Dr Timonah

SPH 2170 PHYSICS 1 18/09/2019

Course Outline

- Units and Dimension
- International Standards of Units (SI) & Standards
- Kinematics
- Dynamics
- Circular motion.
- Calorimetry.
- Gase Thermal Expansion
- Change of State
- Transfer of heat
- Thermometry
- Optics : Reflection at planee surface.
- Refraction through Prism.
- Dispersion spectra
- Refraction through Lens.
- Optical Instruments
- Velocity of light
- Photometry
- Waves and Oscillation
- Simple Harmonic Motion (SHM)
- Sound and Light Interference
- Diffraction
- ⇒ Polarization.

Units and Dimension.

- The laws of physics are expressed in physical quantities Examples: Length, mass, density, pressure, force, work etc.
- In order to quantify a physical quantity a reference called Standard is needed eg Length ⇒ metre, mass ⟹ Kilogram therefore a physical quantity is expressed as a product of a number and a unit.

CamScanner CS

Physical Quantity	Dimension
Pressure	$ML^{-1}T^{-2}$
Power	$ML^{2}T^{-3}$

- There are different types of system of units eg MKS, Cgs, British System, ST that are used worldwide However SI is adopted.
- Physical quantities maybe divided into two:
  * Fundamental quantities
  * Derived quantities.
- Fundamental quantities are measurement system of three basic measures of mass, length and time.
- By the dimension of a physical quantity we mean that is related to the fundamental quantity
- Dimensions do not depend on type of system of units used.

Physical Quantity	Units	Dimension
Length	Metre (m)	L
Mass	Kilogram (Kg)	M
Time	Seconds (s)	T
* Charge	Coulomb (C)	C
Temperature	Centigrade (°C) or Kelvin (K)	K
Volume	metre cubed (m^3)	L^3
Velocity	metres per second (m/s)	LT^{-1}
Force	Newtons (N)	MLT^{-2}
Work	Joules (J)	ML^2T^{-2}
Plane angle	Radians (rad)	
Solid angle	Staradian (sr)	
Dynamic Viscosity	η	$ML^{-1}T^{-1}$

- In the table above, add more physical quantities their units and dimension and group them according to Fundamental and derived quantities. The last two Physical Quantities in the table are called Supplimentary Quantities
- The dimensions or units may be used to show validity of equation (Correctness of a formula) or to predict the form of

CamScanner CS

equations. Example;

Consider a stone whirled round in a horizontal circle at the end of a string. The tension force F in the string depends on the speed v of the stone, the length of the string (radius, r), and the mass m of the stone.

$$F \propto m^x v^y r^z$$

~~$F \propto m^x g$~~ $F = K m^x v^y r^z$

In dimension form;

$$[MLT^{-2}] = [M]^x [LT^{-1}]^y [L]^z$$

Equate indices

$L : 1 = y + z$

$M : 1 = x$

$T : -2 = -y$

$x = 1 \quad y = 2 \quad z = -1$

Subtituting back into original equation.

$$F = kmv^2r^{-1}$$

$$F = \frac{kMv^2}{r}$$

- From experiment $k=1$ therefore $F = \frac{Mv^2}{r}$

Examples;

1 Simple pendulum, the period T of oscillation of a simple pendulum depends on a) length L of pendulum.
b) Mass M of the ~~bat~~ bob. $(T = 2\pi\sqrt{\frac{L}{g}}$
c) Acelation due to gravity g.

Using dimension analysis, find the equation relating T, L, M and g.

2. Consider a wave set up in a straight string by plucking it, If

the velocity V of the wave depends on the tension F in the string, the length L of the string and its mass M. Find the equation relating V to F, L and M

3. The period T of an oscillating liquid in a U-tube depends on gravitational acceleration g and height difference h between its liquid levels; use dimension analysis to obtain the equation for T.

$$T = k\sqrt{\frac{h}{g}}$$

4. Assuming that the velocity of sea-waves V depends on the wavelength λ, density ρ of water and acceleration due to gravity g. Use the method of dimension analysis to show that $V = k\sqrt{g\lambda}$ where k is a dimensionless quantity

~~Linear Motion~~

(1) $T \propto L^y M^x A^z$

$T = k L^y M^x a^z$

$T = k L^y M^x (LT^{-2})^z$

$T = [L]^y [M]^x [LT^{-2}]^z$

$0 = y + z$ $\quad 1 = -2z$

$0 = x$ $\quad z = -\frac{1}{2}$

$y = \frac{1}{2}$

$T = L^{\frac{1}{2}} M^0 (LT^{-2})^{-\frac{1}{2}}$

$T = k\sqrt{l} \times \frac{1}{\sqrt{g}}$

$T = k\sqrt{\frac{l}{g}}$

(2) $V \propto F, L, M$

$V = kF^x L^y M^z$

$LT^{-1} = [MLT^{-2}]^x [L]^y [M]^z$

$1 = x + y$ $\quad y = \frac{1}{2}$

$-1 = -2x$ $\quad x = \frac{1}{2}$

$0 = Mx + z$, $\quad z = -\frac{1}{2}$

$V = kF^{\frac{1}{2}} L^{\frac{1}{2}} M^{-\frac{1}{2}}$

~~$V = k\sqrt{FL}$~~ $\quad V = k\sqrt{\frac{FL}{M}}$

(3) $T \propto g^x h^y$ $\quad T = kg^x h^y$

$T = [LT^{-2}]^x [L]^y$

$1 = -2x$

$x = -\frac{1}{2}$ $\quad x + y = 0$

$T = kg^{-\frac{1}{2}} h^0$ $\quad y = \frac{1}{2}$

~~$T = k\sqrt{g}$~~ $\quad T = k\sqrt{\frac{h}{g}}$

CamScanner CS

Same
by
Unit
Assign

Linear Motion

Read on Displacement & Distance; Speed and Velocity & Acceleration.

Assignment:

Read & Write about Graphical Representation and Interpretation of the following types of Graphs describing Linear Motion

① Displacement / Distance – Time graph

② Speed / Velocity – Time graph.

Equations of Motion

– Consider a particle moving under the action of a constant force (at a uniform acceleration a) in a straight line. Suppose the velocity changes from the initial velocity u to final velocity v over time t then;

$$a = \frac{v-u}{t} \quad ; \quad \underline{v = u + at} \quad \text{---- (i)}$$

– If a particle travels a distance s in time t then;

$$s = \text{Average Velocity} \times \text{Time taken}$$

$$= \left(\frac{v+u}{2}\right)t \qquad \text{but } v = u + at$$

$$s = \tfrac{1}{2}(u + u + at)t$$

$$\underline{\underline{s = ut + \tfrac{1}{2}at^2}} \quad \text{..... (ii)}$$

– Similarly the distance s can be given by:

$$s = \left(\frac{u+v}{2}\right)t \qquad \text{but } t = \frac{v-u}{a}$$

$$\therefore s = \frac{1}{2a}(v+u)(v-u) \quad \Rightarrow s = \frac{1}{2a}(v^2 - u^2)$$

CamScanner CS

$$v^2 = u^2 + 2as \quad \text{----------(iii)}$$

- Equations (i), (ii) and (iii) rep. equations of motion of particles moving in a straight line with uniform acceleration.

Example;

A car accelerates from rest to a speed of 36km/hr in 10sec. Find;

a) Acceleration — $1m/s^2$

b) Distance travelled — 50m

c) The speed at the end of the 5th seconds — 5m/s

d) The distance travelled in the 5th second. — 4.5m

a) $v = u + at$

$\frac{36 \times 10}{36} = 10m/s.$

$10 = 0 + a \times 10$

$a = 10/10 = \underline{1m/s^2}$

b) $v^2 = u^2 + 2as$

$10^2 = 0^2 + 2 \times 1 \times s$

$2s = 100$

$= \underline{50m}$

$\cancel{v^2 = u^2 + 2as}$

$\cancel{5^2 = 0^2 + 2}$

$s = ut + \frac{1}{2}at^2$

$s = 0 + \frac{1}{2} \times 1 \times 4^2$

$= \underline{8m}$

$12.5m - 8m = \underline{4.5m}$

c)

$v = u + at$

$= 0 + 1 \times 5$

$= \underline{5m/s}$

d) $s = ut + \frac{1}{2}at^2$

$= 0 \times 5 + \frac{1}{2} \times 1 \times 5^2$

$= 0 + 25/2 = \underline{12.5m}$

$v^2 = u^2 + 2as$

$5^2 = 0^2 + 2 \times 1 \times s$

$\frac{25}{2} = s$

$= \underline{12.5m}$

CamScanner CS

Motion Under Gravity

- For particles falling under gravitational pull (free fall) have a constant/uniform acceleration at $9.8\,m/s^2$ usually approximated to $10\,m/s^2$ and is called acceleration due to gravity (g)
- g is considered positive for falling particles (moving towards centre of the earth) and negative for rising particles. Therefore in the equation of motions (i), (ii) and (iii); a is replaced with g taking into consideration the direction of the motion ie falling/rising;

Falling	Rising
(i) $v = u + gt$	(i) $v = u - gt$
(ii) $s = ut + \frac{1}{2}gt^2$	(ii) $s = ut - \frac{1}{2}gt$
(iii) $v^2 = u^2 + 2gs$	(iii) $v^2 = u^2 - 2gs$

Example:

An object is thrown straight up from the ground with an initial velocity of 20m/s. How high does it rise

$v^2 = u^2 - 2gs$

$0^2 = 20^2 - 20s$

$s = \frac{400}{20} = 20m.$

or

$v = u + gt$

$0 = 20 - 10t$

$t = 2$

$s = ut + \frac{1}{2}gt^2$

$s = 40 - 20$

$= 20m.$

A ball is thrown vertically upwards and reaches a height of 90m, Find:

a) the velocity with which it was thrown. 42m/s

b) How far the ball will be from its starting point 7 seconds after throwing 53.9m

~~a) $v = u - 2gt$~~

~~$0 = u - 2 \times 10 \times 90$~~

~~$u =$~~

a) $v^2 = u^2 - 2gs$

$0 = u^2 - 2 \times 10 \times 90$

$u^2 = 1800$

$u = 42.426\,m/s.$

b) $s = ut + \frac{1}{2}gt^2$

$= (42.426 \times 7) + -(\frac{1}{2} \times 10 \times 7^2)$

$= 296.985 + 245$

$= 541.985m.$

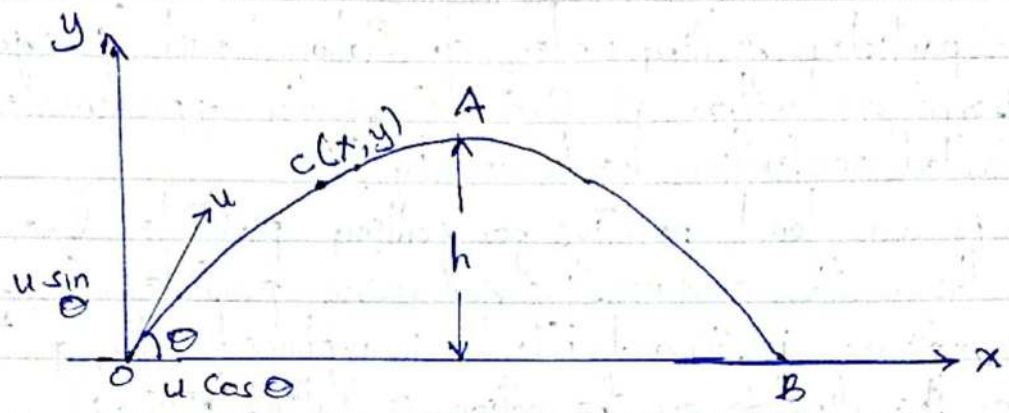
$= 51.985m.$

CamScanner CS

$u\sin\theta \Rightarrow u$

$u\cos\theta \Rightarrow R$

Projectiles



- Consider a particle projected from O at an angle θ to the horizontal with initial velocity u
- The motion is a combination of two independent motions:
  - * Horizontal / Impulse motion
  - * Vertical / Free fall motion

a) Vertical Motion

- While the particle is rising, it is subjected to a constant acceleration $a = -g$. If h is the maximum height attained and initial velocity is $u\sin\theta$ while final velocity is 0, then from equation (iii) of linear motion:

$$v^2 = u^2 - 2gs$$

$$0 = (u\sin\theta)^2 - 2gh$$

$$h = \frac{u^2\sin^2\theta}{2g} \quad \text{.....} \quad (iv)$$

- If t is the time taken to reach maximum height then from (i):

$$v = u - at$$

$$0 = u\sin\theta - gt$$

$$t = \frac{u\sin\theta}{g} \quad \text{.....} \quad (v)$$

CamScanner CS

- The time taken to fall to B from A is the same as the time taken to reach maximum height (from O to A) therefore the time taken from O to B is called Time of Flight (T)

$$T = 2t \Rightarrow \frac{2u\sin\theta}{g} \quad \text{.....} \quad (vi)$$

b) Horizontal motion

- The horizontal component of velocity $u\cos\theta$ remains constant throughout the flight and therefore;

Horizontal distance (OB) = Horizontal Velocity × time taken
(Range)

$$OB = u\cos\theta \times \frac{2u\sin\theta}{g}$$

$$= \frac{2u^2\sin\theta\cos\theta}{g}$$

But $2\sin\theta\cos\theta = \sin 2\theta$

$$OB = \frac{u^2\sin 2\theta}{g} \quad \text{....} \quad (vii)$$

Consider equation describing the projectile; suppose the particle is at a point C (x, y) and at time t after projection from O, then

$$x = ut\cos\theta \quad \text{.....} \quad (a)$$

$$y = ut\sin\theta - \tfrac{1}{2}gt^2 \quad \text{...} \quad (b)$$

Making t the subject of equation a and substituting it into equation b

$$t = \frac{x}{u\cos\theta}$$

$$y = \left(\frac{x}{\cancel{u}\cos\theta}\right)\cancel{u}\sin\theta - \tfrac{1}{2}g\left(\frac{x}{u\cos\theta}\right)^2$$

$$y = x\tan\theta - \left(\frac{g}{2u^2\cos^2\theta}\right)x^2 \quad \text{...} \quad (viii)$$

CamScanner CS

- Equation (viii) is similar to $y = ax + bx^2$ which describes a parabolic path thus a projectile is a parabolic path.

Example;

* A bullet is projected at 55° to the horizontal with the initial velocity of 8m/s; calculate;
  a) Maximum height reached — 2.15m
  b) Range — 6.01m
  c) Time of flight — 1.31s
  d) Velocity of bullet when it hits the ground.

a)

$$h = \frac{u^2 \sin^2 \theta}{2g}$$

$$= \frac{8^2 \sin^2 55°}{2 \times 10}$$

$$= \frac{42.94464459}{20}$$

$$= 2.1472m.$$

b) $$\text{Range} = \frac{u^2 \sin 2\theta}{g}$$

$$= \frac{8^2 \sin(2 \times 55)}{10}$$

$$= \frac{60.14032773}{10}$$

$$= 6.01403m$$

c) $$T = \frac{2u \sin\theta}{g}$$

$$= \frac{2 \times 8 \sin 55}{10}$$

$$= \frac{13.10643271}{10}$$

$$= 1.3106 \text{ seconds.}$$

d) Velocity

$= 0$

$$v = u + gt$$

$$t = \frac{1.3106}{2} = 0.6553$$

$$v = 0 + 10 \times 0.6553$$

$$= 6.553 \text{ m/s}$$

CamScanner CS

2. A bomb is dropped on an enemy post by a plane flying with a horizontal velocity of 60kmth at a height of 490m, How far the plane must be from the enemy post at the time of dropping the bomb for it to hit the target 166.66m

3. Find the velocity of projection of a missile that has a horizontal range of 150m if its time of flight is 3second. 52.16m/s

Newton's Law of Motion

- Mechanics is the study of the behaviour of various types of bodies when subjected to the action of external forces.
- This behaviour is described by Newtons 3 laws of motion;

Newton's 1st Law of Motion;

States; A body tends to remain at rest or in uniform motion in a straight line unless acted upon by a resultant external force.

- Newton's First Law expresses the idea of inertia ie; the reluctance of a body to start moving or to stop moving if in motion
- Mass is a measure of the inertia of a body.

Newton's 2nd Law of Motion;

States; The rate of change of momentum with time is proportional to the applied force and the momentum change take place in the direction of force.

$$F \propto \frac{m(v-u)}{t} = ma$$

Newtons 3rd Law of Motion;

States; To every action force, there is an equal and opposite reaction force.

