B.Sc. PHYSICS

I YEAR – I SEMESTER

COURSE CODE: 7BPHA1

ALLIED COURSE I – PROPERTIES OF MATTER, THERMAL PHYSICS AND OPTICS (THEORY)

Unit I PROPERTIES OF MATTER

Young's modulus – Rigidity modulus – Bulk modulus – Poisson's ratio (definition alone) – Bending of beams – Expression for bending moment – determination of young's modulus – uniform and non-uniform bending.

Expression for Couple per unit twist – work done in twisting a wire – Torsional oscillations of a body– Rigidity modulus of a wire and M.I. of a disc by torsion pendulum.

Unit II VISCOSITY

Viscosity – Viscous force – Co-efficient of viscosity – units and dimensions – Poiseuilles formula for co-efficient of viscosity of a liquid – determination of co-efficient of viscosity using burette and comparison of Viscosities - Bernoulli's theorem – Statement and proof – Venturimeter – Pitot tube.

Unit III CONDUCTION, CONVECTION AND RADIATION

Specific heat capacity of solids and liquids – Dulong and Petit's law – Newton's law of cooling – Specific heat capacity of a liquid by cooling – thermal conduction –coefficient of thermal conductivity by Lee's disc method.

Convention process – Lapse rate – green house effect – Black body radiation – Planck's radiation law – Rayleigh Jean's law, Wien's displacement law – Stefan's law of radiation. (No derivations)

(1) Green house effect (2) Stefan's law (3)

Unit IV THERMODYNAMICS

Zeroth and I Law of thermodynamics – II law of thermodynamics – Carnot's engine and Carnot's cycle – Efficiency of a Carnot's engine – Entropy – Change in entropy in reversible and irreversible process – change in entropy of a perfect gas – change in entropy when ice is converted into steam.

Unit V OPTICS

Interference – conditions for interference maxima and minima – Air wedge – thickness of a thin wire – Newton's rings – determination of wavelength using Newton's rings.

Diffraction – Difference between diffraction and interference – Theory of transmission grating – normal incidence – optical activity – Biot's laws – Specific rotatory power – determination of specific rotatory power using Laurent's half shade polarimeter..

Text Books:

1. Properties of matter – Brijlal and Subramanyam – Eurasia Publishing co., New Delhi, III Edition 1983
2. Element of properties of matter – D.S.Mathur – S.Chand & Company Ltd, New Delhi, 10th Edition 1976
3. Heat and Thermodynamics–Brijlal& Subramanyam, S.Chand & Co, 16th Edition 2005
4. Heat and Thermodynamics – D.S. Mathur, SultanChand & Sons, 5th Edition 2014.
5. Optics and Spectroscopy –R.Murugeshan, S.Chand and co., New Delhi, 6th Edition 2008.
6. A text book of Optics – Subramanyam and Brijlal, S. Chand and co.. New Delhi, 22nd Edition 2004.
7. Optics – Sathyaprakash, Ratan Prakashan Mandhir, New Delhi, VIIth Edition 1990.

♣♣♣♣♣♣♣♣♣♣

Staff Name: S. PRADHEEPA

Signature: S. Pradheepa

PROPERTIES OF MATTER.

Introduction:

Elasticity:

When an external force is applied to a body, The body gets deformed in shape or size.

The property by virtue of which a deformed body tends to regain its original shape and size after the removal of deforming force is called elasticity.

Stress:

Stress is defined as the restoring force per unit area. Suppose a force F is applied normally to the area of cross-section A of a wire.

$$\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{F}{A}.$$

It's dimensions are, $ML^{-1}T^{-2}$

Strain:

When a deforming force is applied, there is a change in length, shape or volume of the body. The ratio of change in dimention to its original value is called the strain.

$$\text{Strain} = \frac{\text{Change in dimension}}{\text{Original dimension}}.$$

Hooke's law:

With in elastic limit, the stress is directly Proportional to strain.

$$\text{Stress} \propto \text{Strain}.$$

$$\frac{\text{Stress}}{\text{strain}} = E \text{ (constant)}.$$

E is a constand called modulus of elasticity.

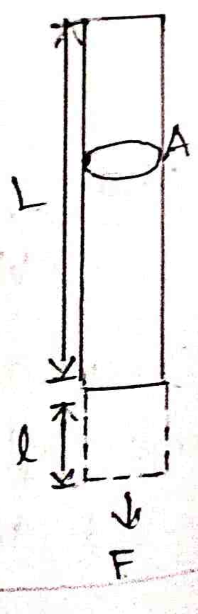
The dimensional formula of modulus of elasticity is $ML^{-1}T^{-2}$ its unit are, Nm^{-2}.

Differrent moduli of Elasticity:

Youngs modulus: (E)

It is defind as the ratio of longitudinal stress to longitudinal strain, with in the Elastic limit.

$$E = \frac{\text{longitudinal stress}}{\text{longidudinal strain}}$$

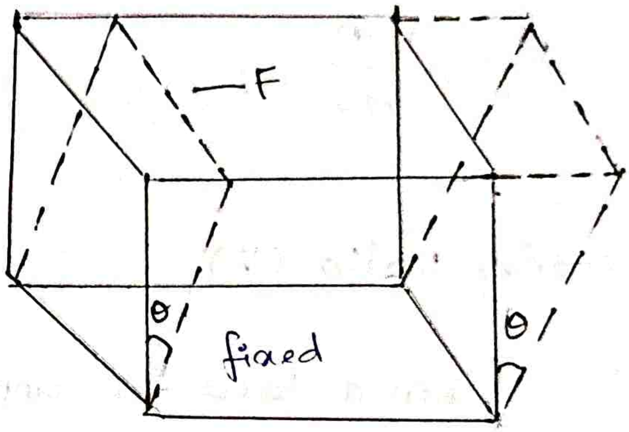


Consider a wire of length L and area of cross section A. It undergoes an increase in length l with a streching force F is applied.

Longitudinal Stress = F/A

Longitudinal Strain = l/L.

$$E = \frac{FL}{Al}.$$



Rigidity modulus : G

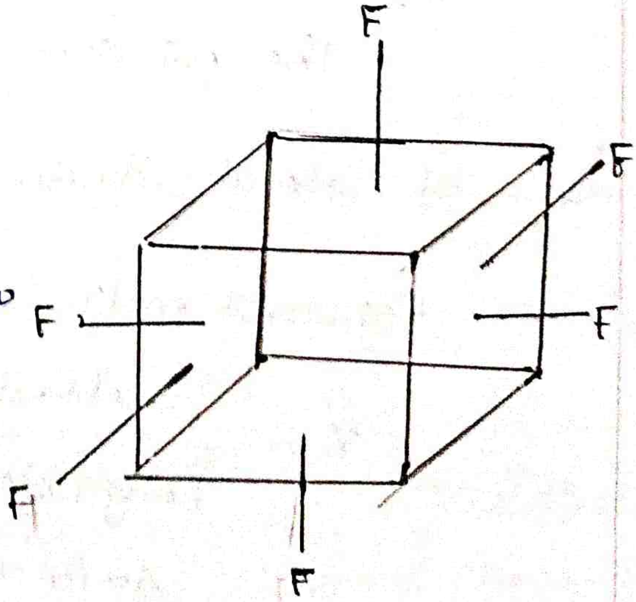
It is defind as the ratio of tangential stress to shearing strain.

$$G = \frac{\text{Tangential stress}}{\text{shearing strain}}.$$

Suppose the lower face of a cube is fixed and a tangential force F is applied at the upper of area A.

Shearing strain = θ ; Tangential Stress = F/A.

$$G = \frac{F/A}{\theta} = \frac{F}{A\theta}.$$



Bulk Modulus : (k)

It is defind as the ratio of volume stress (Bulk stress) to volume strain.

$$k = \frac{\text{Volume stress}}{\text{Volume strain}}.$$

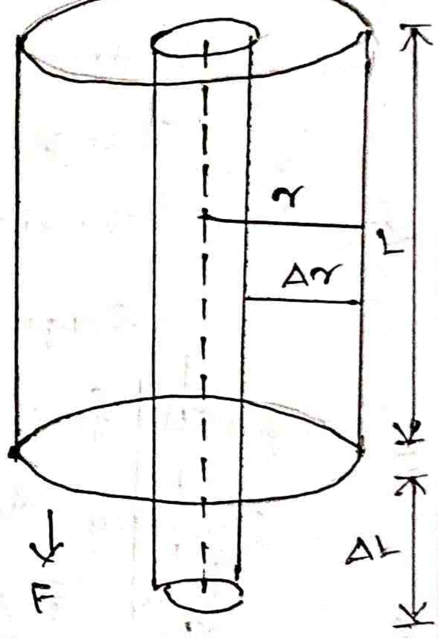
Suppose three equal stresses (F/A) act on a body in mutually perpendicular directions.

There is a change in volume v in its original volume V.

Bulk stress = F/A ; Volume strain = v/V.

$$k = \frac{F/A}{v/V}.$$

Poisson's Ratio (ν)



When a force is applied along the length of wire. The wire elongates along the length but it contracts radily.

$$\text{Longitudinal strain} = \frac{\Delta L}{L}.$$

$$\text{Lateral strain} = \frac{\Delta r}{r}.$$

The poissions ratio (ν) is defined as the ratio of lateral strain to longitudinal strain.

Poisson's ratio (ν) is defined as:

$$\nu = \frac{\text{Lateral strain}}{\text{Longitudinal strain}}.$$

$$= -\frac{\Delta r/r}{\Delta L/L}$$

BENDING OF BEAMS

Definitions:

Beam:

A beam is defined as a rod or bar of uniform cross - section (circular or rectangular) whose length is very much greater than its thickness.

Bending Moment:

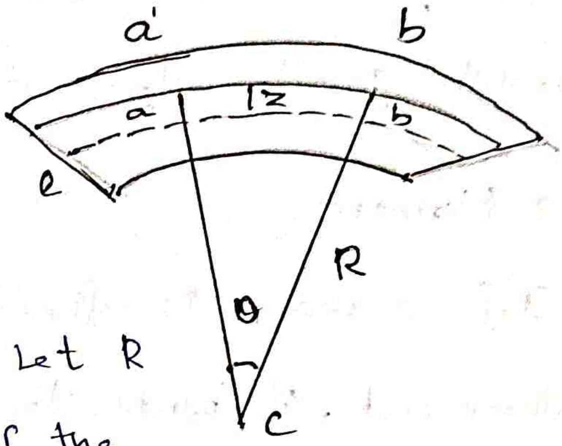
If a beam is fixed at one end and loaded at the other end, it bends the load acting vertically downwards at its free end and the reaction at the support acting vertically upwards, constitude the external bending couple. A restoring couple is developed inside the beam due to its elasticity. The moment of this elastic couple is called the internal bending moment. When the beam is in equilibrium,

Internal bending moment = External bending moment.

Neutral Axis:

When a beam is bent filaments like ab in the upper part of the beam are elongated. Filaments like cd in the lower part are compressed. Therefore there must be a filament like ef in between. Which is neither elongated nor compressed. Such a filament is called the neutral filament. The axis of the beam lying on the neutral filament is the neutral axis. The change in length of any filament is proportional to the distance of the filament from the neutral axis.

Expression for the bending moment:



Consider a portion of the beam to be bent into a circular arc.

ef is the neutral axis. Let R be the radius of curvature of the neutral axis.

θ is the angle subtended by the neutral axis at its centre of curvature c.

Filaments above ef are elongated while filaments below ef are compressed. The filament ef remains unchanged in length.

Let a' b' be a filament at a distance z from the neutral axis. This length of this filament a' b' before bending is equal to that of the corresponding filament on the neutral axis ab equal to that of the corresponding filament on the neutral axis ab.

Original length = ab = $R\theta$.

Its extend length = $a'b'$ = $(R+z)\theta$.

Increase in its length = $a'b' - ab = (R+z)\theta - R\theta = z\theta$

Linear strain = $\frac{\text{Increase in length}}{\text{Original length}} = \frac{z.\theta}{R.\theta} = \frac{z}{R}$.

Young's modulus (E) = $\frac{\text{Stress}}{\text{linear strain}}$

Stress = E × linear strain = E(z/R).

Force acting on the element of area of cross-section δA is,

F = Stress × area $= \frac{Ez}{R}\delta A$.

Moment of this force about the neutral axis.

$= \frac{Ez}{R}\delta A \times z = \frac{E}{R}\delta A . z^2$.

The sum of the moment of forces acting on all the filaments is the internal bending moment.

Internal bending moment $= \Sigma \frac{E}{R}\delta A . z^2 = \frac{E}{R}\Sigma \delta A . z^2$

$\Sigma \delta A z^2$ is called the geometrical moment of inertia.

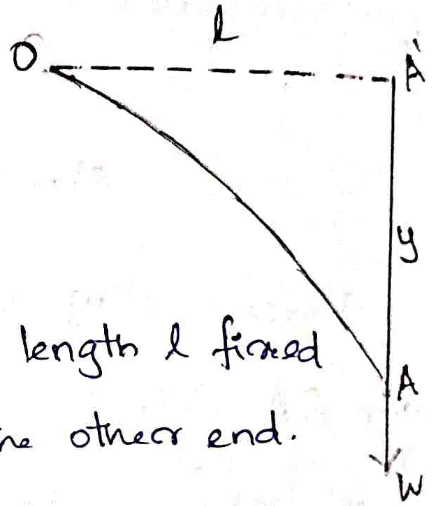
It is denoted by $AK^2 = \Sigma \delta A . z^2$

(A = Area of cross section and k = radius of gyration).

$\therefore$ Internal bending moment $= \dfrac{EAK^2}{R}$.

Note: For a rectangular beam of breadth b and depth (thickness) d, $A = bd$ and $k^2 = d^2/12$.

Depression of the loaded end of cantilever.



A cantilever is a beam fixed horizantally at one end and loded at the other end.

Let OA be the cantilever of length l fixed at o and loaded with weight w at the other end. OA' its the unstrained position of the beam.

The depression A'A of the free end is.

