① Before sound is produced, there must be a vibration of source, and there must be a resonance structure.

② As the source is vibrating, particles within the medium are vibrating along the source and as these particles are vibrating, there is a transfer of energy.

## Propagation of Sound

1. Free-field propagation: this is when there is no surface obstacle to change the direction of the sound waves.
2. Boundary propagation: this is when there are obstacles

## Sources of Sound

① Natural sources: wind, rainfall, thunder, heartbeat, human speech

② Manmade sources: generators, mechanical sources, electrical sources

## Speech production

The nose is the resonant structure that makes the sound made by the vibration of the vocal ~~chords~~ cords audible. The lung contracts air comes out, vocal cords are set into vibration. The nose, throat and mouth serve as resonance structures.

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