CamScanner CS

Momentum

- Momentum P is the product of the mass m of an object and its velocity V; ie

$$\vec{P} = m\vec{V}$$

- From Newton's Second Law of Motion

$$\text{Force } F \propto \frac{\text{Change in Momentum}}{\text{Time}} = \frac{mv - mu}{t} = ma$$

$$Ft = mv - mu \quad \text{(Impulse of Force)}$$

Principle of Conservation of Momentum

- States that; When bodies in a system interact the total momentum remains constant provided no external force acts on the system
- To illustrate this principle;

Suppose object A of mass m_1 and initial velocity u_1 collides with another object B of mass m_2 and initial velocity u_2 moving in the same direction; then From Newton's Third law of Motion; Force F exerted by A on B is equal and opposite to that exerted by B on A.

The total momentum therefore of the system before collision $m_1u_1 + m_2u_2$

Suppose after collision object A moves with velocity v_1 and B with velocity v_2; then the total momentum after collision moving in the same direction will be $m_1v_1 + m_2v_2$

From Principle of conservation of momentum; total momentum before collision is equal to the total momentum after collision

$$\therefore \quad M_1v_1 + M_2v_2 = M_1u_1 + M_2u_2$$

CamScanner CS

Note: In collision the total momentum of colliding bodies is always conserved by Kinetic Energy may / may not be conserved. If K.E is also conserved during collision then;

$$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$

- This type of collision is called Elastic collision.
- If Kinetic energy is not conserved then the collision is called Inelastic Collision; where energy is lost inform of heat, sound, light and work.

Example:

An 1800kg car, stopped at a traffic, is struck from behind by a 900kg car and the two become entangled. If the smaller car was moving at 20m/s before collision; what is the speed of the entangled mass after collision; Find the energy lost during this collision.

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

But $v_1 = v_2 = v$

$$m_1u_1 + m_2u_2 = (m_1 + m_2)v$$

$$0 + 900 \times 20 = 2700v$$

$$18000 = 2700v$$

$$\underline{\underline{v = 6.667\,ms^{-1}}}$$

Before Collision:

$$\frac{1}{2}m_2u_2^2 = \frac{1}{2} \times 900 \times 20^2$$

$$= 180000\,J$$

After Collision

$$\frac{1}{2}(m_1 + m_2)v^2$$

$$= \frac{1}{2}(2700) \times 6.67^2$$

$$= 60060.015\,J$$

$$= 180000 - 60060.015\,J$$

$$\underline{\underline{= 119939.985\,J}}$$

CamScanner CS

a) A child bounces a ball on the side wall. The linear impulse delivered by the side wall to the ball is 2Ns during 1/800 second of contact. What is the magnitude of the average force exerted on the ball by the side wall. 1600N

b) A riffle bullet weighing 7g leaves the burrel of the riffle with a velocity of 300m/s. If the riffle recoils at 1m/s, Find the mass of the riffle 2.1kg

c) A particle of mass 9.1×10^{-31} g with a speed of 6×10^{3} m/s passes through an electric field for 3×10^{-7} second and emerges with a speed of 7.5×10^{5} m/s. Calculate;

(i) The initial and final momentum of the particle

(ii) The average force experienced by the particle

d) A bullet of mass 5g is fired in a block of wood of mass 1kg suspended from a weightless string, the bullet entangles with the wooden block and the entire system swings through a height of 5cm; Find: $Pe = mgh$.

(i) The initial speed of the bullet $201 ms^{-1}$

(ii) The energy loss due to collision

101.0025

0.5025

$\theta = \frac{s}{r}$ but $s = vt$

$\theta = \frac{vt}{r}$ $t = \frac{r\theta}{v}$ $\frac{1}{2}mv^2$ $1.005 \times 10 \times 0.05$

$\frac{mv^2}{r}$ for full revolution $\theta = 2\pi$ 0.0025

$\frac{v}{2\pi r} = \frac{1}{8}$ $F = m\omega^2 r$

$20 \times v \times 14$. $t = \frac{2\pi r}{v}$ but $\omega = \frac{v}{r}$ thus $\frac{r}{v} = \frac{1}{\omega}$

$= 2\pi$

CamScanner CS

Circular Motion

$\theta \Rightarrow \omega t$ For 1 revolution $\theta = 2\pi$ $t = T$

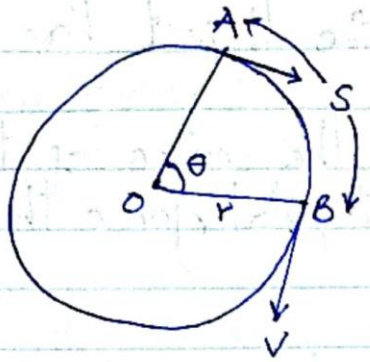
$2\pi = \omega T$

$T = \frac{2\pi}{\omega}$

$\omega t = s/r$

$s = \omega t r$

$s/rt = \omega$



$\theta = \omega t = s/r$

$\omega = s/rt$

But $s/t = v$

$\omega = v/r$

Consider an object moving in a circle with unifor speed v round a fixed point O. The object experiences a linear as well as an angular velocity

$$\text{Angular Velocity } (\omega) = \frac{\text{Change of angle } \theta}{\text{time } t}$$

$$\omega = \frac{\theta}{t} \quad \cdots (1)$$

where $\theta \rightarrow$ radian and 2π rad $= 360°$

Thus angular velocity measured in rad/second.

- If s is the length of the arc AB then

$$\theta = \frac{s}{r} \quad \omega = \frac{\theta}{t} = \frac{s}{rt} = \omega = \frac{v}{r}$$

$$\omega = \frac{v}{r} \quad \cdots (2)$$

Period T is the time taken for one complete circle given by

$$T = \frac{2\pi}{\theta} \quad \cdots (3)$$

$$\text{Angular Frequency } (f) = \frac{1}{T} = \frac{\omega}{2\pi} \quad \cdots (4)$$

CamScanner CS

- Although the object is moving with a constant speed, the presence of the force (necessary to keep the object moving in its circular path) implies that the object has an acceleration
- The acceleration acts towards the centre of the circle in the same direction as the centripetal force thus acceleration;

$$a = \frac{v^2}{r} \quad \text{--- (5)}$$

but $v = \omega r$

$$a = \omega^2 r \quad \text{--- (6)}$$

The centripetal Force F;

$$F = ma$$

$$F = \frac{mv^2}{r} = m\omega^2 r \quad \text{--- (7)}$$

- For an object in uniform circular motion; acceleration a and velocity v are always at right angle to each other.

Examples:

An object of mass 0.5kg at the end of a string is whirled round in a horizontal circle of radius 2m at a constant speed of 10m/s. Find the angular velocity and the tension on the string. If the object was whirled in a vertical circle; Find the minimum and maximum tension on the string.

$$\omega = \frac{v}{r} = \frac{10}{2} = \underline{5 \text{ rad/s}}$$

$$F = \frac{mv^2}{r} = m\omega^2 r = 0.5 \times 5^2 \times 2 = \underline{\underline{25N}}$$

CamScanner CS

Max. Tension $F = m\omega^2 r + mg$ $= 25 + 0.5 \times 10$
$= \underline{30N}$

Min Tension $F = m\omega^2 r - mg$ $= 25 - 0.5 \times 10$
$= \underline{20N}$

a) An 8kg mass tied at the end of a string of length 2m is whirled in a horizontal circle at 6m/s. Find the angular velocity and hence the centripetal force.

b) A mass of 70kg is making 8 revolutions per second round a circle of 14m. Find the force towards the centre of the circle which must be acting on the mass $2.476 \times 10^6 N$

$\omega = \frac{v}{r} = \frac{6}{2} = 3$ rad/sec.

$\frac{mv^2}{r}$ but $\omega = \frac{v}{r}$

$F = m\omega^2 r = 8 \times 3^2 \times 2 = 48N \times 3 = \underline{144N}$

$= \frac{8 \times 6^2}{2} = \frac{8 \times 36}{2} = \frac{288}{2} = 144N.$

Heat

Thermometry
Heat Transfer
Heat energy
Change of State

Gas Laws
Thermal Expansion in solids

Reference: Nelkon & Parkey
University Physics – Sears & Zemansky.
Halliday & Resnick

- Pyrometer – Uses principle of radiation; Measure temp greater than 2000K

$$E = \sigma T^4$$

TEMPERATURE AND THERMOMETRY

- Temp is a physical quantity corresponding to hotness/coldness of ~~a substanc~~ a substance.
- It depend on thermometer type used and scale used.

Types of Thermometer

- Thermometric property include:
  - * Expansion of a fluid
  - * Resistance in an electric circuit
  - * Radiated energy
  - * Colour or light
  - * Magnetic susceptibility

- Type of thermometer include:

- Mercury thermometer	- Gas thermometer → Constant Pressure Gas thermometer	- Based on Gas law
- Constant Volume thermometer	- Electrical thermometers	- Based on EMF induced between joint of two different wires
- Thermocouple thermometer	- Resistance thermometer (Platinum Resistance Thermometer)	- Based on a spiral of a fine wire.

emf $\varepsilon = \alpha T + \beta T^2$

Temp measure 500K–2300K

Temp. Scales

- To establish a temp scale; the following must be present
  - * Physical property sensitive to temp changes (Increase with increase in temp.)

$$T = kX$$ linear equation

T – Temperature
X – thermometric property
k – constant

For mercury thermometer:

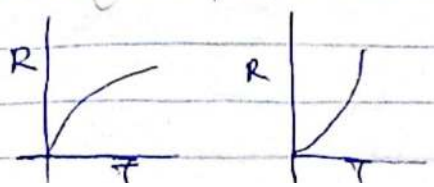
$$\Delta T = k \times \Delta L$$

$$T = ax^2 + bx + c$$ Non-linear

a, b & c – Constants

Example Resistance of a wire

$$R = R_0(1 + aT + bT^2)$$



CamScanner CS

*Fixed and easily obtainable temperature (fixed point) – Such two fixed points are : Ice point 0°c
Steam point 100°C (Celcius Scale)

273.15k [Thermodynamic scale] Absolute temp.

– Point where ice, liquid water and steam co-exist in equilibrium 273.15k and 4.58mmHg

Celcius Temperature Scale:

– Has two fixed point and is divided into 100 equal parts

– If X is the chosen temp measuring quantity; thermometric property then ~~T~~ θ_x on celcius scale corresponding to X_θ is given by

$$\theta_x = \frac{X_\theta - X_0}{X_{100} - X_0} \times 100°C$$

$X_\theta \Rightarrow$ Temp measuring property at θ
$X_0 \Rightarrow$ Thermometric property at 0°C

Example

The length of mercury in a mercury glass thermometer is 5cm and 25cm when placed in pure ice and steam respectively. If its length is 16cm, what is the corresponding temp?

$$\theta_x = \frac{X_\theta - X_0}{X_{100} - X_0} \times 100 = \frac{16-5}{25-5} \times 100$$

$$= 55°C$$

CamScanner CS

Thermodynamic Temperature Scale.

- Based on triple point of water; when ice, liquid water co-exist.
- Measured in K
- The scale is independent of the property of any substances used in the thermometer
- Suppose X is the temp measuring quantity then unknown temp T will be;

$$T = \frac{X_T}{X_{tr}} \times 273.15\,K$$

$X_T \Rightarrow$ Thermometric property at unknown

$X_{tr} \Rightarrow$ Thermometric property at triple point

For pressure:

$$T = \frac{P_T}{P_{tr}} \times 273.15\,k$$

Example:

Using the constant volume gas thermometer the gas pressure of 40cm of mercury is measured at the triple point of water. If the pressure is 65cmHg at unknown temperature T of the thermodynamic scale, calculate T

$$T = \frac{P_T}{P_{tr}} \times 273.15$$

$$= \frac{65}{40} \times 273.15$$

$$= 443.87K$$

$$c = \frac{Q}{m\Delta T}.$$

CamScanner CS

Factors Considered When Choosing a thermometer

(i) Range of the thermometer
(ii) Availability
(iii) Time of Response.
(iv) Accuracy
(v) Cost
(vi) Ruggedness of the thermometer – should not be disturbed by environment of working.

Heat Energy (J).

1 Joule → Work done when a force of 1N move a distance 1m in the direction of force

Production of heat measured depend on:

* Mass of substance
* Quantity of heat supplied

Heat Capacity; C

Is the amount of energy required to raise the temp of a body/material by 1K

- The S.I unit is Joules per Kelvin. (JK^{-1})

Specific Heat capacity; (c)

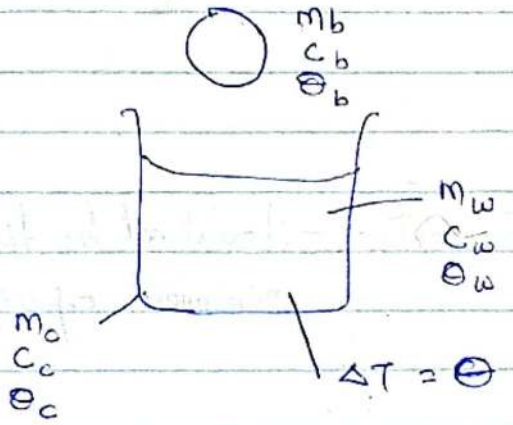
- Is the amount of energy required to raise the temp of 1Kg of substance by 1K
- The S.I unit is Joules per Kilogram per Kelvin ($J/Kg/K$)
- If a body of mass m, specific heat capacity c and Q joules of heat cause temperature rise of Q then

$$Q = mc\Delta T$$

Kirchhoff's law of Thermal Radiation; for a body of any arbitrary material emitting and absorbing thermal electromagnetic radiation at every wavelength in thermodynamic equilibrium, the ratio of its emissive power to its dimensionless coefficient of absorption is equal to a universal function only of radiative wavelength & temp.

Law of Mixture:

states; The total heat lost is equal to the total heat gained



For an arbitrary body emitting or absorbing thermal radiation, in thermodynamic equilibrium, the emmisivity is equal to absorptivity.

Heat lost = Heat gained

$$m_b c_b (\theta_b - \theta) = m_w c_w (\theta - \theta_w) + m_c c_c (\theta - \theta_c)$$

Heat - Is the amount of energy flowing from one body to another spontaneously due to their temp. difference.

Heat Transfer

- Thermal energy is the total internal energy of an object

(Thermal energy) $U = k.e + p.e$

- Thermal equilibrium occur only when 2 bodies are at same temp.
- Occur through:
  - * Conduction
  - * Convection
  - * Radiation

Energy flow per second (J/s) => Watts (Power)

Conduction

- Mode of heat transfer in solid
- Energy is transferred by molecular collision and movement of free electrons from higher to ~~low temp.~~ lower temperature.

Flow of heat $\frac{dQ}{dt} \propto \frac{A \Delta T}{\Delta L}$

Power $\rightarrow P_{ij} = \frac{\Delta T}{R_{ij}}$ (Temp. Change) $\rightarrow$ Resistance to heat loss.

$$\frac{dQ}{dt} = \frac{kA(T_1 - T_2)}{L}$$

k ⇒ Thermoconductivity of the material / Nature of material

$$k = \frac{dQ \times L}{dt \times A(T_1 - T_2)} = \frac{J\,m}{s\,m^2\,\Theta \rightarrow K}$$

$$= J\,s^{-1}\,m^{-1}\,\Theta^{-1} \rightarrow K$$

$$= W\,m^{-1}\,\Theta^{-1} \rightarrow K$$

$$= W\,m^{-1}\,K^{-1}$$

$Wm^{-1}K^{-1}$ is also called <u>Fourier equation</u>

~~Conduction~~

Convection

- Is the process in which heat is transferred by actual mass motion of particle

q – ~~Heat flux~~ Heat Rate (W)

dT – ΔT – Temperature change.

$q \propto A\,dT$

- The heat ~~flask~~ flux is in W/m^2 But $\frac{q}{A}$ = Heat flux

$$q = hA\,dT$$

where h – constant for convective heat transfer

$$h = \frac{q}{A\,dT} = \frac{W}{m^2\,K} \qquad h = W\,m^{-2}\,K^{-1}$$

$$q = hA(T_s - T_\infty)$$

T_s – Temperature ~~of service~~ surface

T_∞ – Temperature of (silk) where temp / heat change occur.

CamScanner CS

Wilhelm Wien displacement law; The black-body radiation curve for different temperature will peak at different wavelengths that are inversely proportional to temp.

Assignment:

Hot air at 80°C is blown over 2m X 4m surface at 30°C. If the average conventional heat transfer co-efficient is 55 $kJm^{-2}°C^{-1}$ rise. Determine the rate of heat transfer from air to plate.