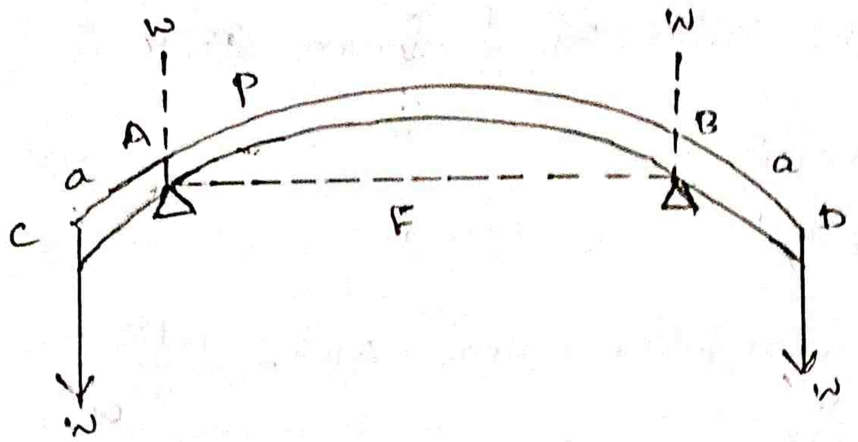
$$y = \frac{Wl^3}{3EAk^2}.$$

Determination of Young's modulus by uniform bending.

Theory:

Consider a beam supported symmetrically on two knife edges. The A and B. Let AB = L

Equal weights W, W are suspended at its ends C and D. Let AC = BD = a.



Reactions W, W act upwards at the knife edges.

The beam bends into an arc of a circle of radius R.

The midpoint of the beam is EF = y.

Consider the cross-section of the beam at any Point P. The external bending moment with respect to P = W.CP − W.AP = W(CP − AP) = W.AC = W.a

This must be balanced by the internal bending moment.

$$\frac{EAk^2}{R} = Wa.$$

$$\frac{1}{R} = \frac{Wa}{EAK^2}$$

From the property of a circle,

$$EF(2R - EF) = AF^2$$

$$y(2R - y) = (l/2)^2$$

$$y.2R = l^2/4.$$

$$y = l^2/8R.$$

Substituting the value of $\frac{1}{R}$ from ①.

$$y = \frac{Wal^2}{8EAK^2}.$$

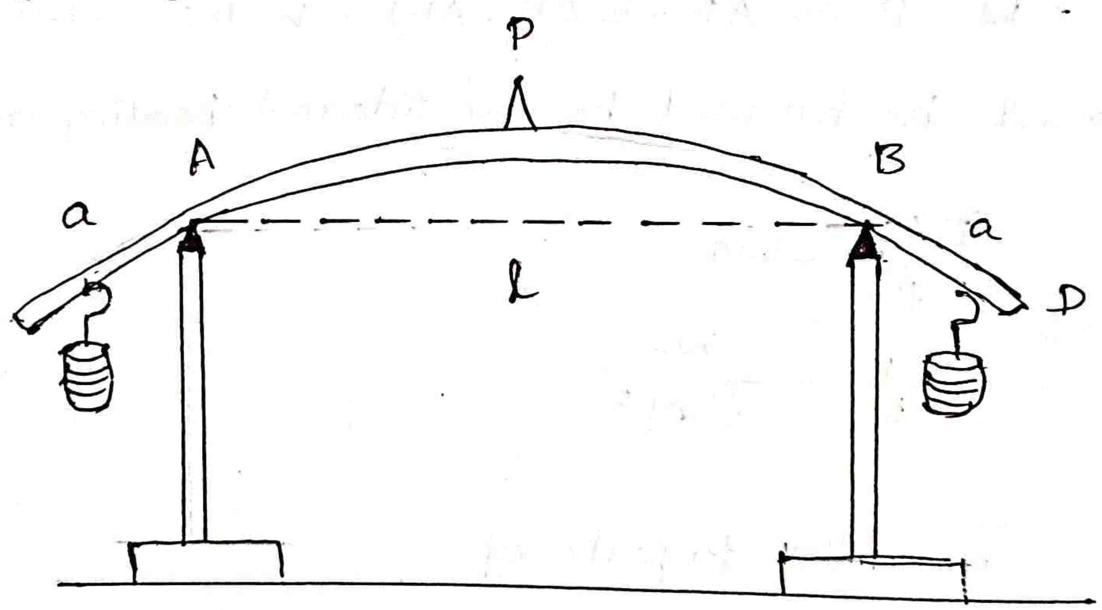
$W = mg$ for a rectangular beam, $AK^2 = \frac{bd^3}{12}$.

$$y = \frac{Mgal^2}{8E\,(bd^3/12)}$$

$$E = \frac{3Mgal^2}{2bd^3 y}.$$

Experiment : Pin and Microscope method.

The given beam is supported symmetrically on two knife-edges A and B.



The distance between the knife-edges is l. Two equal weight hangers are suspended from C and D. $AC = BD = a$.

A pin is placed vertically at the centre of the beam. The elevation produced at the midpoint of the beam is measured using a microscope the load on each hanger is increased in equal steps of m kg. The corresponding microscope readings are noted. Similarly, readings are noted while unloading. The results are tabulated as follows.

Load in kg	Readings of the microscope			y for M kg.
	Load Increasing.	Load decreasing	mean.	

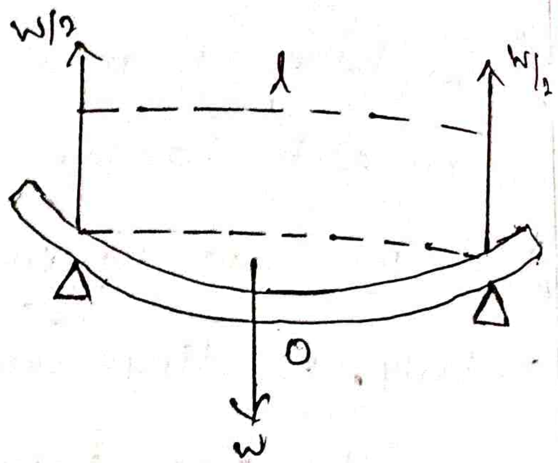
The mean elevation (y) of the centre for M kg is found. The breath b and the thickness d of the beam are measured using vernier calipers and screw gauge respectively.

The Youngs modulus of the material of the beam is calculated using the formula.

$$E = \frac{3Mga l^2}{2bd^3y}.$$

Determination of Young's modulus by non-uniform bending.

Theory:



AB represents a beam of length l, Supported on two knief-edges at A and B. A load w is suspended at the centre c. The reaction at each knief edge is w/2 acting vertically upwards. The beam bends. The depression is maximum at the centre. The bending is non-uniform. Let CD = y.

The portion DA of the beam may be considered as cantilever of length l/2. fixed at D and bending upwards under a load. w/2.

The depression of D below A is,

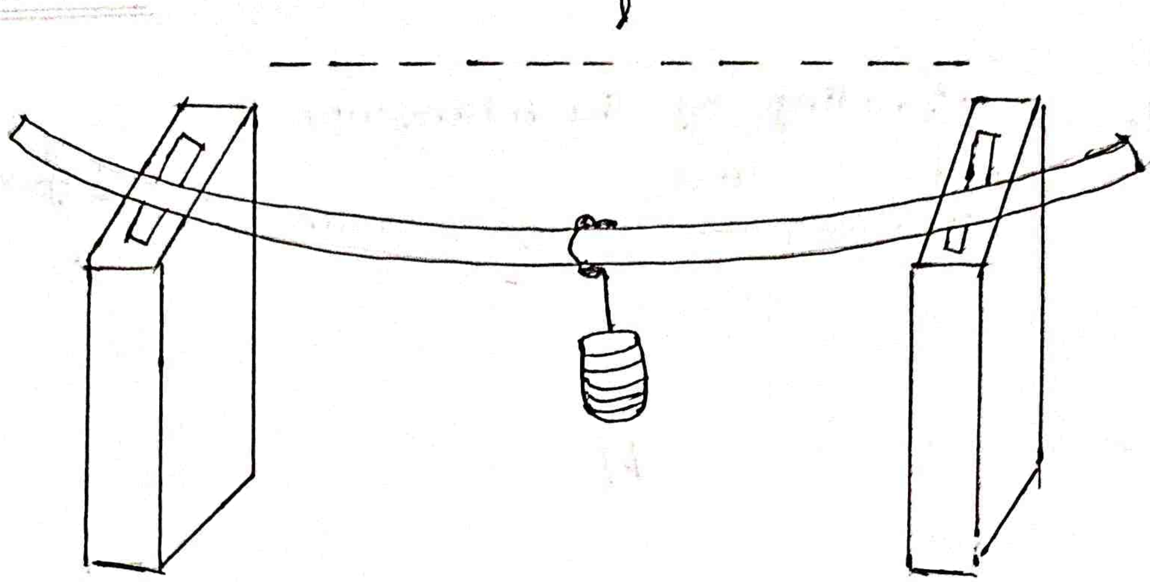
$$y = \frac{(W/2)(l/2)^3}{3EAK^2} = \frac{Wl^3}{48EAK^2}.$$

W = Mg, For a rectangular beam, $AK^2 = bd^3/12$.

$$y = \frac{Mgl^3}{48E(bd^3/12)}$$

$$E = \frac{Mgl^3}{4bd^3y}.$$

Experiment :



The given beam is symmetrically supported on two knife - edges. A weight - hanger is suspended by means of a loop of thread from centre c. A Pin is fixed vertically at c by some wax. A travelling microscope is focused on the tip of the pin such that the horizontal cross section wire coincides with the tip of the pin. The reading in the vertical traverse scale of microscope is noted. weights are added in equal steps of m kg. The corresponding readings are noted. Similarly, readings are noted while unloading. The results are tabulated as follows.

Load in kg	Readings of the microscope			y for M kg.
	Load Increasing	Load decreasing	mean	

The mean depression y is found for a load of M kg. The length of the beam (l) between the knife-edges is measured. The breath b and the Thickness of the beam are measured with a vernier callipers and screw gauge respectively.

The youngs modulus of the ~~b~~ material of the beam is calculated using the formula.

$$E = \frac{Mgl^3}{4bd^3y}.$$

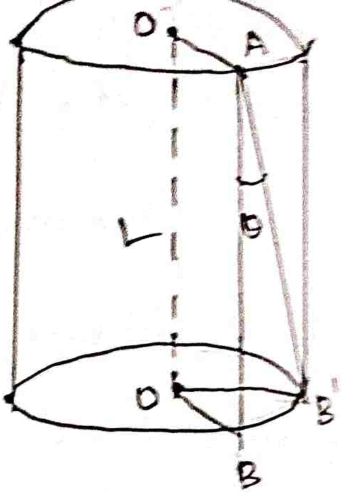
I Section Girders:

Girders standing on pillars at their ends support load. As a result, the girder suffer bending.

The middle portion gets depressed. The neutral surface lying in the middle of the girder experiences no strain. The filaments in the lower part suffer extention. The filaments in the upper part suffer compression. The compression or extension is proportional to the distance from the neutral surface. Hence, the stresses produced in the beams are maximum at the upper and the lower surface of the beam. Consequently the girders must be strong at the upper and the lower surface. This is the reason why the iron girders used in buildings are made of I - Section. Thus a large amount of material is saved.

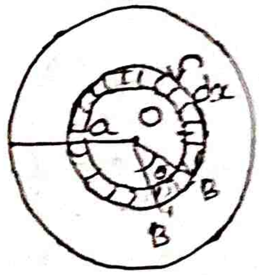
Torsion of a cylinder.

Consider a cylinderical rod.



Its upper end is clamped. The rod is twisted by applying a couple (torque) to its lower end. The rod is said to be under torsion. Torsion involves shearing strain. So the modulus involved is the rigidity modulus.

Expression for couple per unit twist:



Consider a cylindrical wire of length L and radius fixed at its upper end. It is twisted through an angle θ by applying a torque (couple) at the lower end. Consider the cylinder to consist of an infinite number of hollow co-axial cylinders. Consider one such cylinder of radius x and thickness dx.

Consider a line such as AB initially parallel to the axis OO' of the cylinder.

It is displaced to the position AB' through an angle φ due to the twisting couple.

Work done in twisting:

Consider a cylinderical wire of length L and radius a fixed at its upper end. It is twisted through an angle θ by applying a torque at the lower end. c is the torque per unit twist of the wire.

Torque required to produce a twist θ in the wire is,

$$C = c\theta.$$

The work done in twisting the wire through an angle θ is a small angle $d\theta$,

$$C\,d\theta = c\theta\,d\theta.$$

The total work done in twisting the wire through an angle θ is,

$$W = \int_0^\theta c\theta\,d\theta$$

$$W = \frac{1}{2}c\theta^2.$$

The result of twisting a cylinder is a shear strain.

The angle of shear $= \angle BAB' = \phi$.

Now, $BB' = x\theta = L\phi$ or $\phi = x.\theta/L$.

Rigidity modulus $= G = \dfrac{\text{Shearing stress}}{\text{Angle of shear } (\phi)}$

Shearing stress $= G.\phi = x\theta/L$.

Shearing force = Shearing Stress x Area.

The area over which the shearing force acts $= 2\pi x\,dx$

Hence, the shearing force $= F = \dfrac{Gx\theta}{L} 2\pi x\,dx$

The moment of this force about the axis OO' of the cylinder,

$$= \frac{Gx\theta}{L} 2\pi x\,dx \,.\, x = \frac{2\pi G\theta}{L} x^3 dx.$$

$\therefore$ Twisting torque on the whole cylinder,

$$c = \int_0^a \frac{2\pi G\theta}{L} x^3 dx.$$

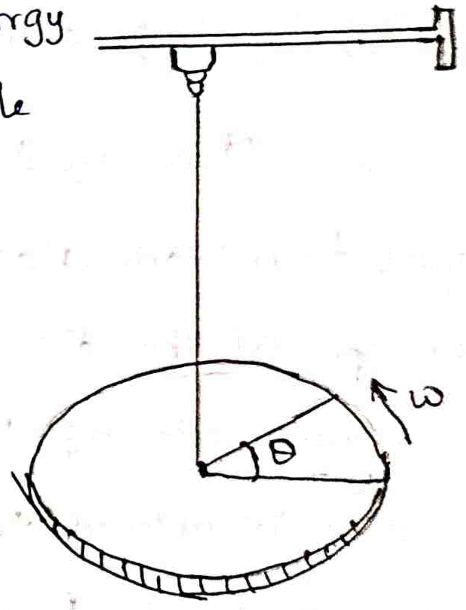
or $$c = \frac{\pi G a^4 \theta}{2L}$$

The torque per unit twist, $c = \dfrac{\pi G a^4}{2L}$.

Torsional oscillations of a body

Suppose a wire is clamped vertically at one end. The other end carries a disc of moment of inertia I about the wire as the axis. The wire twisted through a small angle and released. The disc executes torsional oscillations. The arrangement is called Torsional pendulum.

Let us consider the energy of the vibrating system when the angle of twist is θ. Let ω be the angular velocity of the body,



The potential energy of the wire due to the twist $= \frac{1}{2} C\theta^2$.