Applications of Convections

* Cooling in motor car radiator
* Ventilation
* Sea and Land Breeze
* Refrigiration

Radiations:

- Is mode of heat transfer in a vacuum (Don't require material medium)
- The rate at which heat is radiated from a body at absolute Temperature T is given by Stephanie Boltzman equation:

$$\frac{P}{A} \propto T^4 \qquad P \propto T^4 A \qquad P = \sigma T^4 A$$

For Black Body

P - Radiant Power
A - Surface Area.
T - Absolute Temp.

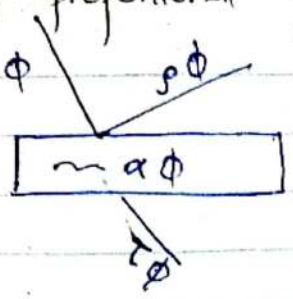
Rate of power radiation is proportional to fourth power of absolute temperature and Area.

$$\sigma = 5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$$

$$\sigma = \frac{P}{T^4 A} = \frac{W}{K^4 m^2} = Wm^{-2}K^{-4}$$

CamScanner CS

Stefan Boltzman Law; state the total energy radiated per unit surface area of a black body across all wavelength per unit time is directly proportional to the fourth power of the black body's absolute Thermodynamic temp.



Real Surface

$$\phi = \rho\phi + \alpha\phi + \tau\phi$$

$$\phi = \phi(\rho + \alpha + \tau)$$

$$1 = \rho + \alpha + \tau$$

$$0 \leq \rho, \alpha, \tau \leq 1$$

$\boxed{\alpha \doteq e \text{ for black body}}$

$P_r = e\sigma A T^4$ Where e - emmisivity of the surface

- Heat radiation only warm a body if it falls directly on the body.
- Bodies radiate heat only if their temp is higher than their sorrounding.
- If the body and its environment are at same temp. then the two bodies radiate heat at the same rate But: Wont have final similar heat quantity (depends on Area)

For Surface exchanging heat

then

$$\frac{P}{A} = e\sigma\left(T_s^4 - T_{sur}^4\right)$$

T_s - Temperature of source
T_{sur} - Temperature on surface

Assignment:

Consider a person whose exposed surface area is $1.7m^2$ and the emmisivity is 0.5 and the surface temp is 32°C. Determine the rate of heat loss from the person by radiation in a large room/ enclosure having walls at a temp of

(a) 300K
(b) 280K

c) ⇒ Comment on the results

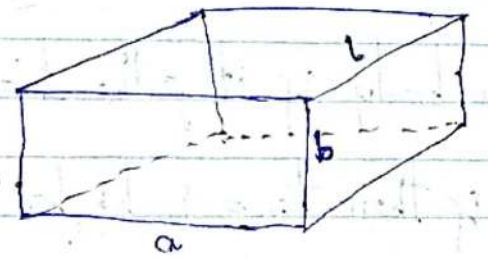
CamScanner CS

Application of Radiation

- Vacuum flask ⇒.

Effect of Heat on Solid Material.

- Consider rectangular slub of ~~with a, he~~ width a, length l and height b.
- On heating it expand in all direction which differs with different material



Co-efficient of Linear Expansivity α.

- The expansion of a rod is directly proportional to the original length and to the temperature change.

If a rod of length l_0 at 0°C and length l_t at T°C then;

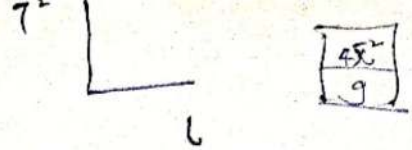
$$l_t - l_0 \propto l_0 \Delta T$$

$$l_t - l_0 = \alpha l_0 \Delta T$$

$$\alpha = \frac{l_t - l_0}{l_0 \Delta T} = \frac{\text{Increase in length}}{\text{Original length} \times \text{Temp rise}}$$

$$\alpha = \frac{\cancel{m}}{\cancel{m}\ °C} = \underline{\underline{°C^{-1}}}$$

CamScanner CS



Application of Linear Expansivity

* Thermostat
* Bimetallic strip

$\beta = 3\alpha$

β – Volume expansivity
α – linear expansivity

Conditions for $\beta = 3\alpha$

→ Material Must be homogenious
→ " " be Isoprotic/ Property must be the same in all directions

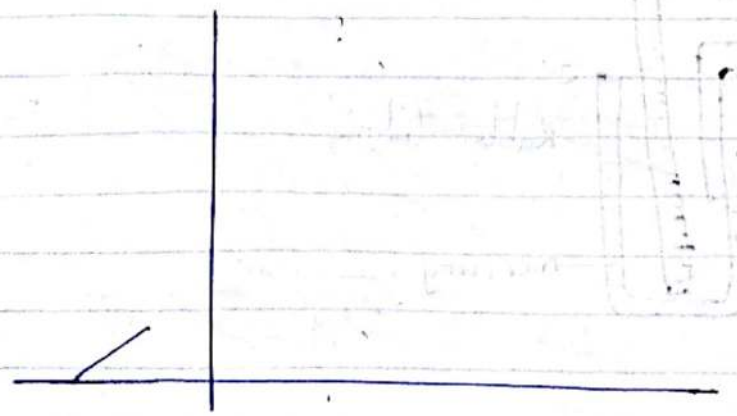
Change of State

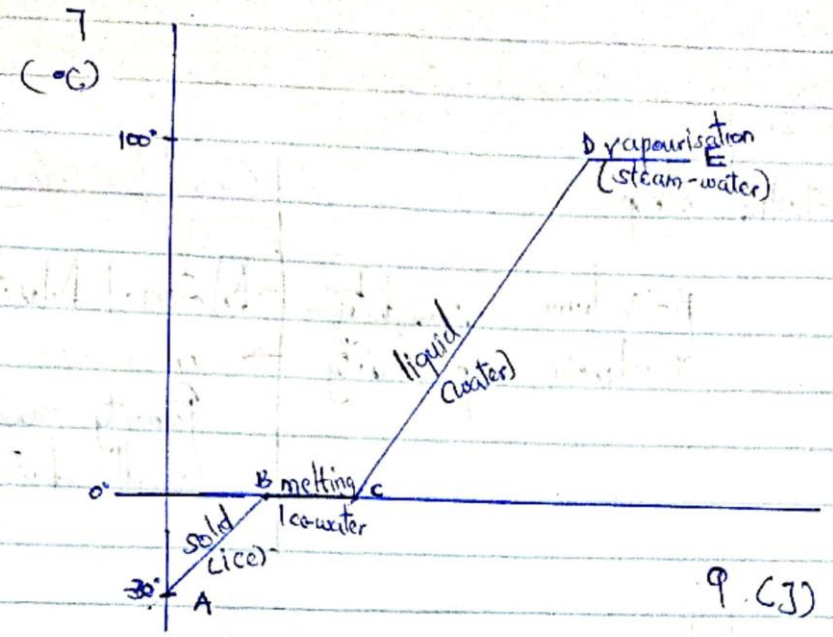
- Latent heat ⇒ latent → hidden
- Latent heat of fusion is the amount of heat required to change a unit mass of a substance to liquid at the same temp.
- Its S.I. unit is Joules per Kilogram (JKg^{-1})

- Latent heat of vaporisation is the amount of heat required to change a unit mass of a liquid to gaseous state at the same temp.

- Latent heat of vaporisation is very high; having an order of $2.3\ MJKg^{-1}$ and for fusion is $2.1\ kJKg^{-1}$

Given a pure ice at $-30°C$; Vaporised completely; Draw a graph of T against Q and explain all the happenings at each state:





At AB ; The temp increases with increase in heat supplied

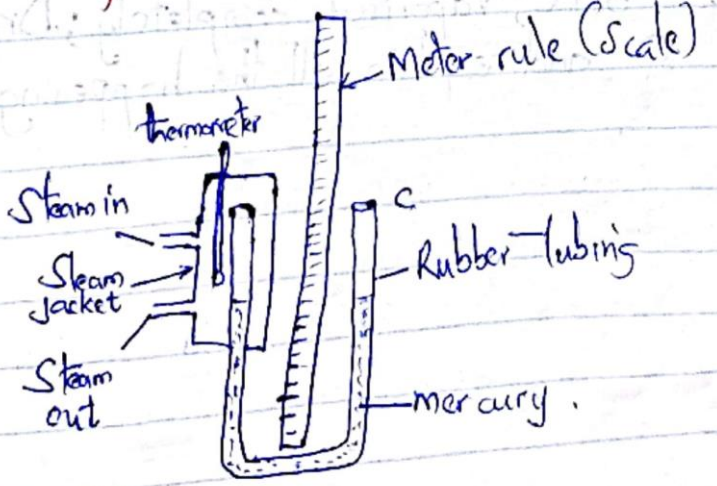
BC ; Temp remain constant as ice changes to liquid.

CD ; Temp increases with increase in heat supplied

DE ; Temp remain constant as water changes to steam.

Expansion of Gases

Expansion of Gas at constant Pressure



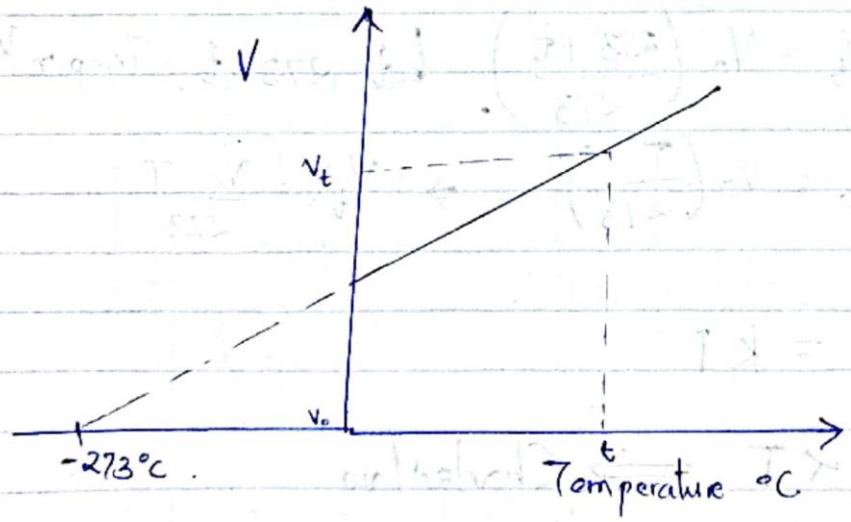
Let steam into the steam jacket, the temp rises as recorded by the thermometer upto 100°c. As a result the volume increases and the level in the manometer differs/changes. The level is kept constant on both sides ~~and~~ by tilting/varying/adjusting the manometer to ensure the level are the same on both sides. The value of height h and temp. is recorded.

The steam is let out and the gas at the bulb cools and the height and temperature recorded after some specific duration. The height/level of mercury is kept constant on both sides of manometer.

- The table is ~~at~~ as;

temp	t_1	t_2	t_3
height	h_1	h_2	h_3
Volume	Ah_1	Ah_2	Ah_3

The graph is as below:



From $\beta_p = \dfrac{\text{Increase in Volume}}{\text{Volume at 0} \times \Delta\text{Temperature}} \Rightarrow \beta_p = \dfrac{V_t - V_o}{V_o t}$

$$V_t = B_p V_o t + V_o$$

$$y = mx + c$$

Gradient $= \beta_p V_o = \dfrac{dV}{dT}$. But from -273°c to 0°c then,

Gradient $= \frac{dv}{dt} = \beta_p V_0 = \frac{V_0}{273}$

$$\beta_p = \frac{1}{273}$$

Charles Law in Brief:

1. The Volume of a mass of a given gas increases by $1/273$ of its volume at $0°C$ per every $°C$ rise.

Substituting $\beta_p = 1/273$ in $V_t = \beta_p V_0 t + V_0$

then $V_t = V_0 (1 + \beta_p t)$

$$V_t = V_0 \left(1 + \frac{1}{273} t\right)$$

$$V_t = V_0 \left(\frac{273 + t}{273}\right).$$ but $273 + t$ = Temp in Kelvin.

$$V_t = V_0 \left(\frac{T}{273}\right) \Rightarrow V_t = \frac{V_0}{273} T$$

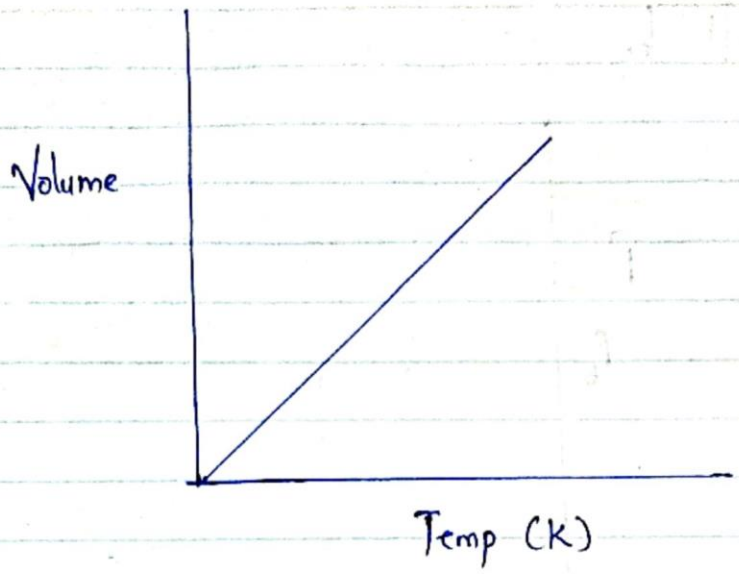
$$V = kT$$

$V \propto T \Longrightarrow$ Charles' law

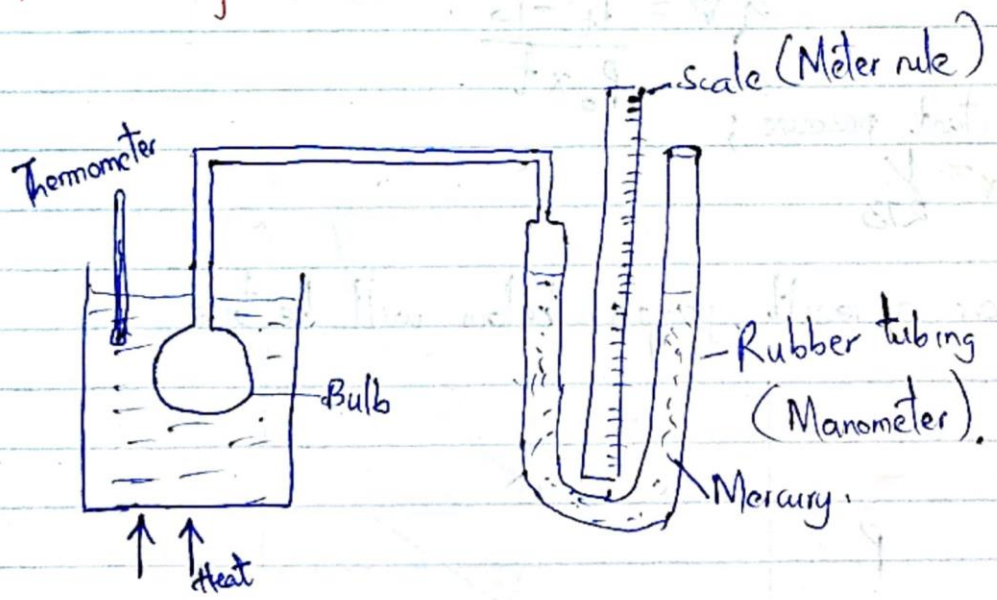
2. The volume of a given mass of gas is directly proportional to the absolute temperature provide pressure is kept constant.

$$\frac{V_1}{T_1} = \text{Costant} \qquad \frac{V_1}{T_1} = \frac{V_2}{T_2} = \frac{V_3}{T_3} \ldots\ldots$$

CamScanner CS



Pressure Variation ~~Expansion of Gas at~~ Constant Volume.