The kinetic energy of the body due to its rotation $= \frac{1}{2} I\omega^2 + \frac{1}{2} I \left(\frac{d\theta}{dt}\right)^2$

The total energy of the system.

$$= \frac{1}{2} I \left(\frac{d\theta}{dt}\right)^2 + \frac{1}{2} C\theta^2 = \text{Constant}.$$

Differentiate it with res to t.

$$\frac{1}{2} I\, 2 . \frac{d\theta}{dt} . \frac{d^2\theta}{dt^2} + \frac{1}{2} C\, 2\theta \frac{d\theta}{dt} = 0.$$

$$I \frac{d^2\theta}{dt^2} + C\theta = 0 \quad (\text{or}) \quad \frac{d^2\theta}{dt^2} + \frac{C}{I}\theta = 0.$$

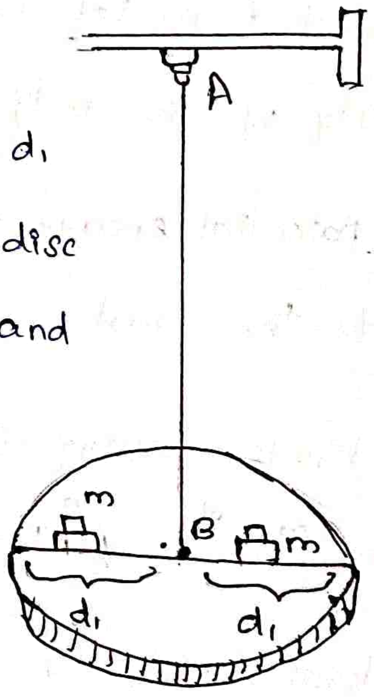
The body has simple harmonic motion. Its period is given by,

$$T = 2\pi\sqrt{\frac{I}{c}}.$$

Rigidity Modulus by Torsion Pendulum.

The wire AB of length L and radius a is fixed at the end A. The lower end B is clamped to the centre of a circular disc.

Two equal masses (each equal to m) are placed along a diameter of the disc at equal distance d_1 on either side of the centre of the disc. The disc is rotated through an angle and is then released. The system executes torsional oscillations about the axis of the wire. The period of oscillations T_1 is determined.



Then, $T_1 = 2\pi\sqrt{\frac{I_1}{c}}$

Or $T_1^2 = \frac{4\pi^2}{c} I_1.$

Here, I_1 = Moment of inertia of the whole system about the axis of the wire.

c = Torque per unit twist.

Let, I_0 = M.I of the disc alone about the axis of the wire.

i = M.I of each mass about a parallel axis through its centre of gravity.

Then, by the parallel axes theorem,

$$I_1 = I_0 + 2i + 2md_1^2.$$

$$T_1^2 = \frac{4\pi^2}{c}\left[I_0 + 2i + 2md_1^2\right]$$

The two masses are now kept at equal distances d_2 from the centre of the disc. The corresponding Period T_2 is determined then,

$$T_2^2 = \frac{4\pi^2}{c}\left[I_0 + 2i + 2md_2^2\right]$$

$$T_2^2 - T_1^2 = \frac{4\pi^2}{c} 2m\,(d_2^2 - d_1^2)$$

But $c = \pi G a^4 / 2L$.

$$\text{Hence, } T_2^2 - T_1^2 = \frac{4\pi^2\, 2m\,(d_2^2 - d_1^2)\, 2L}{\pi G a^4}$$

$$\text{(or)} \quad G = \frac{16\pi L m\,(d_2^2 - d_1^2)}{a^4\,(T_2^2 - T_1^2)}$$

Using this relation Rigidity modulus G is determined.

VISCOSITY

Viscosity

This property by virtue of which a liquid opposes relative motion between its different layers is called Viscosity.

Example

Rain drops fall slowly on account of the viscosity of air.

Viscous Force

The viscous force is directly proportional to the surface area A and velocity gradient dv/dx.

$$F \propto A\frac{dv}{dx} \quad \text{Or} \quad F = \eta A\frac{dv}{dx}$$

Hence, η is a Constant For the liquid. It is Called Coefficient Of Viscosity.

If $A = 1$ and $dv/dx = 1$,

We have $F = \eta$

COEFFICIENT OF VISCOSITY

The Coefficient Of Viscosity is defined as the tangential force per unit area required to maintain a Unit Velocity gradient.

Unit Of Coefficient Of Viscosity

Unit Of η is Nsm^{-2} (Newton Second per Square Metre).

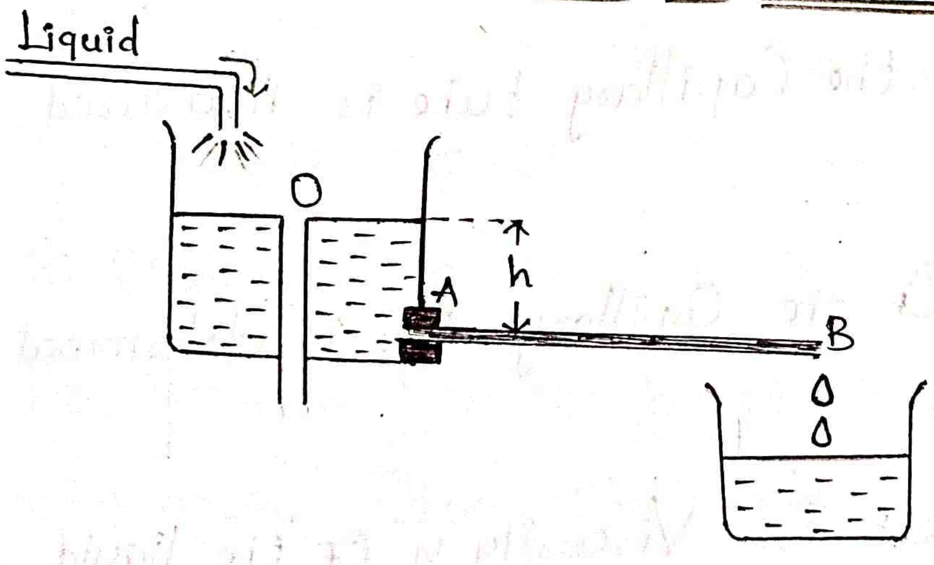
DIMENSION OF COEFFICIENT OF VISCOSITY.

Dimensions Of $[\eta] = \dfrac{[F]}{[A][(dv/dx)]}$

$$= \frac{MLT^{-2}}{L^2 (LT^{-1}/L)}$$

$$= [ML^{-1}T^{-1}]$$

POISEUILLE'S FORMULA FOR CO-EFFICIENT OF VISCOSITY OF A LIQUID.



The liquid is taken in the Constant level tank upto a height h. A Capillary tube AB is fixed to the bottom of the tank. A weighted beaker is placed below the free end B of the Capillary tube. This mass m of the liquid Collected in it in time t is found out.

Volume of liquid flowing per second

$$V = \frac{m}{\rho \cdot t}$$

Here, ρ is the density of the liquid.

Pressure difference between the ends of the Capillary tube is

$$P = h\rho g.$$

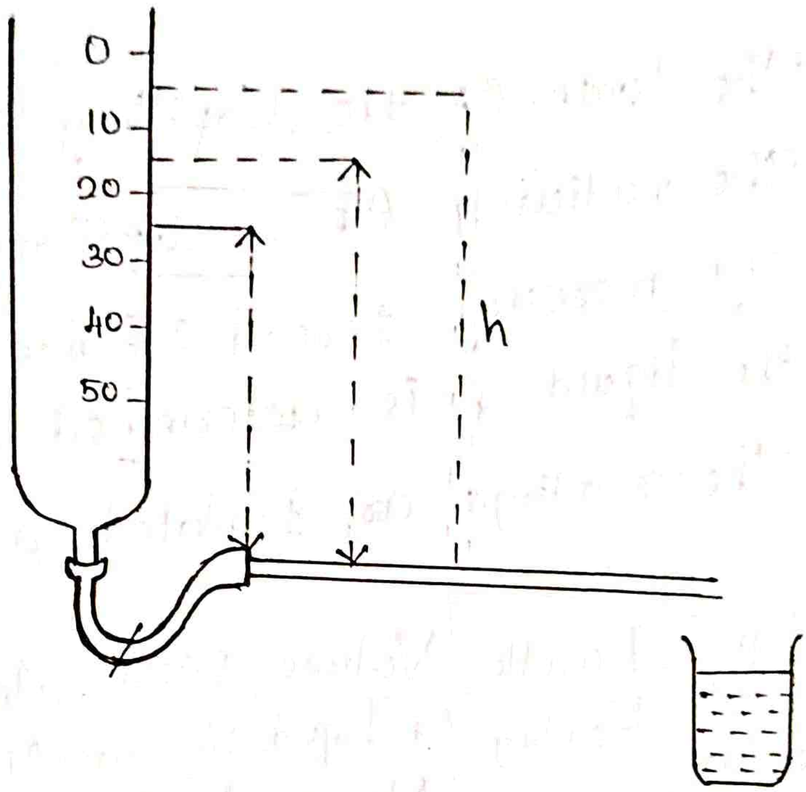
The length l of the Capillary tube is measured by a metre rod.

The radius a of the Capillary tube is determined using a microscope

The Coefficient of Viscosity η of the liquid is Calculated Using the formula,

$$\eta = \frac{\pi P a^4}{8 V l}$$

Determination Of Coefficient Of Viscosity Using Burette



The given liquid is poured into a graduated burette. The Capillary tube is fixed. a The Clip is Opened Fully. The liquid is allowed to Flow Slowly through the Capillary tube. When the liquid level in the burette crosses the Zero marking, a Stop - Clock is Started. The readings Of the Stop clock are noted when the liquid level Crosses the 10cc, 20cc, 30cc etc..., markings.

The vertical height h between the Capillary tube and the mid points Of the range 0 - 10cc, 10 - 20cc, 20 - 30cc, etc..., are measured.

The lngth Of the Capillary tube (l) is measured. The radius a Of a Capillary tube is measured Using mercury thread Or microscope. The desity Of the liquid ρ is determined Using Hare's apparatus. The readings are tablated as follows.

Burette Reading cc	Stop Clock Reading Seconds	Burette Reading range	Volume Of Liquid Flowing m^3	Mean Pressure head h m	Time Of Flow t Seconds	$\frac{ht}{V}$

Mean ht/V =

The Coefficient Of Viscosity is Calculated Using the formula,

$$\eta = \frac{\pi \rho g a^4}{8l}\left(\frac{h.t}{V}\right)$$

Bernoulli's Theorem

Statement

The total energy of an incompressible liquid flowing from one point to another, without any friction remains constant throughout the motion.

Explanation

A liquid in flow possesses three forms of energies.

i) Potential Energy :

Potential energy per unit mass of the liquid $= gh$.

ii) Kinetic Energy.

Kinetic energy per unit mass of the liquid $= \frac{1}{2} v^2$

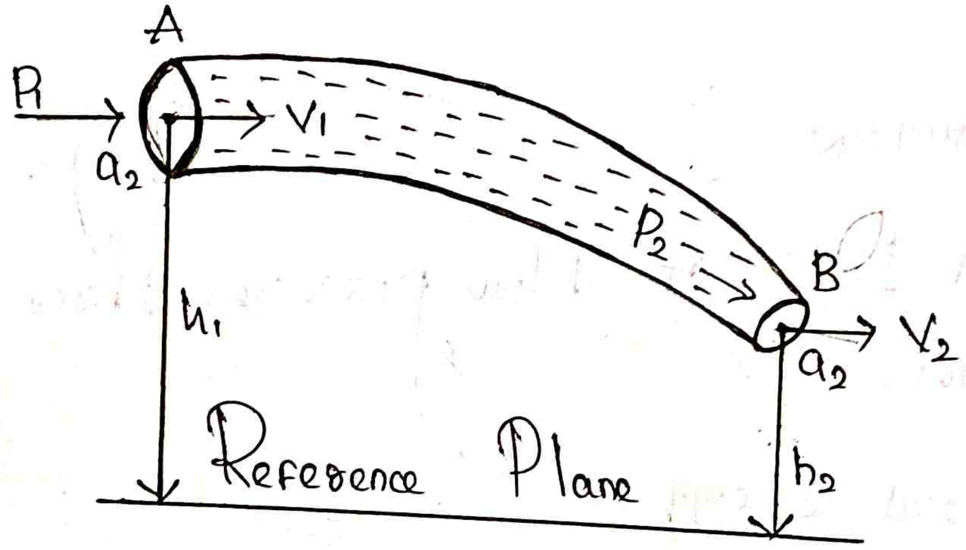
iii) Pressure Energy.

Pressure energy per unit mass $= P/\rho$

Total Energy = (Pressure Energy + Kinetic Energy + Potential Energy)

According to Bernoulli's theorem, the total Energy per Unit mass is a Constant.

Or $$P/\rho + \frac{1}{2}V^2 + gh = \text{Constant}.$$



PROOF

Consider a liquid in Stream line motion along a nonuniform tube. Let A and B be two transverse Sections of the tube at heights h_1 and h_2 from a reference plane (the Surface of the Earth). Let a_1 and a_2 be the areas of Cross-Section at A and B. Let V_1 and V_2 be the Velocities of the liquid at

Work done per second on the liquid entering at A is.

W_1 = Force at A × Distance moved by the liquid in 1 second.

$= P_1 a_1 \times v_1 = P_1 a_1 v_1$

Work done per second by the liquid leaving the tube at B is

$W_2 = P_2 a_2 v_2$

$\therefore$ Net work done by the liquid in passing from A to B is.

$W = W_1 - W_2 = P_1 a_1 v_1 - P_2 a_2 v_2$

But $a_2 v_2 = a_1 v_1$

$\therefore W = (P_1 - P_2) a_1 v_1$

The work done on the liquid is used in changing its potential and kinetic energies.

Decrease in Potential energy $= (a_1 v_1 \rho) g (h_1 - h_2)$

Increase in Kinetic energy $= \frac{1}{2}(a_1 v_1 \rho)(v_2^2 - v_1^2)$

Hence, the total gain in the energy of the system, when the liquid flows from A to B.