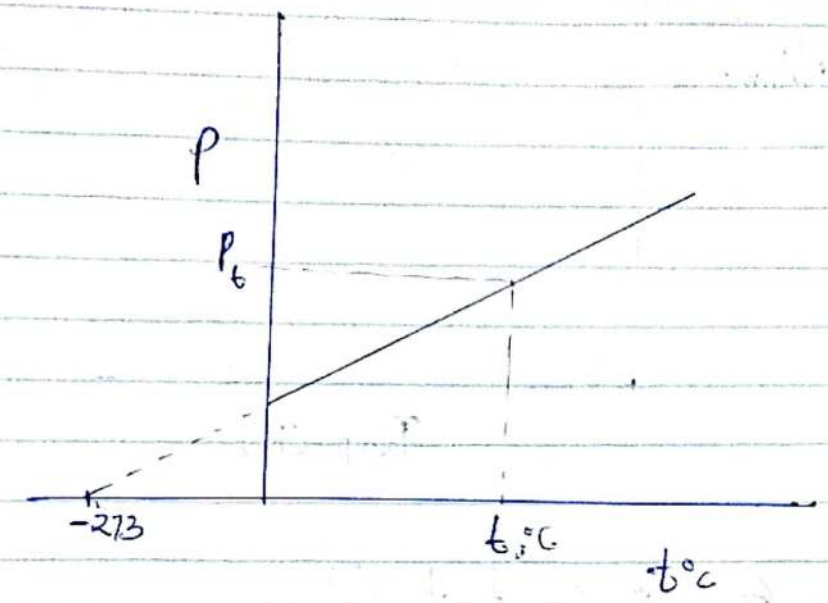
- It is heated in water bath to ensure uniform expansion

Heat, the mercury level increases and differ in the length of the manometer. The manometer is adjusted until the level at the left side goes to the initial level. Height at the Right limb is taken. It is then tabulated

$t°c$	t_1	t_2	
h	h_1	h_1	
P	P_1	P_2	

CamScanner CS

The graph will be

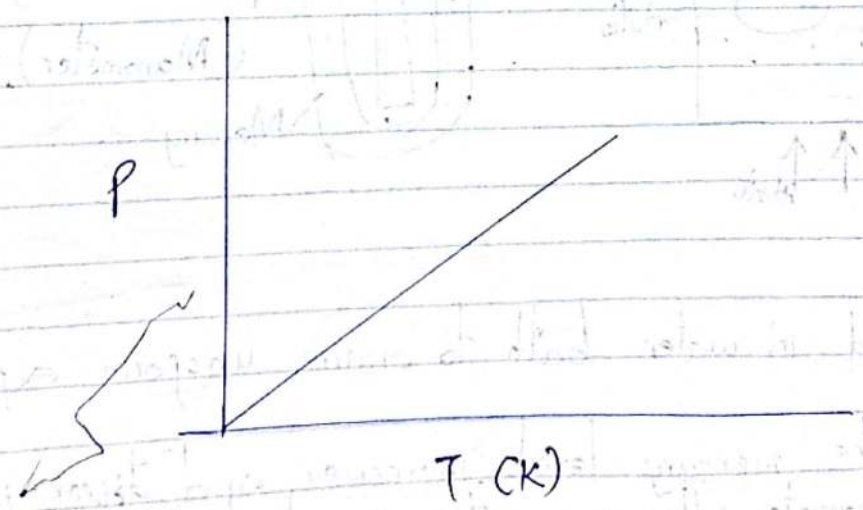


$$\alpha_v = \frac{P_t - P_0}{P_0 \times t}$$

But As for constant pressure ;

$$\alpha_v = \frac{1}{273}$$

thus as a result graph below will be true



thus $P \propto T$ thus $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ for ideal gas

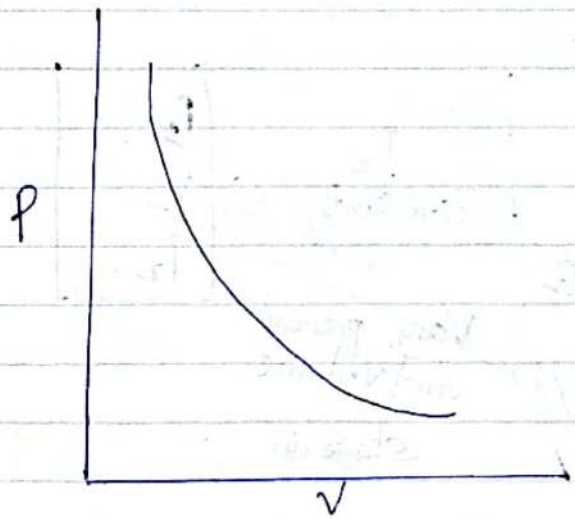
The pressure of a fixed mass of gas is directly proportional to its absolute Temperature at a constant volume; This is called Gay Lussac's Law.

Variation of Pressure and Volume at constant Temp.

Generally;

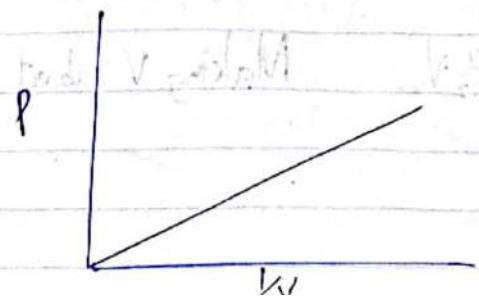
$$P \propto \frac{1}{V}$$

thus Graph of P against V is



- This is <u>Boyle's Law</u> that states Pressure of a given mass of gas is inversely proportional volume at a constant temperature.

thus the Graph of P against $1/V$ is.



$$P \propto 1/V$$

$$P = \frac{k}{V}$$

$$PV = k$$

$$P_1V_1 = P_2V_2$$

CamScanner CS

Combined Gas Law

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \text{thus} \quad \frac{PV}{T} = \text{Constant}$$

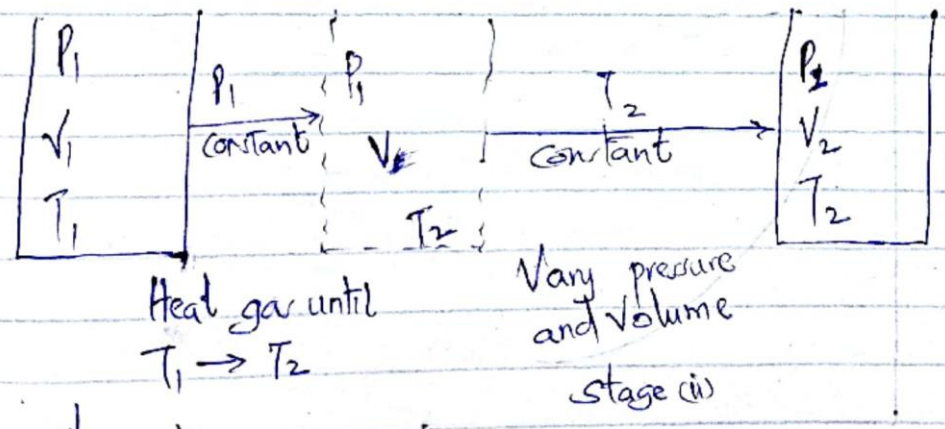
Molar Gas Constant

- Molar Gas Constant gives property of Gases used

$$\frac{PV}{T} = R$$

$$PV = RT$$

Prove that $\frac{PV}{T} = \text{Constant}, R$



stage (i)

Apply Charles' law

$$\frac{V_1}{T_1} = \frac{V}{T_2}$$ Making V subject $V = \frac{V_1 T_2}{T_1}$

stage (ii)

$$P_1V = P_2V_2$$ Making V subject $V = \frac{P_2V_2}{P_1}$

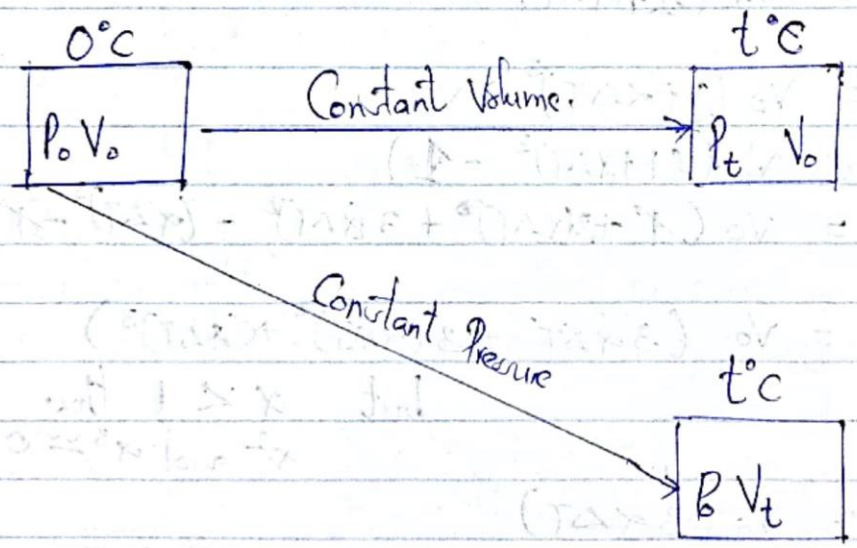
CamScanner CS

Thus $\frac{V_1 T_2}{T_1} = \frac{P_2 V_2}{P_1}$

$$\frac{P_1 V_1 \cancel{T_2}}{T_1 \cancel{T_2}} = \frac{P_2 V_2 \cancel{T_1}}{\cancel{T_1} T_2}$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

this implies that $\frac{PV}{T} = \text{Constant}$.



$P_t V_0$

$P_0 V_t$

Prove Boyle's Law

$P_t V_0 = P_0 V_t$

$$\frac{P_t}{P_0} = \frac{V_t}{V_0}$$

From Charle's law

$V_t = V_0 (1 + \alpha_p t)$

$\frac{V_t}{V_0} = (1 + \alpha_p t)$.

From :

$P_t = P_0 (1 + \alpha_t t)$

$\frac{P_t}{P_0} = (1 + \alpha_v t)$.

$$\alpha_t = \alpha_v$$

CamScanner CS

Show that Volume expansivity is thrice linear expansivity

If length l_0 width w_0 and height h_0 are initial dimension of ~~cot~~ cuboid then

$$V_0 = l_0 w_0 h_0$$

New Volume after expansion

$$V = l_0(1+\alpha\Delta T)\, w_0(1+\alpha\Delta T)\, h_0(1+\alpha\Delta T)$$

$$V = l_0 w_0 h_0 (1+\alpha\Delta T)^3$$

$$V = V_0 (1+\alpha\Delta T)^3$$

$$\Delta V = V_0(1+\alpha\Delta T)^3 - V_0$$

$$\Delta V = V_0\left((1+\alpha\Delta T)^3 - 1\right)$$

$$\Delta V = V_0\left(\cancel{1} + 3(\alpha\Delta T) + 3(\alpha\Delta T)^2 + (\alpha\Delta T)^3 - \cancel{1}\right)$$

$$\Delta V = V_0\left(3\alpha\Delta T + 3(\alpha\Delta T)^2 + (\alpha\Delta T)^3\right)$$

but $\alpha < 1$ thus α^2 and $\alpha^3 \simeq 0$.

$$\Delta V = V_0(3\alpha\Delta T)$$

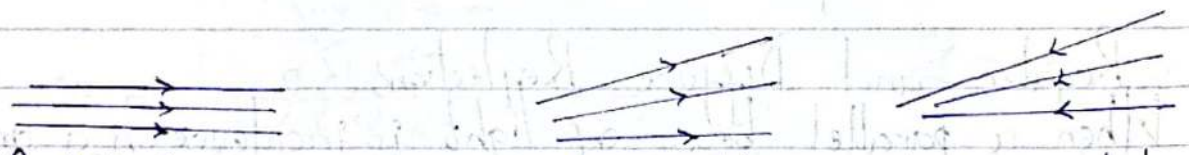
$$\underline{\underline{3\alpha = \beta}}$$

OPTICS

* Reflection at plane surfaces
* Dispersion spectra
* Optical Instrument
* Photometry
* Refraction through prisms
* Refraction through lenses.
* Velocity of Light

Reference; Nelkon and Parker, Advanced Level Physics.
Halliday & Rasnick, Physics Part I & II
Sears and Zemansky, University Physics.

- Light is a form of energy
- A ray of light is the direction along which the light energy travels
- A ray of light is represented by a straight line with an arrow indicating the direction of the ray.
- A beam of light is a collection of rays
- A beam is represented by several rays as shown below:

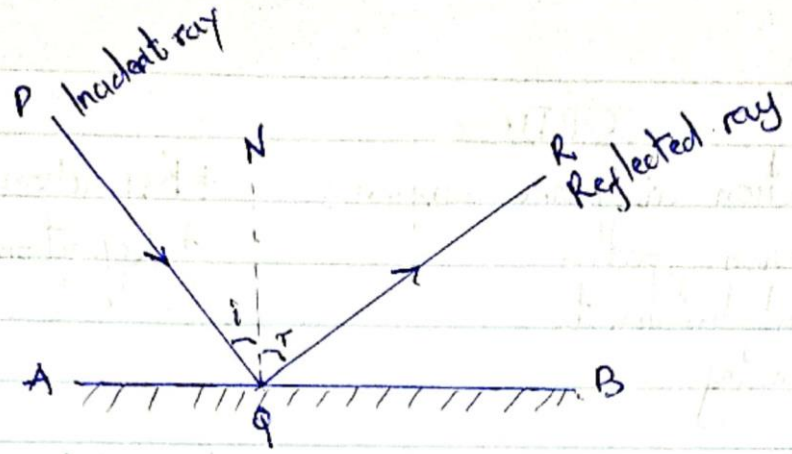


Parallel beam Divergent beam Convergent beam.

Reflection of Light at Plane Surfaces.

a) Laws of Reflection:

- Consider a ray of light PQ incident at point Q on a plane mirror AB as shown below:



NQ – Normal

The angle PQN which the incident ray makes with normal is called angle of incidence and the angle RQN which the reflected ray makes with normal is called angle of reflection

Experiment shows that;

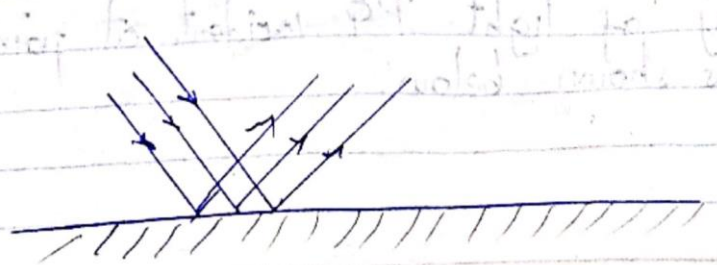
(i) The incidence ray, reflected ray and the normal at the point of incidence all lie in the same plane.

(ii) The angle of incidence is equal to the angle of reflection

Regular and Diffuse Reflection;

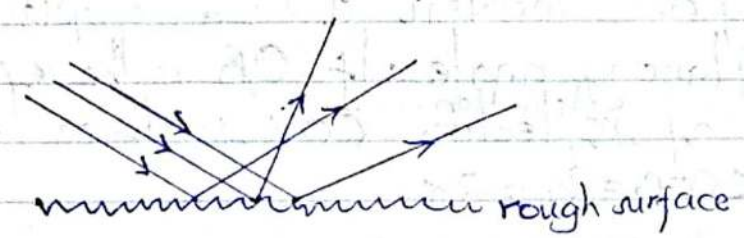
When a parallel beam of light is incidence on a smooth surface such as a plane mirror, it is reflected as a parallel beam.

This kind of reflection is called regular reflection/ Specular reflection



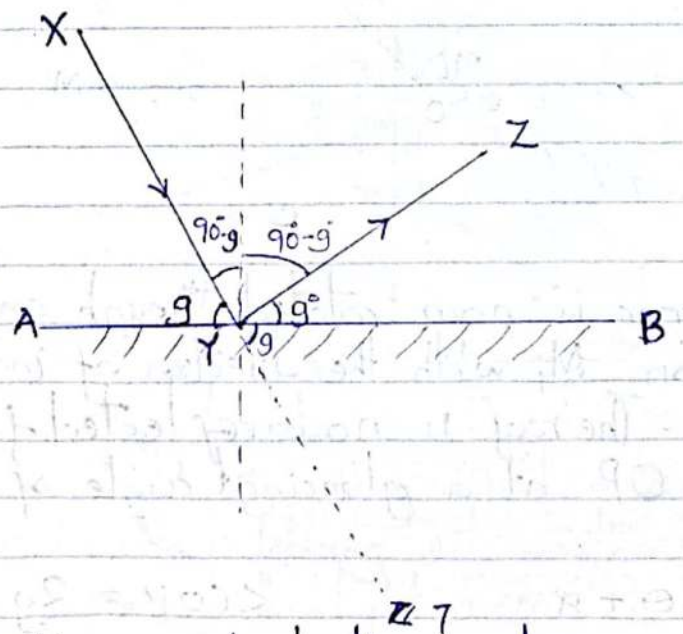
CamScanner CS

- If a parallel beam of light is incidence on a rough surface such as paper, the light rays reflected are not parallel but are in different direction. This is called diffused reflection



c) Deviation of light by a plane mirror

- Consider a ray of light XY incident at point Y on a plane mirror AB



$\angle ZYT = 2g$

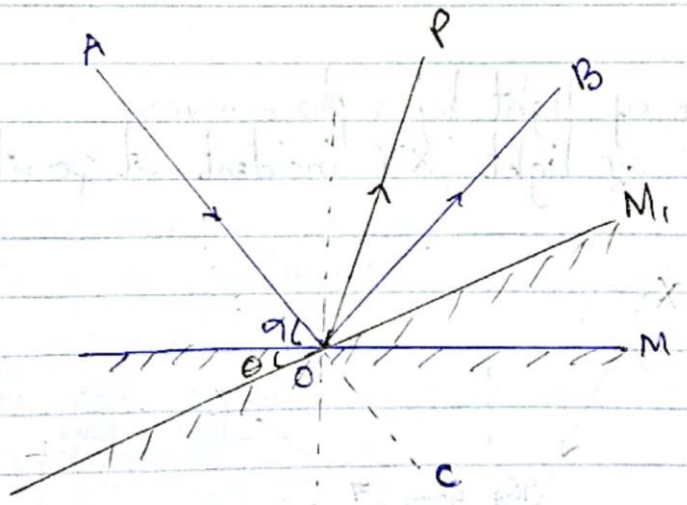
- The angle AYX ~~are~~ which the incidence ray makes with the mirror is known as the glancing angle (g)
- The incidence light has been deviated from direction XY to direction YZ. The angle of deviation is $ZYT = 2g$

The angle of deviation by a plane mirror is twice the glancing angle (g)

d) Deviation of reflected ray by rotated mirror.