$= \frac{1}{2}(a_1 v_1 \rho)(v_2^2 - v_1^2) - (a_1 v_1 \rho g)(h_1 - h_2)$

$$\therefore (P_1 - P_2) a_1 v_1 = \frac{1}{2}(a_1 v_1 \rho)(v_2^2 - v_1^2) - (a_1 v_1 \rho g)(h_1 - h_2)$$

$$(P_1 - P_2) a_1 v_1 = a_1 v_1 \left[\frac{1}{2} \rho (v_2^2 - v_1^2) - \rho g (h_1 - h_2)\right]$$

$$P_1 + \frac{1}{2} \rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g h_2$$

Or

$$P + \frac{1}{2} \rho v^2 + \rho g h = \text{Constant}$$

Or

$$P/\rho + \frac{1}{2} v^2 + g h = \text{Constant}$$

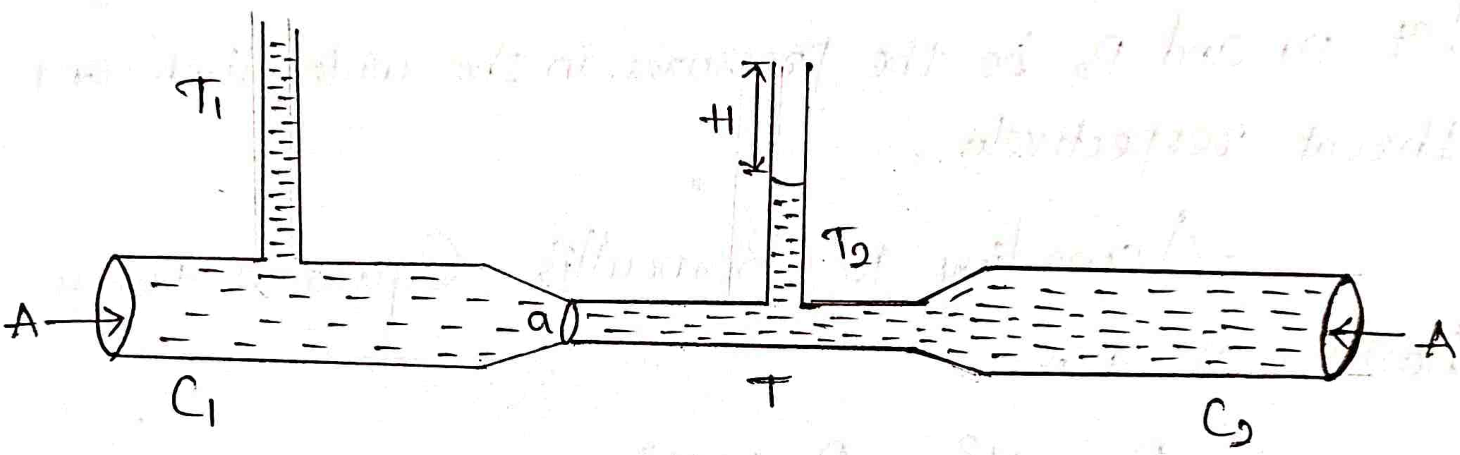
APPLICATION OF BERNOULLI'S THEOREM.

VENTURIMETER.

It is a device based on Bernoullis theorem. It is used for measuring the rate of flow of liquids in pipes. It constants of two wide conical tubes C_1 and C_2 with a constriction T between them.

T is Called the throat. Let the area Of Cross Section Of C_1 and C_2 be A.

Let a be the area Of Cross Section Of the throat.



When the flow is Steady, let V be the Volume Of water flowing per Second through the Venturimeter.

Then, $V = Av_1 = a_2 v_2$

Here, v_1 = Velocity in C_1 Or C_2 and v_1 = Velocity in T.

$\therefore v_1 = V/A$, $v_2 = V/a$

Hence Velocity of water in T is greater than the velocity in C_1 and C_2. Consequently, the pressure in T is smaller than the pressure in C_1 and C_2. This difference in pressure H is measured by the difference of the water levels in the vertical glass tube T_1 and T_2 Connected to C_1 and T respectively. Let p_1 and p_2 be the pressures in the wider limb and throat respectively.

According to Bernoulli's Equation for a horizontal flow,

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} = \frac{P_2}{\rho} + \frac{V_2^2}{2}$$

Or

$$\frac{P_1 - P_2}{\rho} = \frac{V_2^2 - V_1^2}{\rho}$$

The difference in pressure in C_1 and $T = P_1 - P_2 = H\rho g$.

Hence

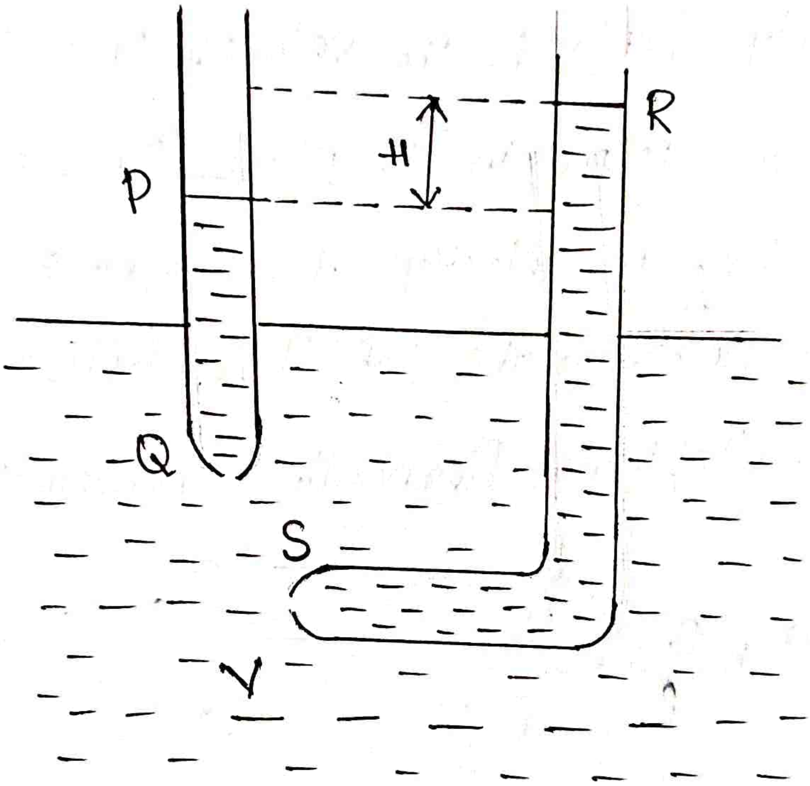
$$\frac{H\rho g}{\rho} = \frac{1}{2}\left[\frac{V^2}{a^2} - \frac{V^2}{A^2}\right]$$

$$= \frac{V^2}{2}\left[\frac{A^2 - a^2}{A^2 a^2}\right]$$

$$\therefore V = Aa\sqrt{\frac{2gH}{(A^2 - a^2)}}$$

The rate of flow of water through the pipe line can be determined by measuring H and knowing the constant A, a, and g.

PITOT TUBE



It is an instrument used to measure the rate of flow of water through a pipe line. It is based on Bernoulli's theorem. It consists of two vertical tubes PQ and RS with small apertures at their lower ends. The plane of aperture of the tube PQ is parallel to the direction of flow of wate. The plane of the tube RS face the flow of water perpendicularly. The rise of the water column in the tube RS therefore, measures the pressure at S.

Let P_1 and P_2 be the pressure of water at Q and S respectively. Let v be the velocity of water at Q. Since the water is stopped in the plane of the aperture S of the tube RS, its velocity at S becomes zero. Hence the pressure increase to P_2 at S. Let H be difference of level in the two tubes. Applying Bernoulli's theorem to the ends Q and S.

$$\therefore \frac{1}{2} v^2 + \frac{P_1}{\rho} = \frac{P_2}{\rho}$$

Or

$$v^2 = \frac{2}{\rho}(P_2 - P_1) = \frac{2}{\rho} \rho H g$$

$$\therefore v = \sqrt{2gH}$$

Rate of flow of water = av

Here, a = area of cross section of the pipe.

UNIT - III

CONDUCTION, CONVECTION AND RADIATION

Conduction:

It is The process in which heat is transferred From one point to another Through The substance without The actual motion of The particles.

Example: Touching a stove and being burned. Ice cooling down your hand

Convection: (or) convection process

It is The process in which head is transmitted From one place to another by The actual motion of The heated particles.

Example: Hot air rising, cooling and falling (convection currents)

Radiation:

It is The process in which heat is transmitted From one Place to The other directly without any material medium.

Example: Heat From The Sun warming your face.

Specific heat capacity of solids and liquids:

Heat capacity: The ratio of The head (dQ) Supplied to a body to it's corresponding temperature rise (dT) is called heat capacity of The body.

Heat capacity $= dQ/dT$

$\therefore$ The heat capacity of the body is defined as the amount of heat required to rise the Temperature of the whole of the body through 1 K.

The unit of heat capacity is JK^{-1}

Specific heat capacity:

The heat capacity per unit mass of a body is called specific heat capacity. It is denoted by c

$$C = \text{heat capacity} / \text{mass}$$
$$= dQ / m.dT$$

$$\boxed{C = \frac{\Delta Q}{M \times \Delta T}}$$

$\therefore$ The specific heat capacity of any substance is defined as the quantity of heat required to rise the temperature of 1 kg of the substance through 1 K

Unit : Joule per kelvin per kilogram, $J/K/kg$, $JK^{-1}kg^{-1}$ ---

From the definitions of heat capacity and specific heat capacity, it follows the heat capacity of a body is equal to the product of the mass (m) of the body and the specific heat capacity (c) of the material of the body.

$$\text{Heat capacity} = m \times c$$

Where, m = mass

c = specific heat capacity

∴ Generally liquids have more Specific heat capacity Than Solids.

Dulong and petit's law :

Dulong and petit's in 1819, Studied The Specific heat elements in a Solid State and equnciated a law called Dulong and Petit's law. According to This law, The product of The Spatiched and The atomic weight atomic heat of all The elements solid State is a constant. The value of This constant was From but it is taken as 6 present. The exact Value 5.96 agree with The Value derived From The kinetic Theory.

The Justification of Dulong and Petit's law was Obtain Boltzman's consideration of The law of equipartitions According to it The energy associates with one gram at substance For each degree of The Freedom at temperature T. Here R is The universal gas constant. If The atom is conisitude be vibrating about The mean position it mean kinetic energy be equal to its mean potential energy.

For each From of energy There are Three degree of Therefore an atom has got Six degrees of Freedom. Thus, The energy associated with one gram of a Substance at temperature T' = 3RT

$U = 3RT$

$$\boxed{\Delta H = \frac{du}{dT} = 3R}$$

ΔH is The atomic heat of The Substances.

$$\Delta H = \frac{3 \times 8.31 \times 10^{7}}{4.18 \times 10^{7}} \text{ cal/g atom.K}$$

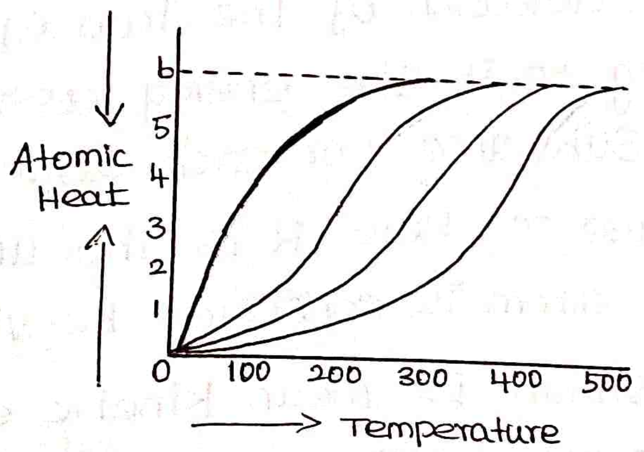
$$\boxed{\Delta H = 5.96 \text{ cals / g atom.K}}$$

Atomic heat of Substances $\Delta H = 20°C$

OF Nacl, Agcl and Kcl. was Formed to be atom 13 and That of Sb_2O_3, Fe_2O_3, AS_2O_3 water found to be equal to 26.

Variation OF Specific heat and Atomic heat with Temperature

H is Found That Dulong and Petit's law is not true in The case of carbon, boron. and Silicons In The case of These element and The atomic heat at 20°C



are 1.92, 3.32 and 11. There Values difficult Format at constant Value of 6. This Variation in atomic heat could not be explained on The basis kinetic Theory of matter. However it was found by named That with decrease in temperature and at absolute zero The specific heat tends to zero. Furthur he was able to show That The Specific heat.

Newton's law of cooling :

Statement :

The rate of cooling of a body is proportional to its excess temperature above that of the surroundings.

Explanation :

The law is true only for small temperature difference between the cooling body and the surroundings. This law applies to cooling by convection and radiation and not by radiation alone. In practice this condition is realized when the hot body is allowed to cool in a good draught to make the loss due to radiation small as compared to that due to forced convection.

Newton's law canbe deduced from Stefan's law. Let T and T_0 be the absolute temperatures of the hot body and the surroundings. According to Stefan's law, rate of loss of heat from the hot body is given by

$$R = \sigma(T^4 - T_0^4)$$

$$= \sigma(T - T_0)(T^3 + T^2T_0 + TT_0^2 + T_0^3)$$

when $T \approx T_0$,

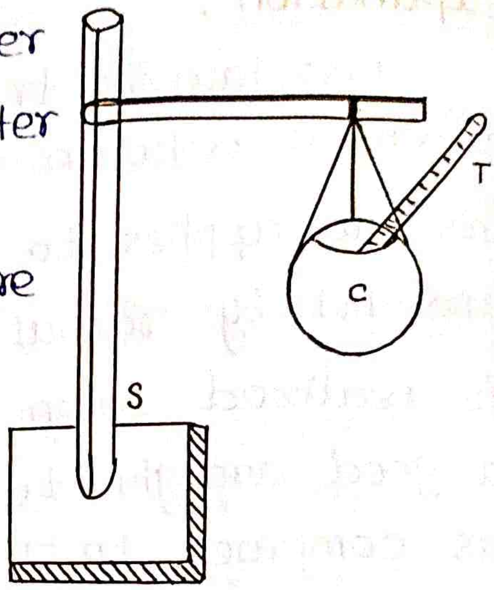
$$R = \sigma(T - T_0)4T_0^3$$

(or) $\boxed{R \propto (T - T_0)}$ (Since $4\sigma T_0^3 = k = \text{constant}$)

Thus the rate of cooling of the body is directly proportional to the excess of temperature of the body over that of the surroundings, if this excess temperature is small. This is Newton's law of cooling.

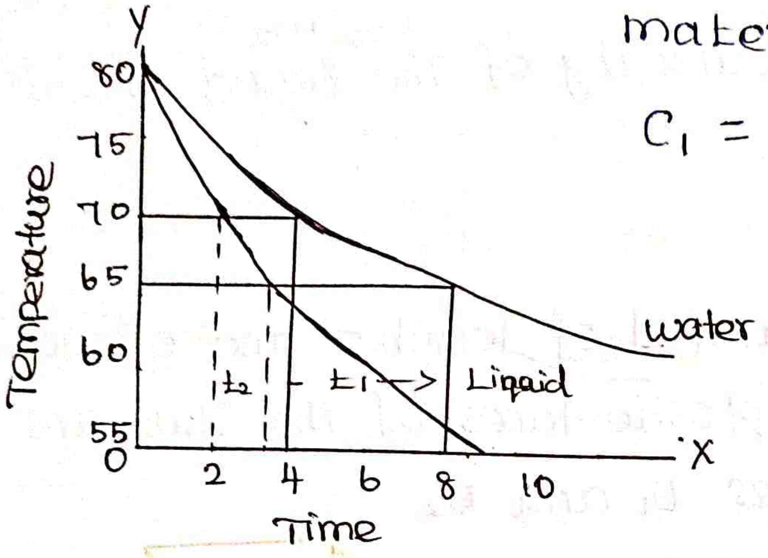
Specific heat capacity of a liquid by cooling:

A Spherical calorimeter is weighed empty (w_1). It is filled with water at a temperature of about 85°c and susbended in air from a stand. A Sensitive Thermometer is inserted into The water Through a Narrow hole in The calorimeter when The temperature reaches 80°c, a Stop watch is Started. The Temperature of The water is noted at regular intervals of one minute, until water cool to 55°c. The Calorimeter is allowed to cool to room Temperature. and Then weighed (w_2)



After removing The water from The calorimeter. It is filled with The given liquid, at about 85°c. The Temperature of The liquid is noted at regular intervals of one minute as The liquid cools from 80°c to 55°c The calorimeter with The contends is allowed to cool to The room temperature and Then weighed (w_3)

Graphs are plotted between temperature and time, For water and The Liquid. The time taken by water to cool from 70°c to 65°c is determined from graph. Similarly The time taken by The liquid to cool Through The same range is also determined $\left(\frac{t_2}{t_1}\right)$ is calculated. Let C = Specific Heat capacity of The material of The calorimeter.



C_1 = Specific heat capacity of water.

C_2 = Specific heat capacity of The liquid.

$m_1 = (W_2 - W_1)$ = mass of water

$m_2 = (W_3 - W_1)$ = mass of liquid

The heat lost per second when The calorimeter containing water cools from $T_1°C$ to $T_2°C$ is,

$$\frac{(m_1C_1 + W_1C)(T_1 - T_2)}{t_1}$$

The heat lost per second when The calorimeter containing The liquid cools Through The same range of temperature $(T_1 - T_2)$ is,

$$\frac{(m_2C_2 + W_1C)(T_1 - T_2)}{t_2}$$

The Nature and extent of The Surface of The calorimeter and The difference between The temperature of The calorimeter and The Surroundings are The Same in both cases. So The rate's of cooling are equal.

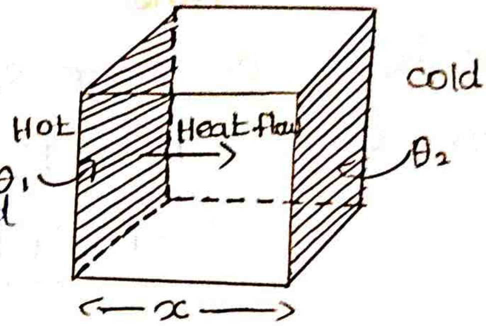
$$\therefore \frac{(m_1C_1 + W_1C)(T_1 - T_2)}{t_1} = \frac{(m_2C_2 + W_1C)(T_1 - T_2)}{t_2}$$

Specific heat capacity of liquid $\boxed{c_2 = \dfrac{(m_1c_1 + w_1c)\frac{t_2}{t_1} - w_1c}{m_2}}$

∴ Thus The Specific heat capacity of The liquid is determined.

Thermal conduction:

Consider a slab of material of length x and of area of cross - section A. The opposite faces of The slab are maintained at temperatures θ_1 and θ_2 where $\theta_1 > \theta_2$. Assume That no heat is lost from the sides of The slab. Then The quantity of heat Q conducted from one face to The other is,



i) directly proportional to The area of cross - section A
ii) directly proportional to The difference of temperature between The ends $(\theta_1 - \theta_2)$
iii) directly proportional to The time of conduction t,
iv) inversely proportional to The length x

(or) $Q \propto \dfrac{A(\theta_1 - \theta_2)t}{x}$ or $\boxed{Q = KA\left(\dfrac{\theta_1 - \theta_2}{x}\right)t}$

Here K is a constant called The coefficient of Thermal conductivity of The slab. The quantity $(\theta_1 - \theta_2)/x$ represents The rate of fall of temperature with respect to distance. It is called The temperature gradient. Consider a slab of infinitesimal thickness dx, across which There is a temperature difference $d\theta$. Then the temperature gradient is $d\theta/dx$. $d\theta/dx$ is negative, since it represents rate of fall of temperature with distance.

Therefore, $\boxed{Q = KA(d\theta/dx)t}$

If $A = 1m^2$, $d\theta/dx = 1$ and $t = 1$ second, Then $Q = K$.

Coefficient of Thermal conductivity:

The coefficient of Thermal conductivity of a material is defined as numerically equal to the quantity of heat conducted per second normally across unit area of cross - Section of the material per unit temperature gradient.

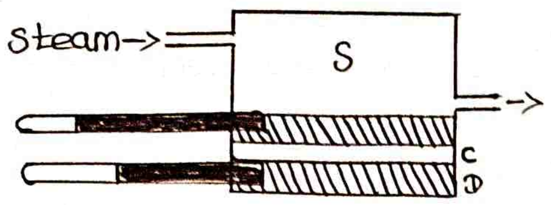
$\boxed{\text{The unit of K is } Wm^{-1} K^{-1}}$

Coefficient of Thermal conductivity by Lee's disc method:

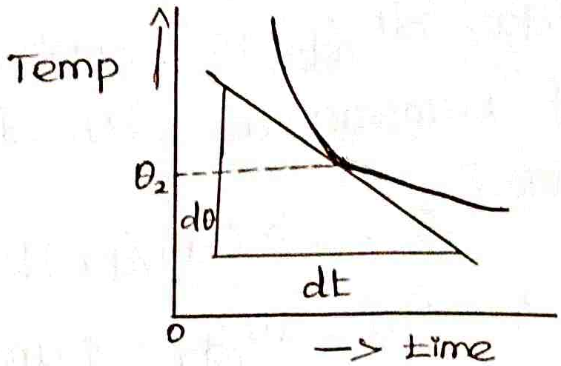
Apparatus:

The apparatus consists of a circular metal disc D Suspended by Three Strings from a Stand [Fig (a)]. Over This rests a hollow cylindrical chamber S of The same diameter. It is provided with an inlet and outlet by which steam is allowed to circulate. The specimen is taken in The form of a Thin disc (C) of The same diameter as D and S. It is placed between D and S. There are holes in S and D into which Thermometers T_1

and T_2 canbe introduced.



(a)



(b)

Experiment :

Steam is passed Through The Steam chamber until the temperatures of The chamber and The lower disc are Steady. When The thermometers show steady temperatures Their readings θ_1 and θ_2 are noted. The radius (r) of The disc C and its Thickness (d) are also noted.

Then,

quantity of heat conducted Through The specimen per second $= Q = K\pi r^2 \dfrac{\theta_1 - \theta_2}{d}$ —— ①

This head Q is radiated to The surroundings by The curved side and flat bottom of The lower disc D

The bad conductor C is now removed and The Steam chamber is placed directly on The metal disc D. The disc D is heated to a temperature of about 5° greater Than θ_2. Thus steam chamber is removed and The disc D is allowed to cool.. Temperature of D is noted at Intervals of half a minute until The temperature of

The disc falls to about 5° below θ_2. A time-temperature graph is drawn [Fig (b)]. From the curve, the rate of fall of temperature $d\theta/dt$ at the steady temperature θ_2 is found. The mass (m) of the lower disc D is found. Its thickness l is also found. Let c be its specific heat capacity.

Calculation:

Quantity of heat radiated per second by the two flat surfaces and one curved surface of the lower disc D $= mc\dfrac{d\theta}{dt}$

Quantity of heat lost by one flat (bottom) surface and curved surface is,

$$Q = mc\frac{d\theta}{dt}\,\frac{\pi r^2 + 2\pi r l}{2\pi r^2 + 2\pi r l} = mc\frac{d\theta}{dt}\left(\frac{r+2l}{2r+2l}\right) \quad \text{--- (2)}$$

This is equal to the heat conducted through the specimen per second. Hence, from equations (1) and (2)

$$\frac{K\pi r^2(\theta_1-\theta_2)}{d} = mc\frac{d\theta}{dt}\left(\frac{r+2l}{2r+2l}\right) \quad \text{--- (3)}$$

$$\boxed{K = \frac{mc\dfrac{d\theta}{dt}\left(\dfrac{r+2l}{2r+2l}\right)d}{\pi r^2(\theta_1-\theta_2)}} \quad \text{--- (4)}$$

K is calculated from Eq (4).

Lapse Rate :

The temperature of air decreases with altitude. The rate of fall of temperature with altitude is called the lapse rate. Lapse rate is defined as the rate at which temperature decreases or lapses, per km increase in altitude. The lapse rate in the troposhere may be caculated assuming that the changes in the pressure and volume of air in the atmosphere take place under adiabatic conditions.

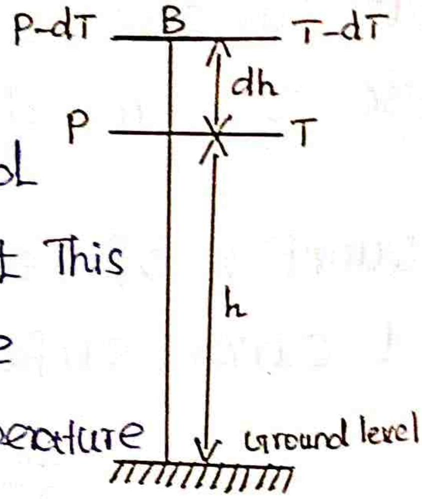


Fig (a)

Consider a vertical section in the troposhere of height h. Let p and T be the pressure and temperature at this altitude, we know that as altitude Increasses by dh, pressure and temperature decreases by dp and dT respectively [Fig (a)]. Further, troposhere is a region of adiabatic equilibrium. Hence the column of air obeys the adiabatic equation.

$$\frac{p^{\gamma-1}}{T^{\gamma}} = k \quad \text{——} ①$$

Here, k is a constant and γ is the ratio of specific heat capacities of air.

Taking logarithms $(\gamma-1)\log p = \log k + \gamma \log T$

Differentiating $(\gamma-1)\frac{dp}{p} = \gamma \frac{dT}{T}$ —— ②

For an Increase in height dh, The decrease in pressure dp is given by $dp = -dh \cdot \rho \cdot g$

Here, ρ is The mean density of The Section of The atmosphere.

$$\text{(or)} \quad dp = -dh \cdot g \frac{M}{V} \qquad (\because \rho = M/V)$$

Since $PV = RT \therefore V = \frac{RT}{P}$

$$\therefore dp = -dh \cdot g \frac{MP}{RT}$$

$$\text{(or)} \quad \frac{dp}{P} = -dh \cdot g \frac{M}{RT}$$

Substituting for dp/p in Eq. (2), we get

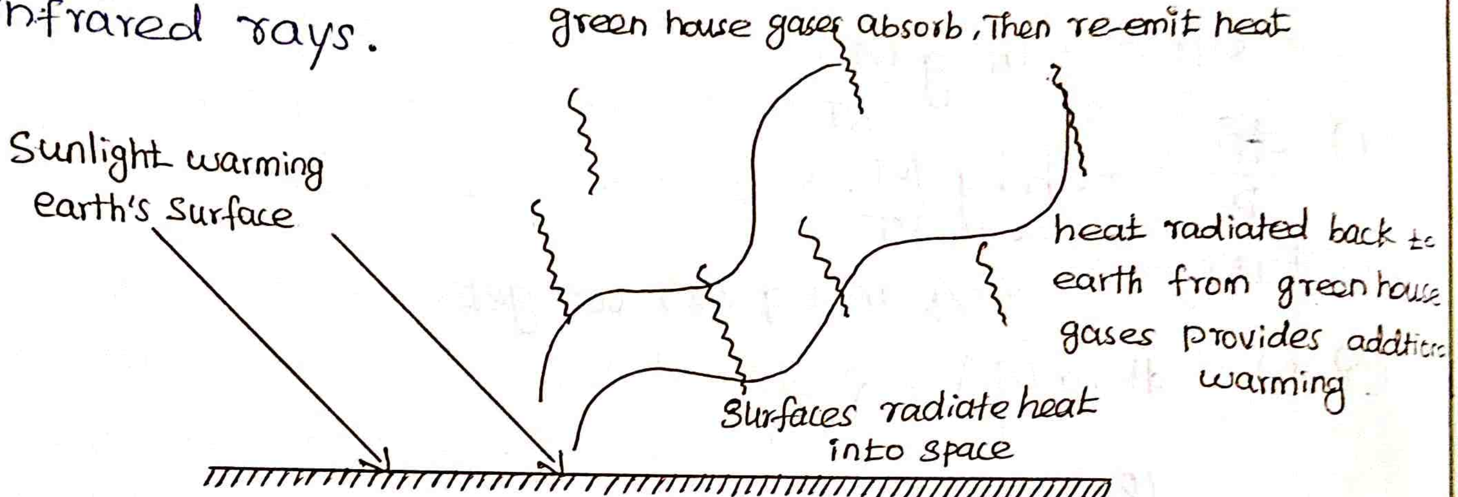
$$(\gamma - 1)\left(-dh \cdot g \frac{M}{RT}\right) = \gamma \frac{dT}{T}$$

$$\text{(or)} \quad \boxed{\frac{dT}{dh} = -\frac{gM}{R}\left(\frac{\gamma - 1}{\gamma}\right)}$$

This is The adiabatic lapse rate For perfect dry air. Substituting The values of M, g, R and γ The lapse rate comes to $-10°C$ per km. This is twice The value actually Observed.

Green House effect:

Certain gases in The atmosphere absorb solar radiant energy and re-emit The heat back to The earth. Those gases which are capable of absorbing and re-emitting The heat radiation are called green house gases water Vapour (H_2O), carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O) and ozone (O_3) are The green house gases. Much of The Short wavelength visible light from The Sun That reaches The earth is radiated as long wavelength Infrared which is readily absorbed by CO_2 and other Green house Gases in The atmosphere [Fig (a)] Thus. carbon dioxide layer acts like a blanked and traps The infrared rays.