Consider a ray AO incident at O on a plane mirror M α being the glancing angle. If OB is the reflected ray then the angle of ~~reflection~~ deviation COB is twice α

$$\angle COB = 2g = 2\alpha$$



- Suppose the mirror is now rotated through angle θ to another position M_1 with the direction of incident ray being constant. The ray is now reflected from M_1 in the direction OP at a glancing angle of M_1

$$g = \theta + \alpha \qquad \angle COP = 2g$$

$$\angle COP = 2(\theta + \alpha)$$

The reflected ray has thus been rotated through an angle

$$BOP = \angle COP - \angle COB$$

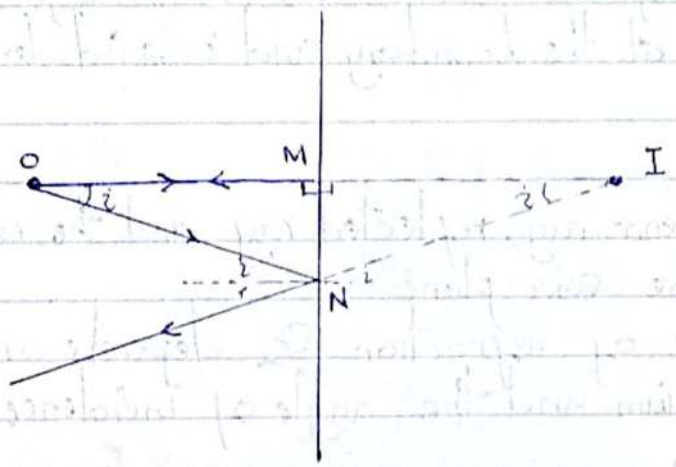
$$= 2(\alpha + \theta) - 2\alpha \quad = 2\theta$$

CamScanner CS

- In conclusion, if the direction of an incident ray is constant, the angle of rotation of the reflected ray is twice the angle of rotation of mirror.
- This concept is applied in;

(e) Image Formation by a Plane Mirror. (Assignment)

- Show geometrically that the image formed by a plane mirror is as far ~~ma~~ much behind the mirror as the object is infront of it.



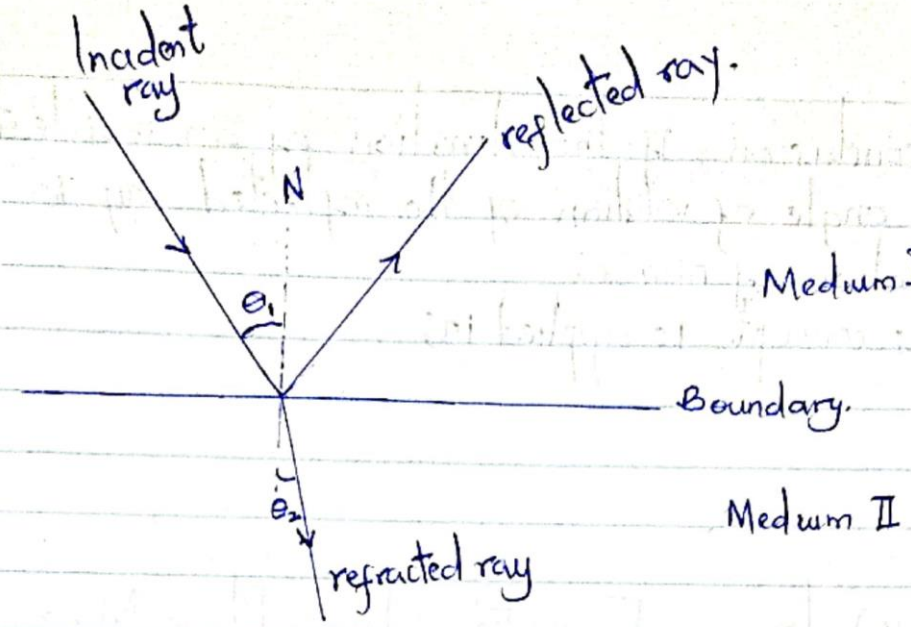
$\triangle OMN \cong IMN$

$OM = MI$

Refraction of light

- When a ray of light travelling through a transparent medium encounters a boundary leading into another transparent medium as shown below; part of the light energy is reflected and part enters the second medium.

CamScanner CS



θ_1 - angle of incidence
θ_2 - angle of refraction

The ray entering the second medium changes its direction of propagation at the boundary and is said to be ~~refraction~~ refracted;

- The incidence ray, reflected ray and the refracted ray all lie on the same plane
- The angle of refraction θ_2 depends on the properties of the two medium and the angle of incidence θ_1 through the relationship

$$\frac{\sin\theta_2}{\sin\theta_1} = \frac{V_1}{V_2} \quad \ldots (1)$$

Where;
V_1 - Velocity of light in 1st medium
V_2 - Velocity of light in Medium II

From equation 1 it can be inferred that when light moves from a material in which its velocity is high to a material in which its velocity is lower, the angle of refraction θ_2 is less than angle of incidence θ_1 and the ray is bent towards normal.

CamScanner CS

- Conversely; if the ray moves from a material in which light moves slowly to a material in which light moves faster then the ray is bent away from the normal.

Index of refraction η (μ) eta

- The refractive index of a transparent material is defined as the ratio;

$$\mu = \frac{\text{Velocity of light in Vacuum}}{\text{Velocity of light in medium}} = \frac{c}{v} \quad \mu = \frac{c}{v}$$

- As light moves from one medium to another, its frequency f does not change but its wavelength λ changes; From;

$$v = \lambda f \qquad v_1 = \lambda_1 f_1 \qquad v_2 = \lambda_2 f_2$$

But $f_1 = f_2 = f$

$$v_1 = \lambda_1 f \qquad v_2 = \lambda_2 f \quad \ldots (2)$$

But since $v_1 \neq v_2$ $\lambda_1 \neq \lambda_2$

$$\frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} \qquad v_1 = \frac{c}{\mu_1} \quad v_2 = \frac{c}{\mu_2}$$

$$\frac{v_1}{v_2} = \frac{c/\mu_1}{c/\mu_2} = \frac{\mu_2}{\mu_1}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{\mu_2}{\mu_1}$$

~~Replace~~ From equation (i). $\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_2}{v_1} = \frac{\mu_2}{\mu_1}$

CamScanner CS

$\mu_1 \sin\theta_1 = \mu_2 \sin\theta_2$

Snells law of refraction

~~$n_1 \sin\theta_1 = n_2 \sin\theta_2$~~

Snell's Law.

The incident ray, the refractive ray and the normal at the point of incidence all lie in the same plane

The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant

$$\frac{\sin i}{\sin r} = \text{Constant}$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1} = n$$ (refractive index of the two medium)

Example:

A light ray of wavelength 589 nm travelling through air is incident on a smooth slump of crown glass of refractive index $\mu = 1.52$ at 30° to the normal.

a) Find the angle of refraction

b) Find the speed of light in glass

$$\frac{\sin\theta_1}{\sin\theta_2} = \mu$$

$\theta_1 = 30°$ $\mu_2 = 1.52$

$\theta_2 = r$

$1.00 \sin 30 = 1.52 \sin \theta_2$

$$\sin \theta_2 = \frac{\sin 30}{1.52} = 0.3289$$

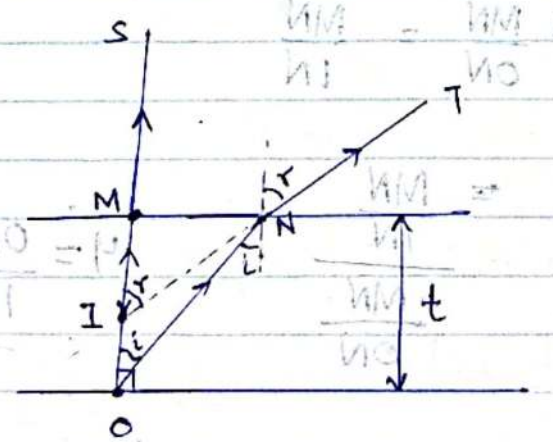
$$\theta_2 = r = \sin^{-1}(0.3289) = 19.2^\circ$$

$$\mu = \frac{c}{v} = v = \frac{c}{\mu} = \frac{3.0 \times 10^8}{1.52}$$

$$= \underline{\underline{1.973 \times 10^8 \, m/s}}$$

Apparent Depth

- An object placed a distance below the surface of water/glass appear closer to surface than actually it is.
- Consider an object O at a distance below the surface of a medium such as of water which has refractive index as μ



- A ray OM from O perpendicular to the surface passes through into the air along MS. A ray ON, very close to OM is refracted at N into the air away from the normal in a direction NT and an observe viewing the object O directly overhead sees it in a position I which is the point of intersection of SM and TM produced.
- Suppose that the angle of incidence in glass is 'i' and angle of refraction in air is r,

By snell's law;

$$\mu_1 \sin i = \mu_2 \sin r$$

$\mu_2 = 1$ (air)
$\mu_1 =$ refractive index of glass.

$$n \sin i = \sin r \quad \text{---} \; (1)$$

Since $i = NOM$ and $R = NIM$ then; $\sin i = \frac{MN}{ON}$

$$\sin r = \frac{MN}{IN}$$

From equation (1)

$$n \sin i = \sin r$$

$$n \frac{MN}{ON} = \frac{MN}{IN}$$

$$\mu = \frac{\frac{MN}{IN}}{\frac{MN}{ON}} \qquad \mu = \frac{ON}{IN}$$

- Rays ON and IN are very close to the normal and hence to a good approximation;

$$ON = OM \text{ and } IN = IM$$

$$\mu = \frac{ON}{IN} = \frac{OM}{IM}$$

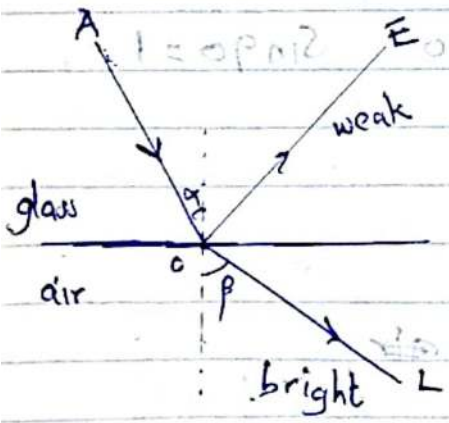
CamScanner CS

$$n = \frac{OM}{IM}$$ Where OM = Real depth
IM = Apparent depth

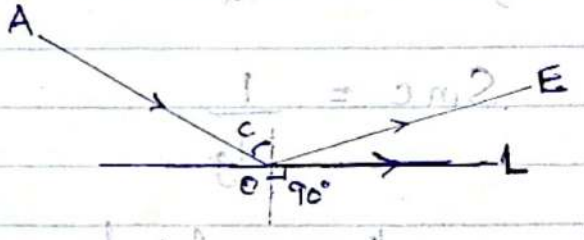
Total Internal Reflection and the Critical Angle

- If a ray AO in glass is incident at a small angle α on a glass air plane boundary, observation shows that part of the incident light is ~~refracted~~ reflected along ~~OM~~ OE while the remainder of line is refracted away from the normal at an angle β in the air.

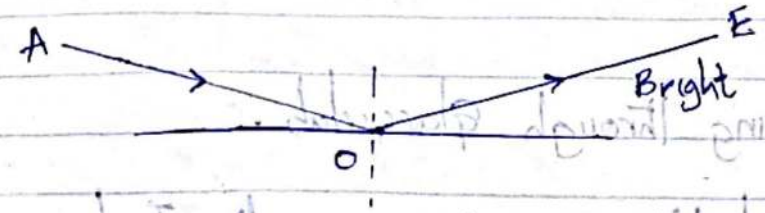
- The reflected ray OE is weak and the refracted ray ON is bright



(a)



(b) Critical angle



(c) Total Internal Reflection

When the angle of incidence α is increased, the angle of emergence β also increases

At some angle of incidence c in the glass, the refracted ray OL travels along the glass air boundary, making the angle of refraction 90° (figure b)

As the angle of incidence in the glass is increased, no refracted ray is observed by the reflected ray becomes bright (figure c)

Since all the incidence ~~re~~ ray energy is now reflected total internal reflection is said to take place in glass at point O.

When the angle of refraction in air is 90°, the angle of incidence is called the critical angle for air and glass.

$$\mu_g \sin c = \mu_a \sin 90^\circ \qquad \mu_a = 1.00 \qquad \sin 90 = 1$$

$$\sin c = \frac{1}{\mu_g}$$

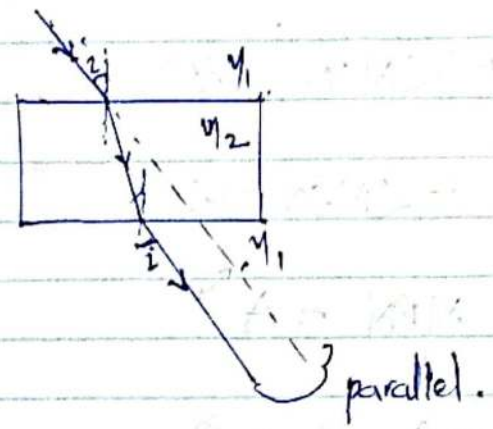
Determine the critical angles for ~~air~~
(a) Air glass boundary
(b) Water glass boundary

If the refractive index of water is 1.33 and glass is 1.51

2. Light passing through glass slab.

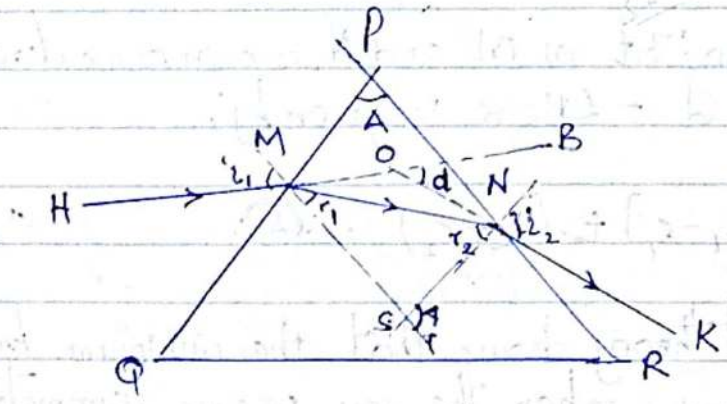
A beam of light passes from medium I to medium II. Medium II being a thick glass slab of refractive inde μ_2. Show

that the beam ~~imaging~~ emerging from medium II is parallel to the incident beam.



Refraction through Prism.

- A prism is a transparent object made of glass and has two plane surfaces inclined at an angle to each other.
- The angle between the inclined surfaces is called angle of prism/ Prism angle or Refracting angle A



- Consider a ray HM incident in air on a prism of refracting angle A and suppose the ray lies in the prism section PQR
- If i_1, r_1 and i_2, r_2 are the angle of incidence and refraction at M and N as shown and μ is the refractive index of the prism then;

$$\sin i_1 = \mu \sin r_1 \quad \text{---} (1)$$
$$\sin i_2 = \mu \sin r_2 \quad \text{---} (2)$$

Further as MS and NS (Normal) are normals to PM and N repectively then angle MPN + Angle MSN = 180

$$\angle MPN + \angle MSN = 180^\circ$$

But $\angle NST + \angle MSN = 180^\circ$ therefore;

$$\angle NST = MPN = A$$

therefore $r_1 + r_2 = A$ ... (3)

because $\angle NST$ is the exterior angle of triangle MSN

- The angle of deviation at M is equals $\angle OMN = i_1 - r_1$

and the angle of deviation at N is equals $\angle MNO = i_2 - r_2$

Since the deviations at M and N are in same direction, the total deviation $d = \angle BOK$ is given by;

$$d = (i_1 - r_1) + (i_2 - r_2) \quad \ldots (4)$$

- Experiments and theory show that the minimum device deviation, D, of light occurs when the ray passes symmetrically through the prism.

Angle of incidence i_1 = Angle of emergence i_2

The ray HMNK in this case passes symmetrically through prism.

- By equation (4)

$$D = (i_1 - r) + (i - r) \quad (5) = 2i - 2r$$

CamScanner CS

$r + r = A$ .... (6)

$r = \frac{A}{2}$ Substitute in equation 5

$D = 2i - 2r$

$D = 2i - 2\left(\frac{A}{2}\right)$

$D = 2i - A$ thus $i = \frac{A+D}{2}$

therefore $\eta = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

Example:

A glass prism of angle 72° and index of refraction 1.66 is emersed in a liquid of refractive index 1.33. What is the angle of minimum deviation for a parallel beam of light passing through the prism.

$A = 72°$ $\eta = \frac{1.66}{1.33}$ $D = ?$

$\eta = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)} \Rightarrow \frac{1.66}{1.33} = \frac{\sin\left(\frac{72+D}{2}\right)}{\sin \frac{72}{2}} \times 1$

$\sin 36 \times \frac{1.66}{1.33} = \sin\left(\frac{72+D}{2}\right)$

$0.733627 = \sin \frac{72+D}{2}$

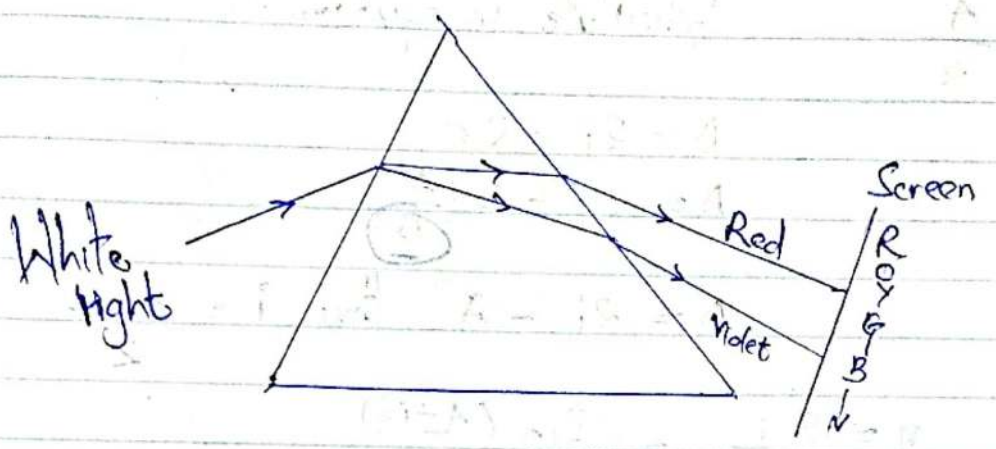
$\frac{72+D}{2} = 47.19°$

$72° + D = 94.38°$

$D = 22.38°$

CamScanner CS

Dispersion Spectra



- Supposed white light is incident on a glass prism as shown above, the rays that emerge spreads out in a series of colours called the spectrum of visible light.
- This separation of white light into its component colours is called dispersion
- The difference between the angle of deviation of two component colours is a measure of the dispersion of these colours
- The red rays are the least deviated by the prism and the violet rays are deviated the most. thus a prism decomposes/separate white light into its ~~ontino~~ constituent colours which are the colours of the rainbow.

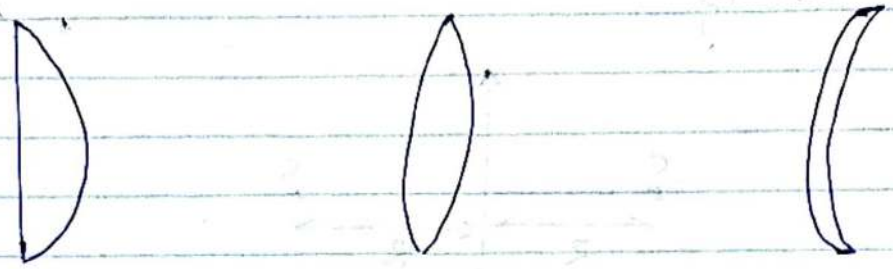
Refraction through Thin Lenses.

- A lense is a piece of glass or other material bounded by one or two spherical surfaces and used to direct or control the rays of light.
- is more compared to its focal length is called thin lense
- When a lense is thicker in the middle than at the edges it is called converging/convex lens.

CamScanner CS

- It refracts incident parallel rays so that they converge on a focal point located on the opposite side of the lense.

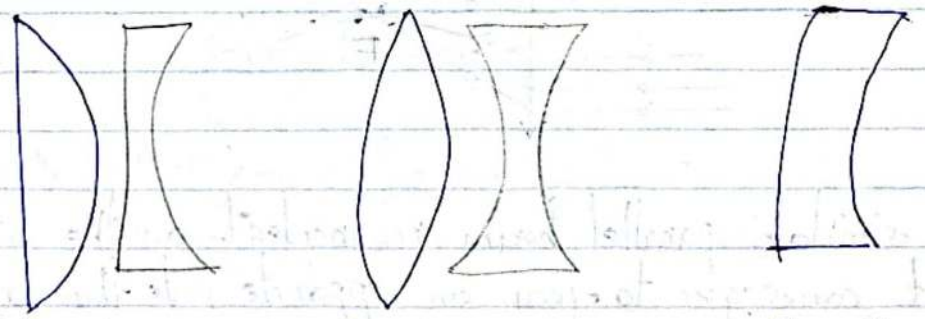
example



Plano convex lens Biconvex lens Convex meniscus

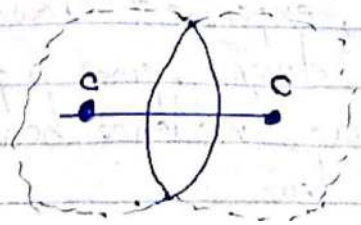
- When a lense is thinner in the middle than edges it is called a diverging/concave lens.
- It refract incident parallel rays so that they diverge from a focal point located on the incidence side of the lense

Example:



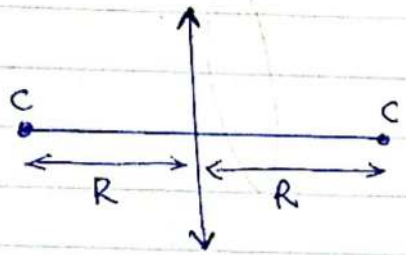
Plano Concave lens Biconcave lens Concave meniscus

- The centre of ~~cur~~ curvature of a lens is the centre of a circle to which the lens is a part of.

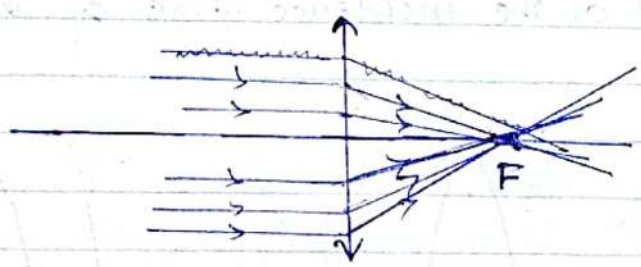


CamScanner CS

Principal axis is the line joining the centres of curvature of the two surfaces and passing through the centre of the lens.
Radius of curvature is the radius of a circle to which the lens is part of



Principal Focus experiments shows that a thin convex lens brings an incident parallel beams of rays to a principal focus or focal point on the other side of lens thus a convex lens is called a converging lens.



- If a similar parallel beam is incident on the other side of lens it converges to focus on opposite side thus a lens has two focal points.

Focal length is the distance from the centre of the lens to focal point.
When a narrow paralle beam close to principal axis is incident on concave lens, experiment shows that a beam is obtained that appear to diverge from a point called principal focus on the same side as incidence beam thus a concave lens is called a diverging lens

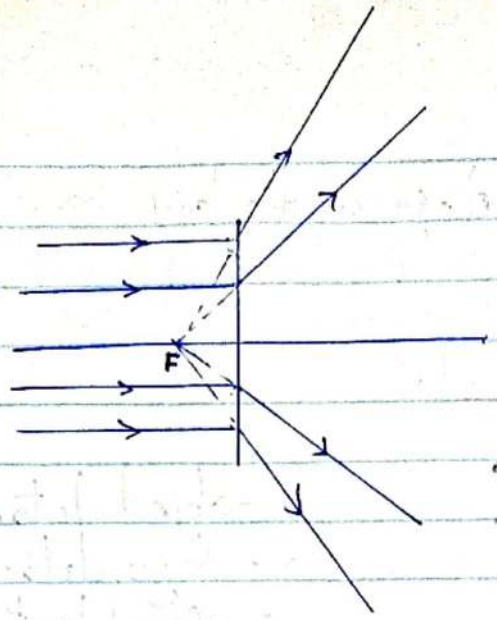


Image Formation By a thin Lens.

- The image formed by a lens can be located in two ways;

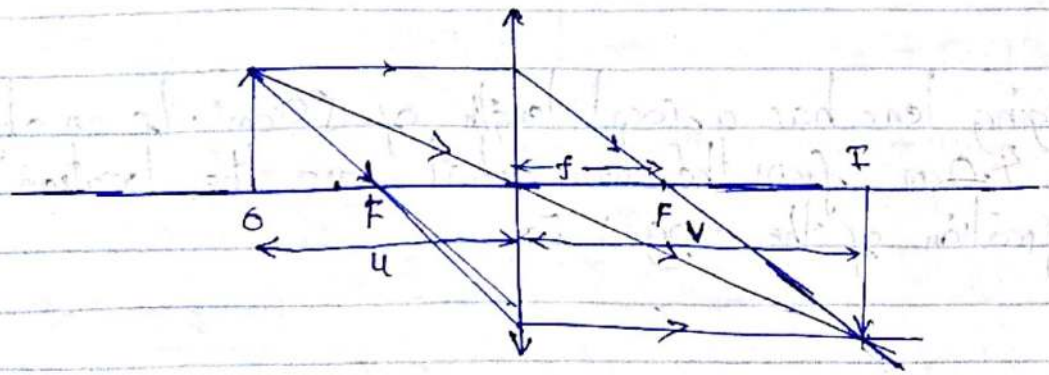
(i) Ray tracing method (ii) Thin lens formular.

a) Ray tracing method

- Three particular rays from a point on object can be used to locate image position when drawn to scale;
  a) A ray of light parallel and close to principal axis of the lens emerges along a line which it crosses the principal axis at the 1st principal focus

  b) A ray that crosses the principal axis at the second principal focus emerges parallel to principal axis

  c) A ray passing through the centre of lens continue undeviated



CamScanner CS

Assignment (Repeat for concave lens)

b) Thin lens formula

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

u - object distance
v - Image distance
f - focal length

Sign Convention

Includes;

* The sign of a focal length f is positive for a convex lens and negative for concave lens.
* The sign of the object distance u is positive if the object is on the same side of lens as the incidence light and negative if the object is on the other side giving virtual object
* The sign of the image distance v is positive or real if the image is on the side of lens opposite incidence ray and negative / virtual if the Image is on the same side
* Object and image height are positive if above the principal axis and negative if below.

A diverging lens has a focal length of 50cm. If an object is held 4.0cm from the lens, what are the location and magnification of the image.

CamScanner CS

Lensmaker's Equation

- Is a mathematical ~~expe~~ expression relating the shape of lens, its index of refraction and its focal length.
- It is stated as;

$$\frac{1}{f} = \left(\frac{n_2 - n_1}{n_1}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

where R_1 and R_2 are radii of curvature of the first and second surfaces respectively.

- The radius is positive if the surface encountered by light ray is convex and negative if it is concave.

Example

2. What is the focal length of a double convex lens made from glass with a refractive index $n = 1.52$ and radius of curvature $0.35m$

(I).

$f = -50\,cm$

$u = +4.0\,cm$

from:

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

$$v = \frac{fu}{u-f}$$

$$= \frac{(-50)(+4.0)}{4-(-50)}$$

$$\cancel{v = +3.87cm}$$

$$v = \underline{-3.7cm}$$

negative v - means image is virtual.

$$\text{magnification} = -\frac{v}{u} \Rightarrow -\left(\frac{-3.7cm}{4.0}\right)$$

$$= +0.93$$

+ve magnification → Image is upright

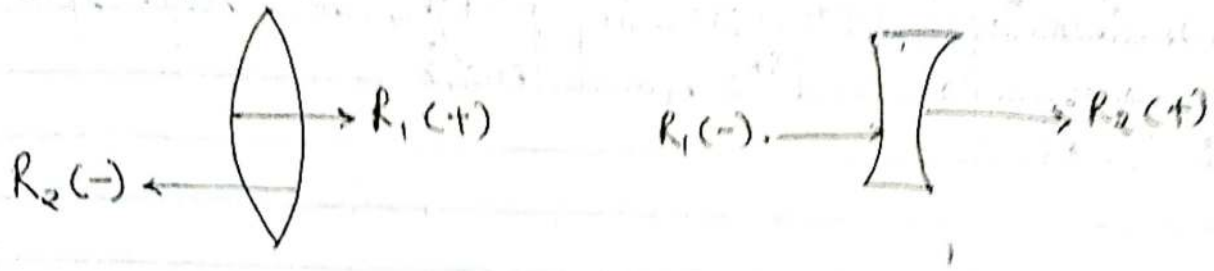
$m < 1$ → Image is diminished.

Nature of Image

Virtual, Upright & Diminished.

CamScanner CS

(2) $n = 1.52$ $R_1 = 35cm$



$$\frac{1}{f} = \left(\frac{n_2 - n_1}{n_1}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right).$$

+ve for convex lens
-ve for concave lens

$$\frac{1}{f} = \left(\frac{1.52 - 1}{1}\right)\left(\frac{1}{0.35} - \frac{1}{(-0.35)}\right).$$

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

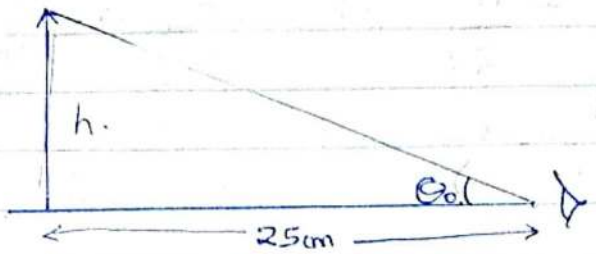
$$f = 0.337m$$

OPTICAL INSTRUMENT

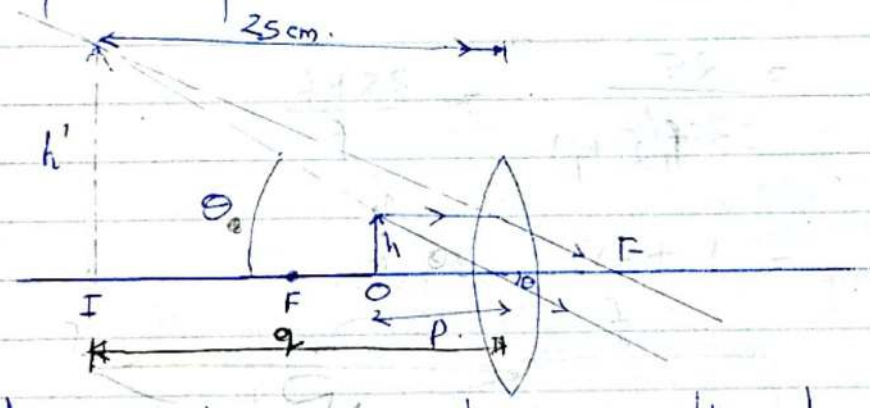
a) Simple ~~Magnify~~ Magnifier

- Is a magnifying glass consisting of a single converging lens
- When an object is placed a distance p from the eye, the size of the image depends on the angle θ

- Angle θ is maximum at about 25 cm from eye.



- A converging lens can be used to increase the apparent angular size of an object by placing the object O at a point inside the focal point of the lens



- We define angular magnification m as the ratio of the angle subtended by an object with a lens in use θ to the angle subtended by object placed at near point with no lens use.

$$m = \frac{\theta}{\theta_0} \quad \text{---} \quad (1).$$

- Angula magnification is at maximum when image distance p is equal to 25cm.