[Fig (a)]

The heat from The surfaces of The earth warms up The green house gases. These gases in turn emit some heat into space and some back down to The surface. This fraction of The heat provides global warming in addition to The Sun's direct heat. without any green house gases. in The atmosphere The average surface temperature would be very cold. ie, around -18°c. Today's green house gases. radiate sufficient heat back to earth to given an average global temperature of +15°c. In future if The concentration of green house gases in Incresed. There will be additional

Here, h = planck's constant
c = speed of Light
k = Boltzmann's constant
T = temperature of the enclosure

Rayleigh Jean's law :

The energy density of radiation in an enclosure at temperature T having wavelengths in the range λ to $\lambda + d\lambda$ is

$$\boxed{E_\lambda \, d\lambda = 8\pi k T \lambda^{-4} d\lambda}$$

Explanation :

Rayleigh - Jean's law agrees with the experimental results in the longer wavelength region. It fails in the shorter wavelength region.

Wien's displacement law :

The wavelength (λ_m) of the strongly emitted radiation in the continuous spectrum of a black body is inversly proportional to the absolute temperature (T) of that body.

$$\boxed{\begin{gathered} \lambda_m \propto 1/T \\ \lambda_m T = b \end{gathered}}$$

Here,

b is a wien's constant $= 2.898 \times 10^{-3}$ m K global warming. It is Therefore, necessary to keep the present level of grean house to avoid any diastic change in The climatic changes.

The heating up of earth's atmospheare due to The infrared rays, which are reflected from The earth's surface by The carbon dioxide layer in The atmosphere is called green house effect.

Black body radiation:

A perfectly black body is one which absorbs all The heat radiations of whatever wavelength, incident on it. when such a body is heated, it emits radiations of all possible wavelengths.

It is found That inside a black body. The Nature of radiation becomes independent of The shape, size and Material of The body and depends only upon The temperatures of The body. This radiation is called black body radiation.

Planck's radiation law:

The energy density of radiation in an enclosure at temperature T having wavelengths in The range λ to $\lambda + d\lambda$ is

$$\boxed{E_\lambda \, d\lambda = \frac{8\pi hc\lambda^{-5}}{\left(e^{hc/\lambda kT} - 1\right)} d\lambda}$$

Stefan's law of radiation :

The total amount of heat radiated by a perfectly black body per second per unit area is directly proportional to the fourth power of its absolute temperature.

$$\boxed{E \propto T^4 \quad \text{or} \quad E = \sigma T^4}$$

Here,

σ is a constant called stefan's constant

It's value is experimentally found to be 5.67×10^{-8} $Jm^{-2}s^{-1}K^{-4}$

If the body is not perfectly black and its relative emittance is e, Then

$$E = e\sigma T^4$$

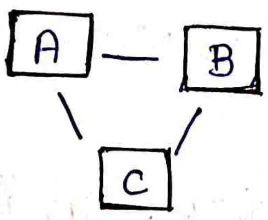
e varies between 0 and 1, depending on the nature of the surface for a perfectly black body e = 1

Boltzmann gave a theoretical proof of Stefan's law on the basis of Thermodynamics. Therefore, This law is also called stefan - Boltzman law.

THERMODYNAMICS

Zeroth law of thermodynamics

The law states that "if two systems A and B are in thermal equilibrium with the system C, then A and B are also in thermal equilibrium with each other."



Significance of the law

Zeroth law of thermodynamics introduces the concept of "temperature" and provides methods to measure it. A hot body is said to have a higher temperature than a cold body. If a hot body is placed in contact with a cold body, heat transfers ~~fo~~ from the former to the latter till they attain thermal equilibrium. The temperature difference can be measured with a "thermometer". Suppose a thermometer is placed in contact with a hot body until thermal equilibrium is reached, the temperature of the body is represented by the position of the mercury column in the thermometer. //

The first law of thermodynamics

The first law of thermodynamics may be stated in two forms.

i) as the law of ~~con~~ conservation of energy

ii) in terms of increase in internal energy

i) law of conservation of energy

The first law of thermodynamics is the law of conservation of energy. It states that "Energy can neither be created nor destroyed. although it may be converted from one form into another." In otherwords whenever one form of energy disappears in a system an exactly equivalent amount of another form is produced. It implies that the total energy of a system and its surroundings. (i,e Universe) remains constant.

ii) First law of thermodynamics in terms of Increase in Internal energy.

Internal energy: Is the total energy content of the System. It is due to the translational, vibrational and rotational motions of the molecules and their mutual attractions (intermolecular force) in a System. It is different from the external energy of the System which originates when a system is placed in a force field like magnetic, electrical, gravitational etc. The internal energy changes when the System changes from one state to another. The energy change ΔE depends on the initial and final state of the System and hence it is a State function.

Consider a gas which expands by absorbing a definite amount of heat. The ~~absorr~~ absorbed heat is utilised in two ways.

i) to increase the internal energy from E_1 to E_2

$$\Delta E = E_2 - E_1$$

ii) to do mechanical work ~~W~~ W against the external pressure, Then

$$q = \Delta E + W$$

$$\Delta E = q - W \rightarrow (1)$$

Thus, "the internal energy change of a system is equal to the quantity of heat absorbed minus the mechanical work done by the system."

For an infinitesimally small change

$$dE = \delta q - \delta W \rightarrow (2)$$

Since, Work = pressure × Volume change

$$\delta W = P.dV$$

$$\therefore dE = \delta q - P.dV \rightarrow (3)$$

Equations (1) (2) and (3) are the mathematical forms of the first law of Thermodynamics. //

The second law of Thermodynamics :

The second law of thermodynamics has been stated in various forms.

1) Kelvin Statement

"It is impossible to construct an engine which is able to convert heat completely into work by a ~~cy~~ cyclic process without producing changes either in the system or in the surroundings."

2) Clausius statement

"It is impossible to construct an engine which is able to convey heat by a cyclic process from a cold reservoir to a hot reservoir without the aid of an External agency".

3) Entropy Statement

"The entropy of the universe remains constant in a ~~rese~~ reversible process but it tends to increase in a spontaneous process.

//

Heat Engine

Heat engine is a device which converts heat into work. A heat engine, in general, consists of three parts.

1. **Source**: A source or high temperature reservoir at temperature. T_1

2. **Sink** : A sink or low temperature at ~~tem~~ reservoir at temperature T_2.

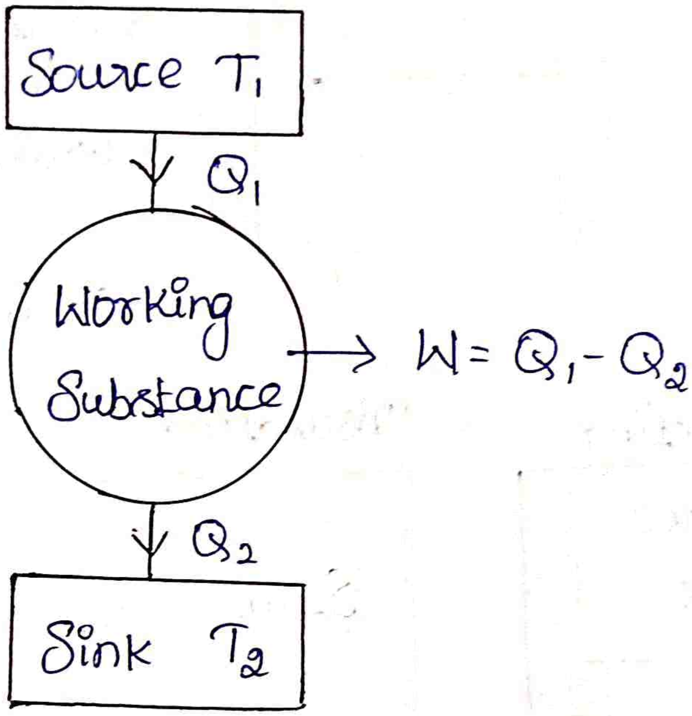
3. **Working Substance**: In a cycle of heat engine, the working substance extracts heat Q_1 from source does some work W and rejects remaining heat Q_2 to sink.

$$\left.\begin{array}{r}\text{Efficiency of heat} \\ \text{engine } \eta\end{array}\right\} = \frac{\text{Work done } (W)}{\text{Heat taken from Source } (Q_1)}$$

$$= \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

$$= \frac{T_1 - T_2}{T_1} \quad (\text{or}) \quad \frac{Q_1 - Q_2}{Q_1}$$

$$= 1 - \frac{T_2}{T_1} \quad (\text{or}) \quad 1 - \frac{Q_2}{Q_1}$$



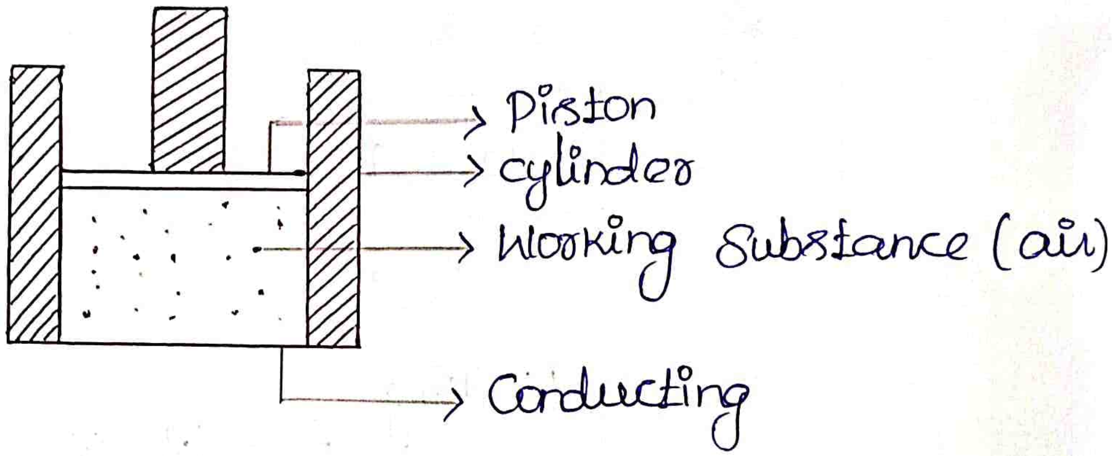
This is general expression for the efficiency of heat engine. //

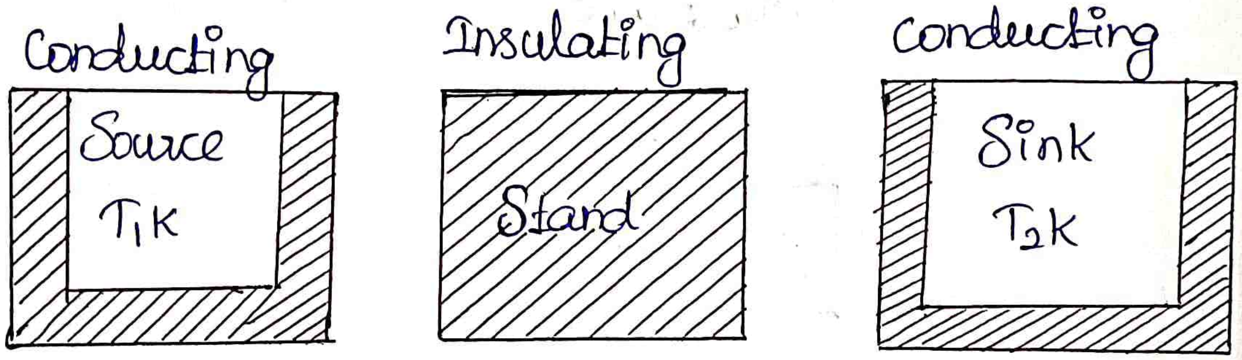
Expression for the efficiency of a carnot's engine.

carnot's engine consists of the following parts.

Source : A Source is ~~ko~~ a hot body at a constant temperature T_1K. The heat engine can drawn heat from the source.

2) Sink : The Sink is a cold body at a constant lower temperature T_2K. Any amount of heat can be rejected to the Sink.





3) Working Substance :

The working Substance is an ideal gas enclosed in a cylinder - piston arrangement.

A perfect non-Conducting stand is also provided so that the working Substance can undergo adiabatic operation.

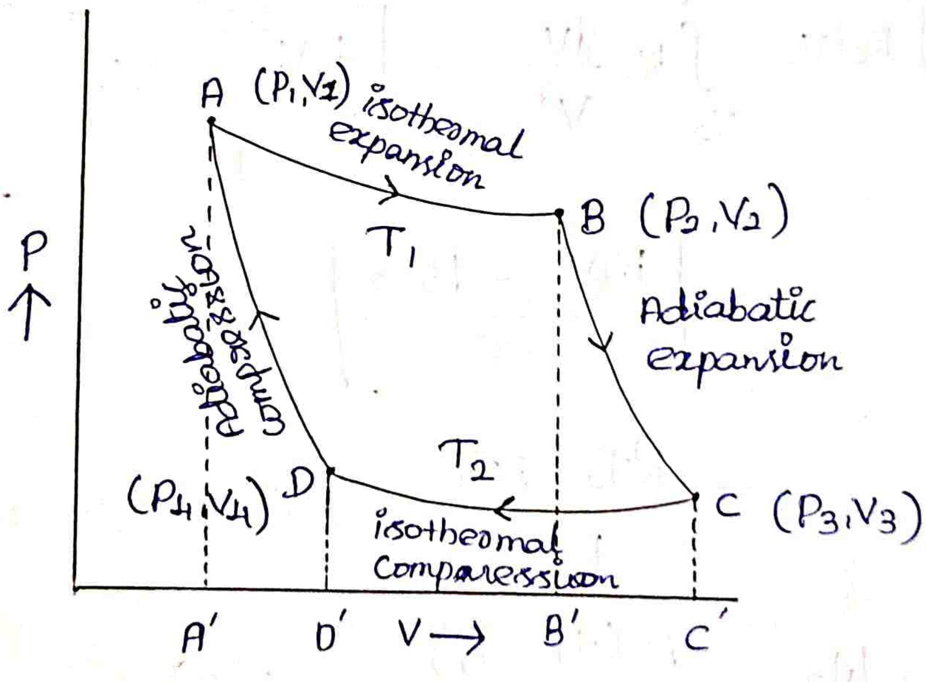
Carnot's cycle

i) Isothermal expansion AB.

Place the cylinder on the Source at temperature T_1.

The piston is moved slowly upward So that the gas expands isothermally. The isothermal expansion of the gas is represented by the curve AB.

Consider one gram molecule of the gas.



Let the quantity of heat absorbed from the Source be Q_1

This is equal to the amount of work done W_1 by the gas in the expansion from initial State (P_1, V_1) to final State (P_2, V_2)

$$Q_1 = W_1 = \int_{V_1}^{V_2} P\,dV = RT_1 \int_{V_1}^{V_2} \frac{dV}{V} = RT_1 \log_e \left[\frac{V_2}{V_1}\right] \rightarrow (1)$$

ii) Adiabatic expansion BC

Place the cylinder on the insulating stand. Allow the gas to expand adiabatically till the temperature falls to T_2. The change is represented by the adiabatic BC.

The work done by the gas W_2 is given by

$$W_2 = \int_{V_2}^{V_3} P\,dV = \int_{V_2}^{V_3} K \frac{dV}{V^\gamma} = \left[\frac{KV_3^{1-\gamma} - KV_2^{1-\gamma}}{1-\gamma}\right]$$

$$= \left[\frac{P_3V_3 - P_2V_2}{1-\gamma}\right] \quad (\because P_2V_2^\gamma = P_3V_3^\gamma = K)$$

$$= \frac{RT_2 - RT_1}{1-\gamma} \quad (\because P_2V_2 = RT_1 \text{ and } P_3V_3 = RT_2)$$

$$W_2 = \frac{R(T_1 - T_2)}{(\gamma - 1)} \rightarrow (2)$$

iii) Isothermal Compression CD:

Place the cylinder on the sink at temperature T_2

$$= RT_1 \log_e\left[\frac{V_2}{V_1}\right] + \frac{R(T_1-T_2)}{(\gamma-1)} - RT_2 \log_e\left[\frac{V_3}{V_4}\right] - \frac{R(T_1-T_2)}{(\gamma-1)}$$

$$W = RT_1 \log_e\left[\frac{V_2}{V_1}\right] - RT_2 \log_e\left[\frac{V_3}{V_4}\right] \longrightarrow (5)$$

The points A and D are on the same adiabatic

$$T_1 V_1^{\gamma-1} = T_2 V_4^{\gamma-1}$$

$$\frac{T_2}{T_1} = \left[\frac{V_1}{V_4}\right]^{\gamma-1} \longrightarrow (6)$$

The points B and C are on the same adiabatic.

$$T_1 V_2^{\gamma-1} = T_2 V_3^{\gamma-1}$$

$$\frac{T_2}{T_1} = \left[\frac{V_2}{V_3}\right]^{\gamma-1}$$

From (6) and (7)

$$\left[\frac{V_1}{V_4}\right]^{\gamma-1} = \left(\frac{V_2}{V_3}\right)^{\gamma-1}$$

$$\frac{V_1}{V_4} = \frac{V_2}{V_3} \longrightarrow (8)$$

The gas is compressed isothermally till the gas attains the State D. The change is represented by the curve CD. let the quantity of heat rejected to the Sink be Q_2. This is equal to the work done W_3 on the gas.

$$Q_2 = W_3 = \int_{V_3}^{V_4} P\,dV = RT \int_{V_3}^{V_4} \frac{dV}{V} = RT_2 \log_e \left[\frac{V_4}{V_3}\right]$$

$$Q_2 = W_3 = -RT_2 \log_e \left[\frac{V_3}{V_4}\right] \rightarrow (3)$$

iv) adiabatic compression DA :

Place the cylinder ~~an~~ on the insulated ~~Stad~~ Stand. The gas is compressed adiabatically untill the temperature rises to T_1. The change is represented by the adiabatic DA.

Work done from D to A is

$$W_4 = \int_{V_4}^{V_1} P\,dV = \frac{-R(T_1 - T_2)}{(\gamma - 1)} \rightarrow (4)$$

The network done by the gas

$$W = W_1 + W_2 + W_3 + W_4$$

From (5) and (8)

$$W = RT_1 \log_e \frac{V_2}{V_1} - RT_2 \log_e \frac{V_2}{V_1}$$

$$= R(T_1 - T_2) \log_e \frac{V_2}{V_1} \rightarrow (9)$$

$$W = Q_1 - Q_2 = R(T_1 - T_2) \log_e \frac{V_2}{V_1} \rightarrow (10)$$

The efficiency (η) of the engine is defined as

$$\eta = \frac{\text{Amount of heat converted into work}}{\text{Total heat absorbed from the source}}$$

$$= \frac{Q_1 - Q_2}{Q_1} = \frac{R(T_1 - T_2) \log_e \left[\frac{V_2}{V_1}\right]}{RT_1 \log_e \left[\frac{V_2}{V_1}\right]}$$

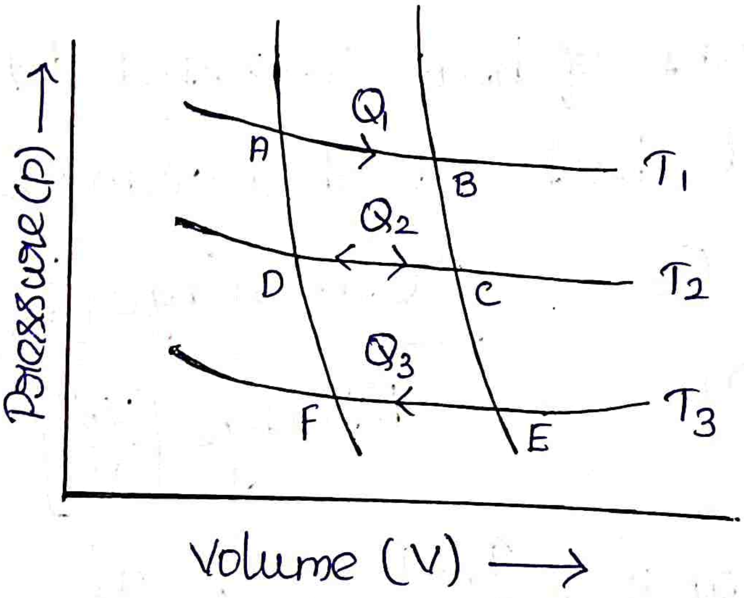
$$\text{Efficiency } \eta = \frac{T_1 - T_2}{T_1} = 1 - \frac{T_2}{T_1} \rightarrow (11)$$

Entropy

The entropy of a substance is that physical quantity which remains constant when the substance undergoes a ~~res~~ reversible adiabatic process.

Explanation

Consider two adiabatics AF and BE crossed by a number of isothermals at temperatures T_1, T_2, T_3. Consider the carnot cycle ABCD. Let Q_1 be the heat absorbed from A to B at temperature T_1. Let Q_2 be the heat rejected from C to D at temperature T_2.



Then, from the theory of carnot engine

$$\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$$

Similarly consider the carnot cycle DCEF Q_2 is heat absorbed at temperature T_2 and Q_3 heat rejected at temperature T_3.

Then $\frac{Q_2}{T_2} = \frac{Q_3}{T_3}$

$$\frac{Q_1}{T_1} = \frac{Q_2}{T_2} = \frac{Q_3}{T_3} = \text{Constant}$$

Thus, if Q is the amount of heat absorbed or rejected in going from one adiabatic to another along any isothermal at temperature T, then

$$Q/T = \text{Constant}$$

This constant ratio is called the change in entropy in going from the adiabatic AF to the adiabatic BE.

If a system absorbs a quantity of heat dQ at constant temperature T during a reversible process, then entropy increases by

$$ds = \frac{dQ}{T}$$

Similarly, if a substance gives out a quantity of heat dQ at temperature T, during a reversible change, then its entropy decreases by

$$ds = \frac{dQ}{T}$$

Unit of entropy is JK^{-1}

For an adiabatic change, we have $dQ = 0$

$\therefore dS = 0$

Thus, there is not change of entropy during a reversible adiabatic process. //

Units of entropy

i) cal deg^{-1} (e.u)

ii) Joules per degree kelvin (JK^{-1})

Entropy change for reversible process

If a system undergoes a reversible change through a series of carnot cycles from state A to B then the entropy change is given by

$$\Delta S_{sys} = \frac{q_{rev}}{T}$$

$$\Delta S_{sur} = \frac{-q_{rev}}{T}$$

$$\Delta S_{(sys)} + \Delta S_{(sur)} = \frac{q_{rev}}{T} - \frac{q_{rev}}{T}$$

$$= 0$$

Thus, In a reversible process, the total entropy change of the System and the Surroundings will be zero. //

Entropy change for an irreversible (or Spontaneous) process.

Consider a process in which the absorption of heat by the System takes place under reversible condition while the remaining part of the carnot cycle is irreversible. Then the entropy change is given by

$$\Delta S_{sys} = \frac{q_{rev}}{T}$$

$$\Delta S_{sur} = \frac{-q_{irr}}{T}$$

$$\therefore \Delta S_{sys} + \Delta S_{sur} = \frac{q_{rev}}{T} - \frac{q_{irr}}{T}$$

We know that

$$W_{rev} > W_{irr}$$

$$\therefore q_{rev} > q_{irr}$$

$$\frac{q_{rev}}{T} - \frac{q_{irr}}{T} > 0$$

(or) $\Delta S_{sys} + \Delta S_{sur} > 0$

$$\Delta_{sys} \neq \Delta S_{sur}$$

Thus, the total energy change of the System and the Surroundings (universe) tend to increase in an irreversible or spontaneous process. This means that the entropy changes of the System and the Surroundings are not the Same. This is the " Clausius inequality principle. //

Entropy of perfect gas

Consider one gram of a perfect gas at a pressure p, volume V and temperature T. Let the quantity of heat given to the gas δH.

$$\delta H = dU + \delta W$$

$$\delta H = 1 \times C_v \times dT + \frac{Pdv}{J}$$

$$\delta H = Tds$$

$$Tds = C_v dT + \frac{P.dv}{J} \rightarrow (1)$$

Also $PV = rT$

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

$$Tds = C_v dT + \frac{\gamma T . dv}{JV} \rightarrow (2)$$

$$ds = C_v \frac{dT}{T} + \frac{\gamma}{J} . \frac{dv}{V}$$

Integration $\int_{S_1}^{S_2} ds = C_v \int_{T_1}^{T_2} \frac{dT}{T} + \frac{\gamma}{J} \int_{V_1}^{V_2} \frac{dv}{V}$

$$S_2 - S_1 = C_v \log_e \frac{T_2}{T_1} + \frac{\gamma}{J} \log_e \frac{V_2}{V_1} \rightarrow (3)$$

$$S_2 - S_1 = C_v \times 2.3026 \log_{10} \frac{T_2}{T_1} + \frac{\gamma}{J} \times 2.3026 \log_{10} \frac{V_2}{V_1} \rightarrow (4)$$

The change in entropy can be calculated in terms of pressure also

$$PV = \gamma T$$

Differentiating $Pdv + Vdp = \gamma dT$

$$PdV = \gamma dT - Vdp \rightarrow (5)$$

Substituting the value of PdV in equation (1)

$$Tds = C_v \times dT + \frac{\gamma dT}{J} - \frac{Vdp}{J}$$

$$Tds = \left(C_v + \frac{\gamma}{J}\right) dT - \frac{Vdp}{J}$$

But $C_v + \frac{\gamma}{J} = C_p$ $\quad Tds = C_p \times dT - V$

$$ds = C_p \frac{dT}{T} - \frac{Vdp}{JT} \rightarrow (6)$$

Also $$PV = rT$$

$$\frac{V}{T} = \frac{r}{P}$$

$$ds = C_v \frac{dT}{T} - \frac{r}{J}\frac{dp}{P}$$

Integrating $$\int_{S_1}^{S_2} ds = C_p \int_{T_1}^{T_2} \frac{dT}{T} - \int_{P_1}^{P_2} \frac{dp}{P}$$

$$S_2 - S_1 = C_p \log_e \frac{T_2}{T_1} - \frac{r}{J} \log_e \frac{P_2}{P_1}$$

$$S_2 - S_1 = C_p \times 2.3026 \times \log_{10} \frac{T_2}{T_1} - \frac{r}{J} \times 2.3026 \log_{10} \frac{P_2}{P_1}$$

Note r is the ~~orgi~~ ordinary gas constant and has to be I units of work. C_p represents the specific heat for 1 gram of a constant pressure.

If C_p represents gram molecular specific heat of a constant pressure and R the Universal gas constant, then

$$S_2 - S_1 = C_p \times 2.3026 \log_{10} \frac{T_2}{T_1} - \frac{R}{J} \times 2.3026 \log_{10} \frac{P_2}{P_1}$$

Change of Entropy in Conversion of ice into steam.

Let m kg of ice at a temperature T_1K be converted into water at the same temperature. Then it is heated up to a temperature T_2K. At T_2K, it is converted into steam. The net change in entropy from ice to steam can be calculated in 3 steps.

i) Let L_1 be the specific latent heat of fusion of ice. To convert m kg of ice at T_1K into water at the same temperature an amount of heat mL_1 is added to it. Hence

$$\text{increase in entropy} = \Delta S_1 = \frac{mL_1}{T_1} \rightarrow (1)$$

ii) m kg of water at T_1K is heated to T_2K

$$\text{increase in entropy} = \Delta S_2 = \int_{T_1}^{T_2} mc \frac{dT}{T}$$

$$= mc \log_e \frac{T_2}{T_1} \rightarrow (2)$$

Here, C is the specific heat capacity of water.

iii) Let L_2 be the specific latent heat of Vaporization. When m kg of water at T_2 K is converted into Steam at the same temperature, it absorbs heat mL_2.

The increase in entropy = $\Delta S_3 = \frac{mL_2}{T_2} \rightarrow (3)$

$\therefore$ Total gain in entropy = $\Delta S = \Delta S_1 + \Delta S_2 + \Delta S_3$

$$\Delta S = \frac{mL_1}{T_1} + mc \log_e \frac{T_2}{T_1} + \frac{mL_2}{T_2} \rightarrow (4)$$

Isothermal process

When a change in the pressure and volume of the a given mass of gas takes place at constant temperature, the process is called an Isothermal process.

Adiabatic process

An adiabatic process is a process in which changes in volume and pressure of a given gas takes place in complete thermal isolation. During an adiabatic process no heat enters or leaves the system but the temperature changes.

Unit - V

OPTICS

(i) Interference

Introduction

Interference is the phenomenon of superposition of two coherent waves in the region of superposition. At some points in the medium, the intensity of light is maximum (constructive interference). At some other points, the intensity is minimum (destructive interference). The positions of maximum intensity are maxima, while those of minimum intensity are called minima.