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} \Rightarrow \frac{1}{p} + \frac{1}{(-25)} = \frac{1}{f} \quad \text{or} \quad p = \frac{25f}{25+f}$$

Where f is focal length of lens in centimetres

By small angle approximation:

$$\tan\theta_0 \approx \theta_0 \approx \frac{h}{25} \quad \text{and} \quad \tan\theta \approx \theta \approx h/p \quad \ldots (2)$$

Substituting in equation i

$$m = \frac{\theta}{\theta_0}$$

$$m_{max} = \frac{h/p}{h/25} = \frac{25}{p} \Rightarrow \text{but } p = \frac{25f}{25+f}$$

$$= \frac{25}{25f/(25+f)} = \frac{25+f}{f}$$

$$m_{max} = 1 + \frac{25}{f} \quad \ldots (3)$$

For the image formed by lens to be at infinity, the object has to be at the focal point of lens

$$\theta_0 \approx \frac{h}{25} \quad \text{and} \quad \theta = h/f$$

$$\text{Min Magnification} = \frac{\theta}{\theta_0} = \frac{h/f}{h/25} = \frac{25\,cm}{f} \quad \ldots (4)$$

Example.

What is the maximum and minimum magnification possible with a lens of focal length 10cm

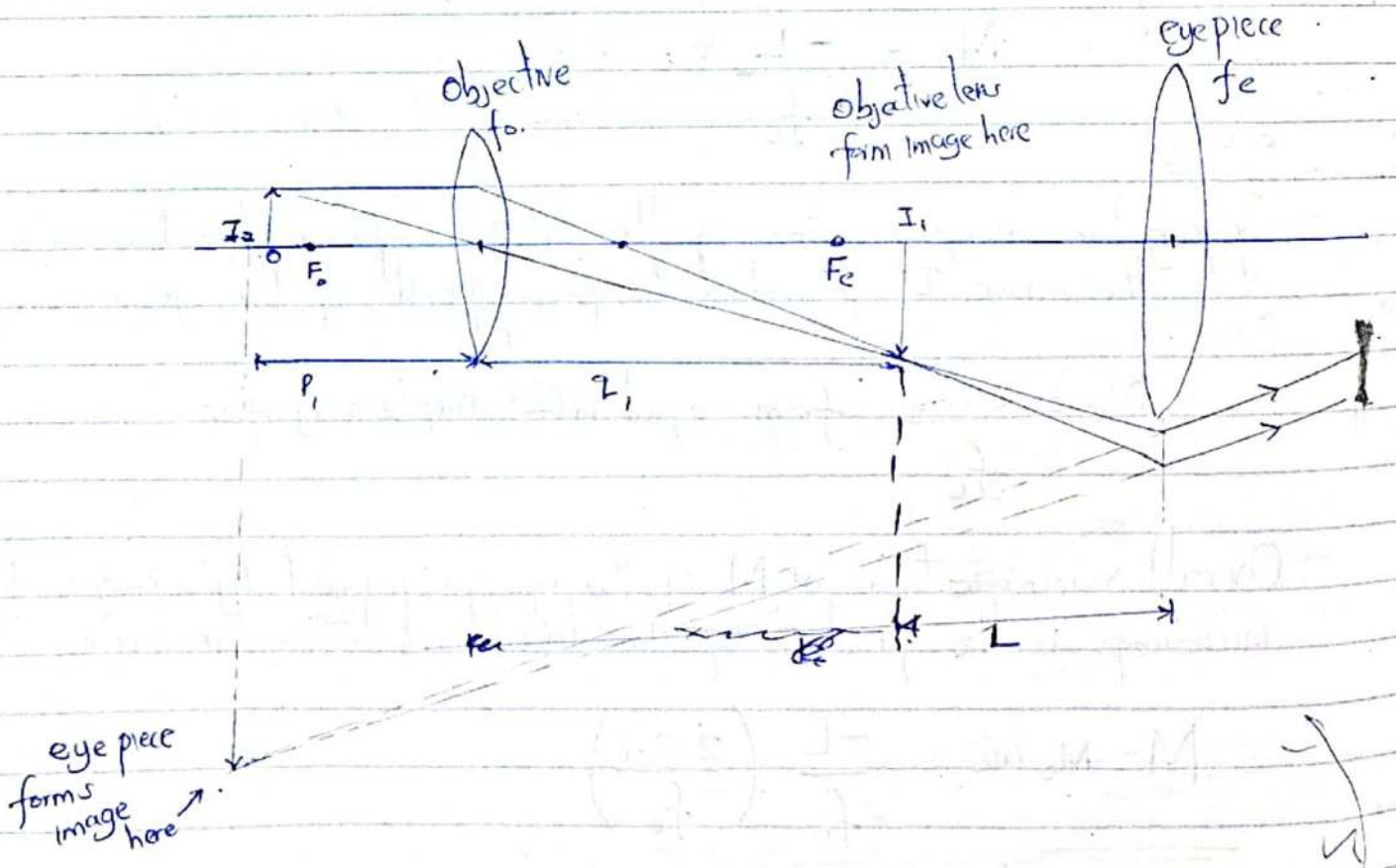
$$m_{max} = 1 + \frac{25}{10} = 3.5 \qquad min = \frac{25}{10} = 2.5$$

2.5 to 3.5

CamScanner CS

b) Compound Microscope.

- Consist of 2 lenses; One lens called Objective lens having a very short focal length f_o and the second called eye piece lens having a larger focal length f_e.
- The two lenses are separated by a distance L that is greater than either f_o or f_e.



- The object O is placed outside focal length of objective and forms a real inverted image at I_1 at or close to the focal point of eye piece

The eyepiece serves as a simple magnifier and produces a large virtual image of I_1 at I_2.
The lateral magnification of the first image is M_o

$$M_o = -\frac{q_1}{p_1}$$

Since q_1 is very close to L and object is very close to the focal point, then;

$$q_1 \approx L$$
$$p_1 \approx f_o$$

therefore

$$M_o = \frac{-L}{f_o}$$

The angular magnification of the eyepiece for an object corresponding to the image I_1 placed at the focal point of the eye piece is

$$m_e = \frac{25cm}{f_e}$$ from equation (4) simple magnifier.

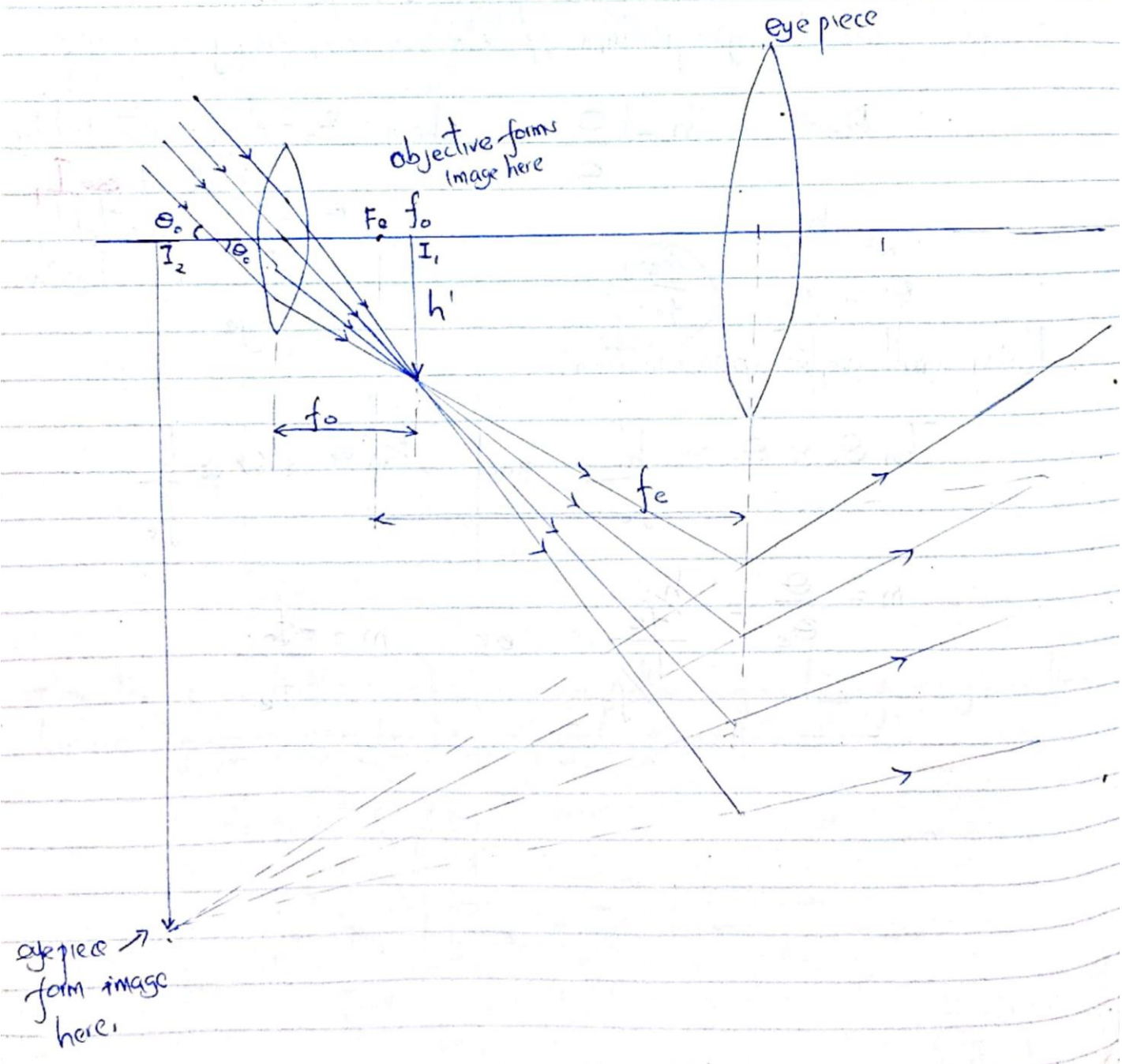
Overall magnification M of the image formed by a compound microscope is the product of the lateral and angular magnification

$$M = M_o m_e = \frac{-L}{f_o}\left(\frac{25cm}{f_e}\right)$$

CamScanner CS

a) Astronomical Telescope. (Refracting Telescope)

- Consist of 2 lenses arranged such that the objective lens forms a real inverted image of a distant object very near the focal point of the eyepiece.



CamScanner CS

- Angular Wave number k
- Angular frequency ω
- Phase angle ϕ

- As the object is at infinity, the image I_1 is at the focal point of objective lens
- The eye piece then forms an enlarged image of I_1 at I_2
- To provide the largest possible magnification, the final image is at infinity and the image due to objective lens must be at the focal point of the eye piece.
- Hence the two lenses are separated by a distance $f_o + f_e$ corresponding to the length of the telescope tube.
- The angular magnification of telescope is given by

$$m = \frac{\theta}{\theta_o}$$

where θ_o - Angle subtended by object at I_1

θ - Angle subtended by final image at viewers eye.

$$\theta_o = h'/f_o$$

$$\theta = h'/f_e$$

$$\frac{f_e}{f_o}$$

Using small angle approximation:

$$\tan\theta_o \approx \theta_o \approx \frac{h'}{f_o} \quad \text{and} \quad \tan\theta \approx \theta \approx \frac{h'}{f_e}$$

$$m = \frac{\theta}{\theta_o} = \frac{h'/f_e}{h'/f_o} \quad \text{or} \quad m = \frac{-f_o}{f_e}$$

CamScanner CS

equation $\Delta y = A \sin(\omega t + kx + \phi)$

$\Delta x = A \cos(\omega t + ky + \phi)$

Normal formular but multiply by 2π radian

where A - Amplitude
ω - Angular frequency
k - Angular wave number
ϕ - Phase angle.

To get $\phi = \sin^{-1}\left(\frac{y(t=0\ x=0)}{A}\right)$ thus equation is for Δy

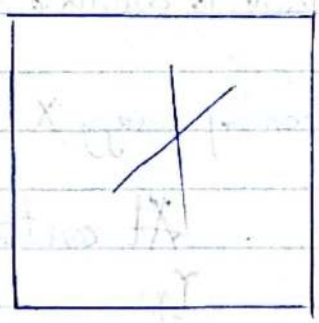
$\phi = \cos^{-1}\left(\frac{x(t=0\ y=0)}{A}\right)$ thus equation is for Δx

Optics

* Geometric (Light as ray/line)
* Physical (Light as wave)
* Quantum (Particle/Photon).

Physics - Study of physical quantities and how they relate

How to Study Physics



Wave

Angular frequency (ω) - number of revolution in radian for a given time
Linear frequency (f) - Number of cycle per unit time

$$\omega = 2\pi f \quad / \quad \frac{2\pi}{T}$$

Phase angle is displacement at $t=0$

from $X = A\cos(\omega t + \phi)$

$\frac{X(t=0)}{A} = \cos\phi \qquad \phi = \cos^{-1}\left(\frac{x(t=0)}{A}\right)$

CamScanner CS

Oscillatory Motion depend on Time
Wave depend on time and position

From $\omega = \frac{\theta}{t}$ $\theta = \omega t$ / Oscillatory

$$X = A\cos(\omega t^c + \phi^c)$$

For Wave

$$Y = A\cos(\omega t + kx + \phi)$$

(displacement)

k - wave number

$k = \frac{2\pi}{\lambda}$ λ - Wavelength

$\omega = \frac{2\pi}{T}$

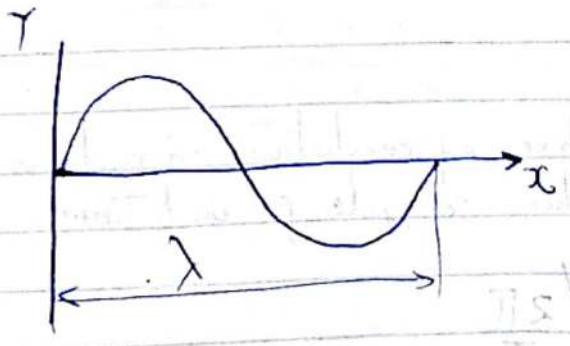
kx - Energy

Wave

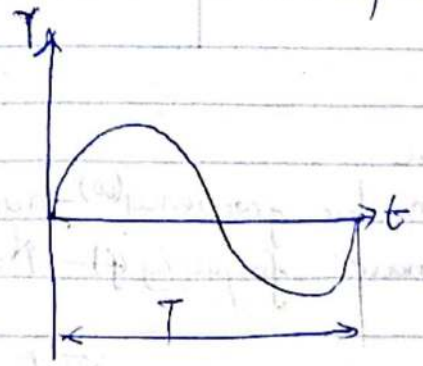
Is a type of motion where energy propagates through a medium and in the process, the medium particles are made to oscillate.

Displacement of wave depend on position of energy X and the Time

At Constant t



At constant x (One particle



CamScanner CS

Features of Waves

Interference

Where ~~one~~ more than 1 displacement acts on a particle

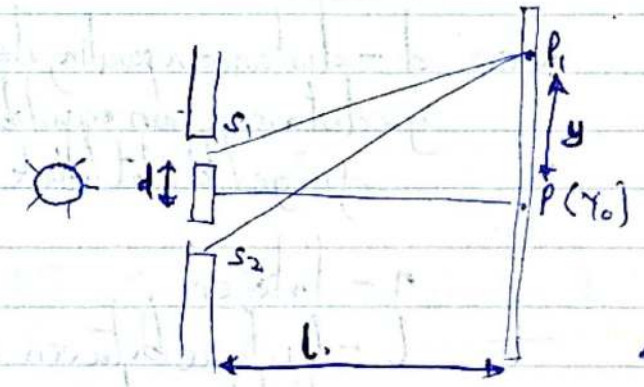
Principle of Interference

The resultant displacement is a vectorsum of individual displacement.

$$Y_r = Y_1 + Y_2$$

$$Y_1 = A \sin(\omega t + kx_1)$$
$$Y_2 = A \sin(\omega t + kx_2)$$

difference is path taken.



Path taken by S_1 to P and S_2 to 2 are same

thus

$$\Delta x = S_2P - S_1P = 0$$

$$S_2P_1 > S_1P_1 \quad \Delta x \neq 0$$

$$Y_R = A' \sin\left(\frac{k}{2}(x_1 + x_2) - \omega t\right)$$

A' - New Amplitude given by

$$A' = 2A \cos\left(\frac{k}{2}\Delta x\right)$$

If $\cos\left(\frac{k}{2}\Delta x\right)$ is 1

$A' = 2A$ (Constructive Interference)

- Resulting Amplitude is double the initial.

CamScanner CS

For $\cos\left(\frac{k}{2}\Delta x\right)$ to be 1 (Constructive Interference)

$$\Delta x = n\lambda$$

$$n = 0, \pm 1, \pm 2, \pm 3$$

For $\cos\left(\frac{k}{2}\Delta x\right)$ to be zero (destructive interference)

$$\Delta x = \left(n + \frac{1}{2}\right)\lambda \qquad n = \text{Integer}$$

$$\lambda = \frac{dy}{nl}$$

where d - distance separating ~~slight~~ slit
y - distance from equilibrium to a fringe / bright / dark
n - Integer
l - Distance between source of light and screen

$$\theta \approx \frac{\lambda}{a}$$

θ - bending
λ - Wavelength
a - Opening size

Polarization
- Defination
- Effects

Quantum Concept

$E \propto F$ F - linear frequency $E = hF$ (For 1 photon)

SI unit J But we eV $1\,eV = 1.6 \times 10^{-19}\,J$

CamScanner CS

Angular Wave Number, k $\frac{2\pi}{\lambda}$

Angular frequency, ω $\frac{2\pi}{T}$ / $2\pi F$

A ~~sinu~~ sinusoidal wave travelling in x direction (positive) has an amplitude of 15.0cm, wavelength 40cm and frequency 8.0 Hz. The vertical displacement of the medium $y(t=0, x=0) = 15cm$. Determine:

a) Angular wave number
b) Periodic Time
c) Angular frequency
d) Phase angle
e) Velocity of wave
f) Equation of wave.

a) $k = \frac{2\pi}{\lambda} = \frac{2\pi}{0.4} = \underline{15.708 \text{ rads/m}}$

b) $T = \frac{1}{f} = \frac{1}{8} = \underline{0.125 \text{ sec}}$

c) $\omega = \frac{2\pi}{T} = \frac{2\pi}{0.125} = \underline{50.265 \text{ rads/second}}$.

d) $y = A \sin(\omega t + kx + \phi)$.

$\phi = \sin^{-1}\left(\frac{y(t=0\ x=0)}{A}\right)$ $\sin^{-1}\left(\frac{15}{15}\right) = \underline{\underline{\pi/2 \text{ radian}}}$.

e) $y = A \sin(\omega t + kx + \phi)$

$y = 0.15 \sin(50.3t + 15.71x + \pi/2)$.

f) $c = \lambda f = \cancel{0.15}\ \frac{40}{100} \times 8 = \underline{\underline{3.2 \text{ m/s}}}$

CamScanner CS

$\sin A + \sin B = 2 \sin \frac{1}{2}(A+B) \cos \frac{1}{2}(A-B)$

Superposition:

- Two waves from slit of equation;

$y_1 = A_1 \sin(kx_1 - \omega t)$ and $y_2 = A_2 \sin(kx_2 - \omega t)$

with d as separating distance of slits and L as distance from slit source to screen

- If two sources are coherent $A_1 = A_2$, $\omega_1 = \omega_2$, $k_1 = k_2$

$$Y_R = Y_1 + Y_2$$

$$= A \sin(kx_1 - \omega t) + A \sin(kx_2 - \omega t)$$

We add if waves move in same direction and vice versa.

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

$$\frac{A+B}{2} = \left(\frac{kx_1 + kx_2}{2} - \omega t\right)$$

$$\frac{A-B}{2} = \frac{kx_1 - kx_2}{2} = k\left(\frac{x_1 - x_2}{2}\right) = \frac{k\Delta x}{2}$$

But $x_1 - x_2 = \Delta x$

$$Y_{result} = 2A \sin\left(\frac{kx_1 + kx_2}{2} - \omega t\right) \cos\left(\frac{k\Delta x}{2}\right)$$

$$Y_R = A' \sin\left(\frac{kx_1 + kx_2}{2} - \omega t\right)$$ where

$$A' = 2A \cos\left(\frac{k\Delta x}{2}\right)$$

CamScanner CS

The amplitude depends on $\cos\left(\frac{k}{2}\Delta x\right)$ or simply Δx (path difference)
path difference $= \delta$

If $\cos\left(\frac{k}{2}\Delta x\right) = 1$ We have maximum amplitude

This occur when; $\left(\frac{k}{2}\Delta x\right) = 0, 2\pi, \pi, 3\pi$ etc.

$$\theta^c = n\pi \quad \text{where } n \in \mathbb{Z}$$

$$\frac{k}{2}\Delta x = n\pi$$

$$\Delta x = \frac{2n\pi}{k}.$$

But $k = \frac{2\pi}{\lambda}$ Substituting $\Delta x = \frac{2n\pi\lambda}{2\pi}$

$$\frac{1}{k} = \frac{\lambda}{2\pi}$$

$$\Delta x = n\lambda \qquad n \in \mathbb{Z}$$

Condition for Constructive Interference
(a) The path difference must be a whole number
Condition for destructive Interference
The $\cos\left(\frac{k}{2}\Delta x\right)$ must be equal to zero

$$\theta^c = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}. \quad \left(n+\frac{1}{2}\right)\pi. \qquad n \in \mathbb{Z}$$

$$\frac{k\Delta x}{2} = \left(n+\frac{1}{2}\right)\pi$$

$$\Delta x = \left(n+\frac{1}{2}\right)\frac{2\pi}{k}$$

$$= \left(n+\frac{1}{2}\right)\lambda \qquad \text{Where } n \text{ is an } \mathbb{Z}$$

CamScanner CS

Conditions for Interference to occur

1. Source of light must be coherent; A, λ, f be equal.
2. Wave must be a monochromatic with single λ

Principle of Superposition

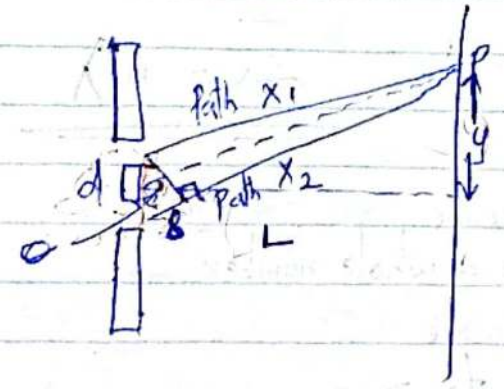
- The resultant wave displacement is the vector sum of the individual displacement from the waves.

Interference of wave

- Is the superpositioning of waves from coherent source.

~~Young~~ Young's Double Slit Experiment

letting the difference in path to be δ $\quad y = n\frac{L\lambda}{d}$



$$\delta = x_2 - x_1 = d\sin\theta$$

$$\delta = d\sin\theta = n\lambda \quad \text{— Bright fringe.}$$

$$\sin\theta = \frac{opp}{hyp} = \frac{y}{L}$$ (Assuming x_1 & x_2 are almost parallel)

For θ too small/almost parallel line;

$$\sin\theta \approx \tan\theta = \frac{Y}{L} \qquad \delta = d\sin\theta = \frac{dY}{L} = n\lambda$$

CamScanner CS

On replacing $\sin\theta = \frac{Y}{L}$

$$\lambda = \frac{dy}{nl}$$ where d - separating distance d
y - Maximum displacement
L - Distance between slit & screen

Example:

a) In a double slit source, the slit separation is 0.2mm and is located 1.2m from a screen; The first bright fringe is formed at 3.3mm from the centre of the screen. Estimate the wavelength of the light and the distance of 3rd order ~~bright~~ dark fringe ~~fringe~~ bright fringe

$$\lambda = \frac{dy}{nl} = \frac{(0.2\times10^{-3})\times(3.3\times10^{-3})}{1\times1.2}$$

$$= 5.5\times10^{-7}\,m \,/\, 550nm.$$

Distance of ~~bright~~ dark fringe:

$$\delta = d\sin\theta = \frac{dY}{L} = (n+\tfrac{1}{2})\lambda \quad 5/2$$

If $n=1$ $\quad \frac{dy}{L} = \frac{3}{2}\lambda$

$$\lambda = \frac{3}{3}\frac{dy}{L} \quad \text{and} \quad y_1 = \frac{3}{2}\frac{L\lambda}{d}$$

Distance between successive ~~bright~~ dark fringes

Considering successive dark fringes for $n=1$ and $n=2$ $\quad y_2 = \frac{5}{2}\frac{L\lambda}{d} \quad y_1 = \frac{3}{2}\frac{L\lambda}{d}$

therefore $\Delta y = y_2 - y_1 = \frac{5}{2}\frac{L\lambda}{d} - \frac{3}{2}\frac{L\lambda}{d}$

$$\Delta y = \frac{L\lambda}{d} = \frac{1.2\times5.5\times10^{-7}}{0.2\times10^{-3}} = _____$$

b) A double slit with a slit separation of 0.2mm is located 1.2m from a screen. The distance between successive bright fringe is 3.3mm. Calculate the wavelength of the light

CamScanner CS

$$\lambda = \frac{d\,\Delta y}{nL} \qquad n = 1$$

$$= \frac{(0.2\times10^{-3})\times(3.3\times10^{-3})}{1.2}$$

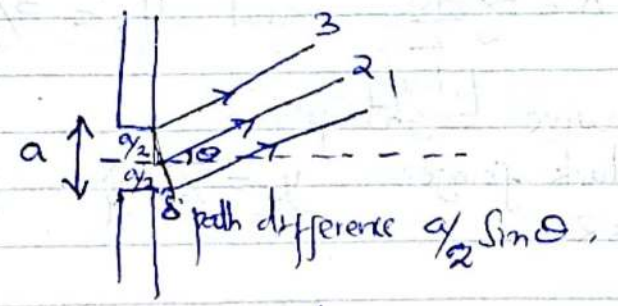
$$= 550\times10^{-9}\ m = \underline{\underline{550\,nm}}$$

Deffraction:

- Is the divergence of light/wave from its initial line of travel.

a) Fraunhofer Diffraction:

- All rays that are passing through a narrow slit are approximately parallel to one another
- This is adhered by placing screen a far distance from opening used to create diffraction. OR. Use of converging lens to focus rays once passed through slit



- All the rays are in phase
- For destructive interference:

$$\Delta x = \frac{n\lambda}{2} = \frac{a}{2}\sin\theta \qquad \sin\theta = \frac{n\lambda}{a}$$

$$\theta = \sin^{-1}\left(\frac{n\lambda}{a}\right)$$

CamScanner CS

Relationship between angle of divergence θ and and wavelength λ and slit opening a.

* $\sin\theta = \frac{\lambda}{a}$ for small θ in radian $\theta \approx \sin\theta$

* $\theta = \frac{\lambda}{a}$ hence $\lambda \propto \theta$ and $\frac{1}{a} \propto \theta$

- The divergence increase with increase in λ and decrease with slit opening.
- The bending θ is too small for large opening and small wavelength.
- Diffraction of sound wave is more pronounced as it's λ is large ~~and~~ compared to light

Example

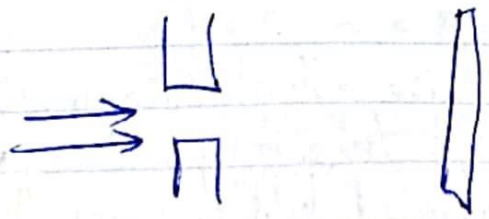
1. Explain why sound waves are easily diffracted compared to visible light

$\theta \approx \frac{\lambda}{a}$ where θ is angle of divergence
λ - wavelength
a - Size of slit opening

2. Explain the effect of increasing the width of a slit to the angle of diffraction

The diffraction pattern reduces with increasing slit size

b) ~~Frest~~ Fresnel



Simple harmonic Motion

Is a special type of periodic motion where restoring force is directly proportional to displacement and acts in opposite direction to that of displacement.

The screen is too near to slit.
The diffraction pattern is more complex

Example.
Differentiate between Fraunhofer diffraction and Fresnel diffraction
Fraunhofer diffraction is ~~conducted~~ conditioned at far distance screen
Fresnel is considered when the screen is near

Discuss any two effects of diffraction

- We cant send a ray of light ove a long ~~dist~~ straight path. It will spread and lower intensity
- We dont have sharp shadow of object even with a point light source
- The headlight of an approaching car appear as

Polarization

- Property of light wave to oscillate with more than one orientation

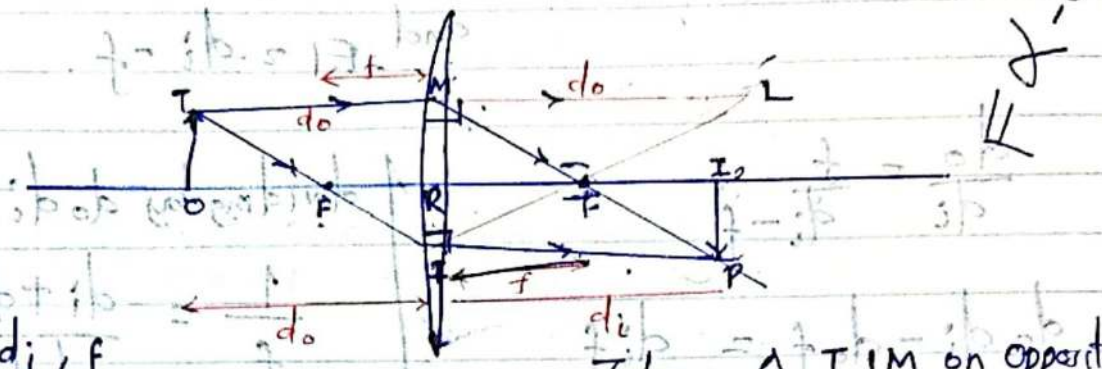
Research

Types of polarization
* Electronic polarization
* Ionic polarization
* Orientation polarization
* Space charge polarization

Application of polarization

The lense in polarized sunglasses have vertical transmission axes to ~~block~~ block light polarized horizontally
In polarized light microscopy plane polarized light is passed through a double refracting material then collected by second polarizing filter to generate high contrast image ie good diagnosis

Relationship between Object Distance, Image distance and Focal length for a mirror



d_o, d_i, f

Taking ΔTIM on opposite side to form ΔIML

$\angle MFL = \angle IFP$ (Vertical opposite angles)

$\angle LIP = \angle ILM$ (Alternate angles on parallel lines).

$\angle IPM = \angle PML$

~~$\angle IML = \angle PIM = 90°$~~

thus triangle MFL and triangle PFI are similar/congruent (AAA congruency)

thus ratio of; d_o, d_i

$$\frac{ML}{IP} = \frac{MF}{FP} \boxed{= \frac{IF}{FL}}$$

thus $\frac{ML}{IP} = \frac{MF}{FP}$.

But triangle MRF is similar to triangle I_2PF (AAA congruency).

since

$\angle RFM = \angle PFI_2$ (Vertically Opposite)

$\angle MRF = \angle PI_2F = 90°$.

$\angle RMF = \angle I_2PF$ (Angle in triangle add upto 180).

(Alternate angle.) thus.

$$\frac{MF}{FP} = \frac{RF}{FI_2}.$$

thus $\frac{ML}{IP} = \frac{MF}{FP} = \frac{RF}{FI_2}$

CamScanner CS

$$\frac{d_o}{d_i} \quad \frac{ML}{IP} = \frac{RF}{FI}$$

but $ML = d_o$ (object distance)
$IP = d_i$ (Image distance)
$RF = f$ (focal length)
and $FI = d_i - f$.

$$\frac{d_o}{d_i} = \frac{f}{d_i - f}$$

$$d_o d_i - d_o f = d_i f$$

$$d_o d_i = d_i f + d_o f$$

$$d_o d_i = f(d_i + d_o)$$

dividing by f

$$\frac{d_o d_i}{f} = \frac{d_i + d_o}{f}$$

dividing by $d_o d_i$

$$\frac{1}{f} = \frac{d_i + d_o}{d_i d_o}$$

$$\frac{1}{f} = \frac{d_i}{d_i d_o} + \frac{d_o}{d_i d_o}$$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

but $d_o = u$, $d_i = v$

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

Stationary Wave - is a wave that oscillate in time but whose peak amplitude profile doe not move in space. resulting from combination of two wave in opposite direction and have same A and f.

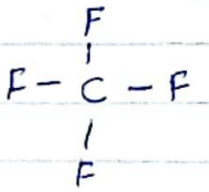
Progressive wave - A wave that continuously travel in a medium in the same direction

$$\frac{RF}{FI} = \frac{RF}{FI}$$

$$\frac{32}{2nd} = 8$$

Difference Btwn Stationary and Progressive Wave.

Progressive Wave	Stationary wave
a) Both energy & momentum move with speed $c = \lambda f$	No net transfer of energy from one point to another
b) Is the same for all particles within a wave (Amplitude).	Amplitude vary from zero at nodes and maximum at antinode
c). All particles oscillate at same frequency	All particles oscillate in same frequency except those at node.
d Equal distance btwn particle at same phase (Wavelength)	Wavelength equals twice distance between adjacent nodes



$CH_3SC_2H_5$ $(CH_3)_2S=O$

$(CH_3)_2CHCH_2CH_3$.

CamScanner CS