Let λ be the wavelength in interfering waves and δ the phase difference at a point under consideration. Then

Condition of maxima : Phase-difference $\delta = 2m\pi$

or path-difference, $\Delta = m\lambda$,

$m = 0, 1, 2 \ldots$ etc

Condition of minima : Phase-difference, $\delta = (2m+1)\pi$

Path-difference $\Delta = (2m+1)\lambda/2$

$m = 0, 1, 2, 3 \ldots$

The relation between the path and Phase differences is given by

$$\text{Phase - difference} = \frac{2\pi}{\lambda} \times \text{path difference}$$

Air wedge

Consider a wedge-shaped film of refractive index n enclosed by two plane surface OP and OQ inclined at an angle θ (Fig (a)).

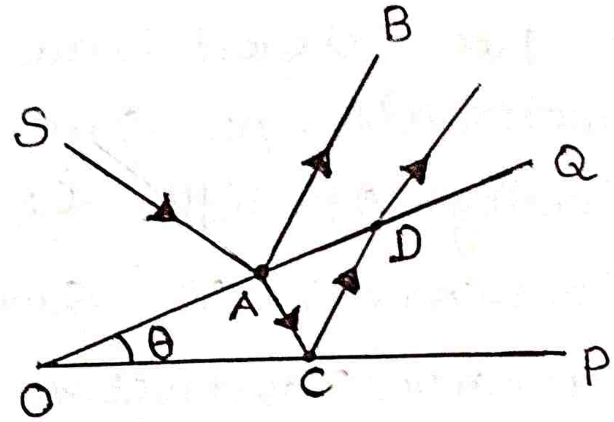


Fig (a)

The thickness of the film increases from O to P. When the film is illuminated by a parallel beam of monochromatic light, interference occurs between the rays reflected at the upper and lower surfaces of the film. So equidistant alternate dark and bright fringes are observed. The fringes are parallel to the line of intersection of the two surfaces. The interfering rays are AB and DE both originating from the same incident ray SA.

Expression for the fringe width:

The Condition for a dark fringe is

$2nt \cos r = m\lambda$

Here for air $n=1$. for normal incidence $\cos r = \cos 0 = 1$. Suppose the mth dark fringe is formed where the thickness of the air film is t_m (Fig(b)). Then,

$$2 \times 1 \times t_m \times 1 = m\lambda$$

or $$2t_m = m\lambda \longrightarrow (1)$$

Suppose the $(m+1)$ th dark fringe is formed where the thickness of the air film is t_{m+1}. then,

$$2t_{m+1} = (m+1)\lambda \longrightarrow (2)$$

Substracting (1) from (2)

$$2(t_{m+1} - t_m) = \lambda \longrightarrow (3)$$

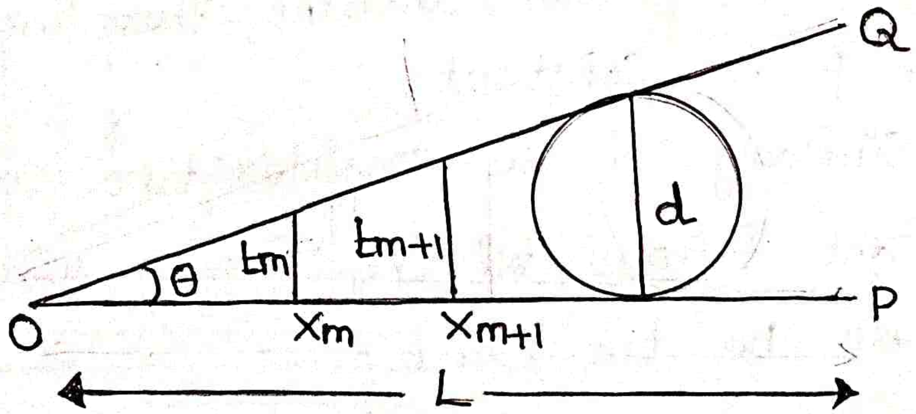


Fig (b)

Let x_{m+1} and x_m be the distances of the $(m+1)$th and mth dark fringes from O.

d - diameter of the wire

L - distance between O and the wire.

Then,
$$\frac{t_{m+1}}{x_{m+1}} = \frac{t_m}{x_m} = \frac{d}{L} = \theta$$

$$t_{m+1} = \frac{d}{L} x_{m+1} \quad , \quad t_m = \frac{d}{L} x_m$$

Substituting these values in Eq (3), we get
$$2\frac{d}{L}(x_{m+1} - x_m) = \lambda$$

But $x_{m+1} - x_m = \beta$ = fringe width

or
$$2\frac{d}{L}\beta = \lambda$$

$$\therefore \beta = \frac{\lambda L}{2d} = \frac{\lambda}{2\theta}$$

d, λ and L are constant. Therefore, fringe width β is constant.

Similarly, if we consider two consecutive bright fringes, ~~wil~~ the fringe width β will be the same.

Experiment to Measure the Diameter of a Thin wire :

An air wedge is formed by inserting the wire between two glass plates. Monochromatic light is reflected vertically downwards on to the wedge by the inclined glass plate G (Fig(a)).

A travelling microscope M with its axis vertical is placed above G. The microscope is focused to get clear dark and bright fringes. The fringe width (β) is measured. The length (L) of the wedge also is measured. Knowing λ, the diameter (d) of the wire is calculated using the formula

$$d = \frac{\lambda L}{2\beta}$$

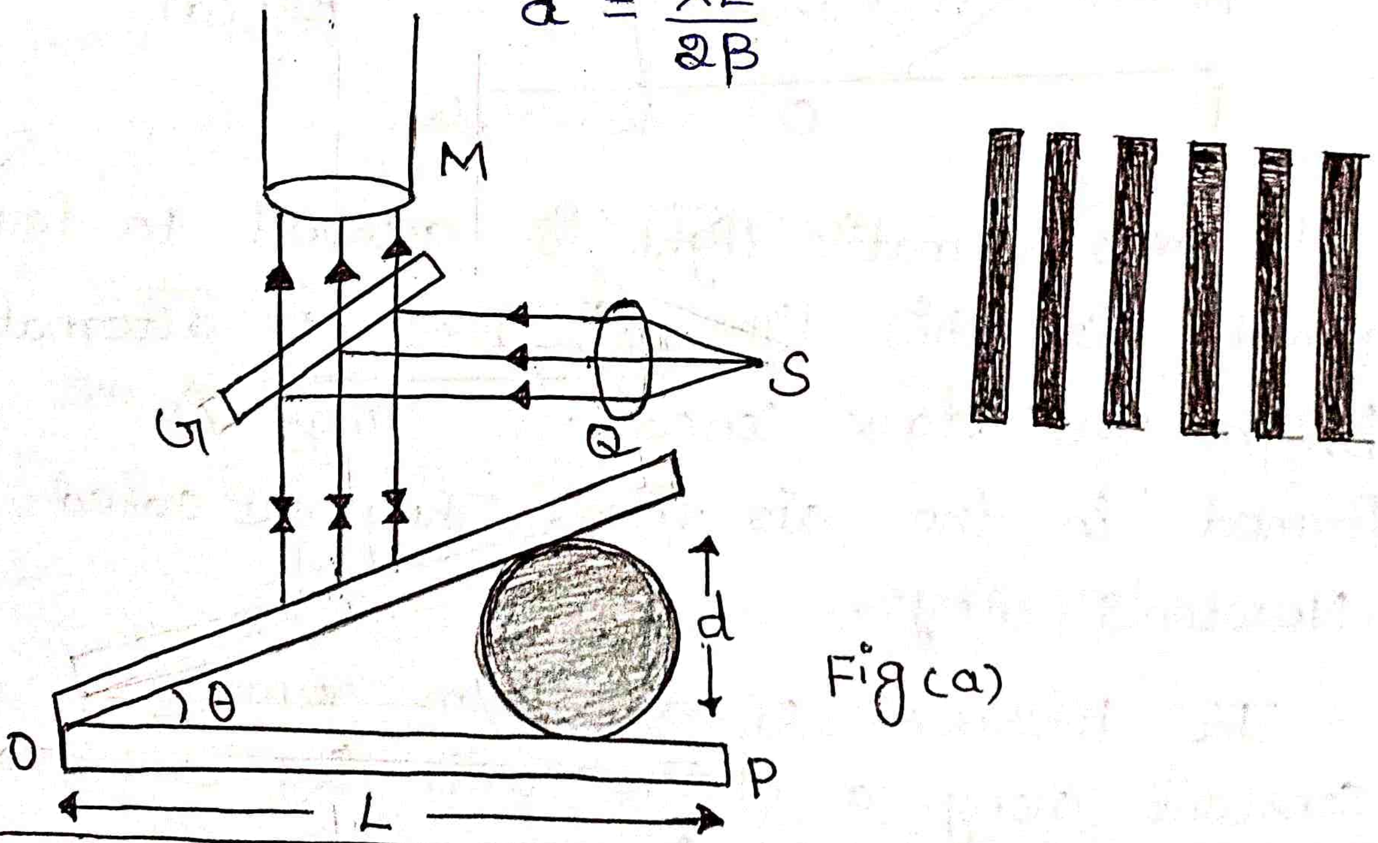


Fig (a)

Newton's Rings

A plano - convex lens of large radius of Curvature is placed with its convex surface in contact with a plane glass plate.

Then an air - film is formed between the lower surface of the lense AOB and the upper surface of the plate POQ (Fig (a)).

The thickness of the air film is zero at the point of contact O and gradually increases from the point of contact out wards.

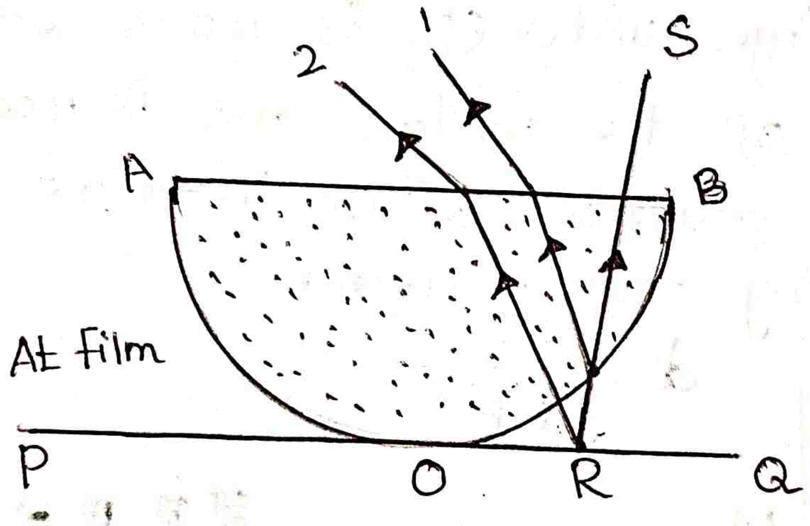


Fig (a)

If monochromatic light is allowed to fall normally on this film, a System of alternate bright and dark concentric rings is formed in the air film. They are called Newton's rings.

The thickness of air - film remains constant along a circle with its centre at O

Hence the fringes are in the form of concentric circles.

Newton's rings are formed as a result of interference between the light waves reflected from the upper and lower surface of the air film.

1 and 2 are the interfering rays corresponding to an incident ray SR.

Expression for the radii of the rings

R is the radius of curvature of the lens and A is the centre of curvature (Fig (b)). Let there be mth dark ring at point c. The thickness of the air film at point c is OB = t. The radius of the mth dark ring is r_m = BC. Let DC be the chord and OE the diameter intersecting at right angles at B.

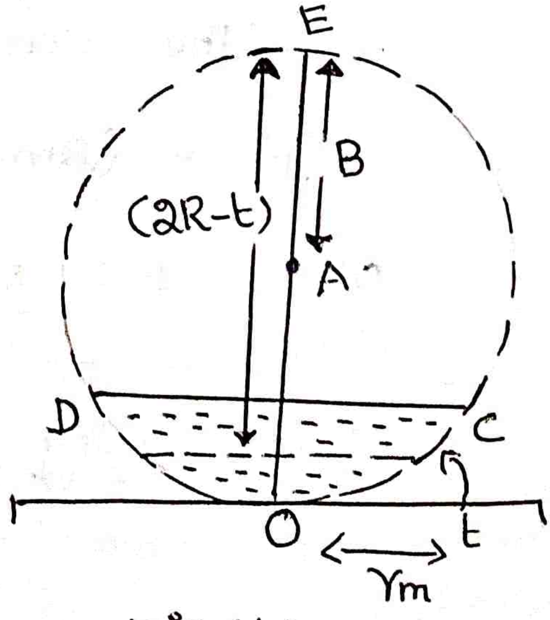


Fig (b)

From the geometry of the circle,

$$DB \times BC = EB \times BO$$

$$r_m^2 = (2R-t) \times t$$

In Practice $t \ll R$, So that $2R - t \approx 2R$

Or $$r_m^2 = 2Rt \longrightarrow (1)$$

The Condition for a dark ring is $2nt = m\lambda$

Here, $m = 0, 1, 2, 3 \ldots$

$$\therefore t = \frac{m\lambda}{2n} \longrightarrow (2)$$

Substituting for t in Eq (1) we get

$$r_m^2 = \frac{2Rm\lambda}{2n} = \frac{Rm\lambda}{n}$$

$$\therefore r_m = \sqrt{\frac{mR\lambda}{n}} \longrightarrow (3)$$

Thus the radii of the dark rings are Proportional to the square roots of the natural numbers.

Bright rings :

The Condition for a bright ring is

$$2nt = (2m-1)\lambda/2 \quad (m = 1, 2, 3 \ldots etc)$$

Or $$t = \frac{(2m-1)\lambda/2}{2n} \longrightarrow (4)$$

Substituting for t in Eq (1), we get

$$r_m^2 = \frac{2R(2m-1)\lambda/2}{2n} = \frac{(2m-1)R\lambda}{2n}$$

$\therefore$ Radius of mth bright ring =

$$r_m = \sqrt{\frac{(2m-1)R\lambda}{2n}} \longrightarrow (5)$$

Thus the radii of the bright rings are proportional to the square roots of add natural numbers.

The diameters of m^{th} dark and bright rings as

$$D_m = \sqrt{\frac{4mR\lambda}{n}} \quad \text{Dark ring} \longrightarrow (6)$$

$$D_m = \sqrt{\frac{2(2m-1)R\lambda}{n}} \quad \text{Bright ring} \longrightarrow (7)$$

Determination of Wavelength of Sodium Light by Newton's Rings

Experimental Arrangement :

Fig(c) shows an experimental arrangement for producing Newton's rings by reflected light. S is an extended source of monochromatic light. The light from S is rendered parallel by a convex lens L_1. These horizontal parallel rays fall on a glass plate G at 45°, and are partly reflected from it. This reflected beam falls normally on the lens L placed on the glass plate PQ.

Interference occurs between the rays reflected from the upper and lower surfaces of the film. The interference rings are viewed with a microscope M focused on the air film

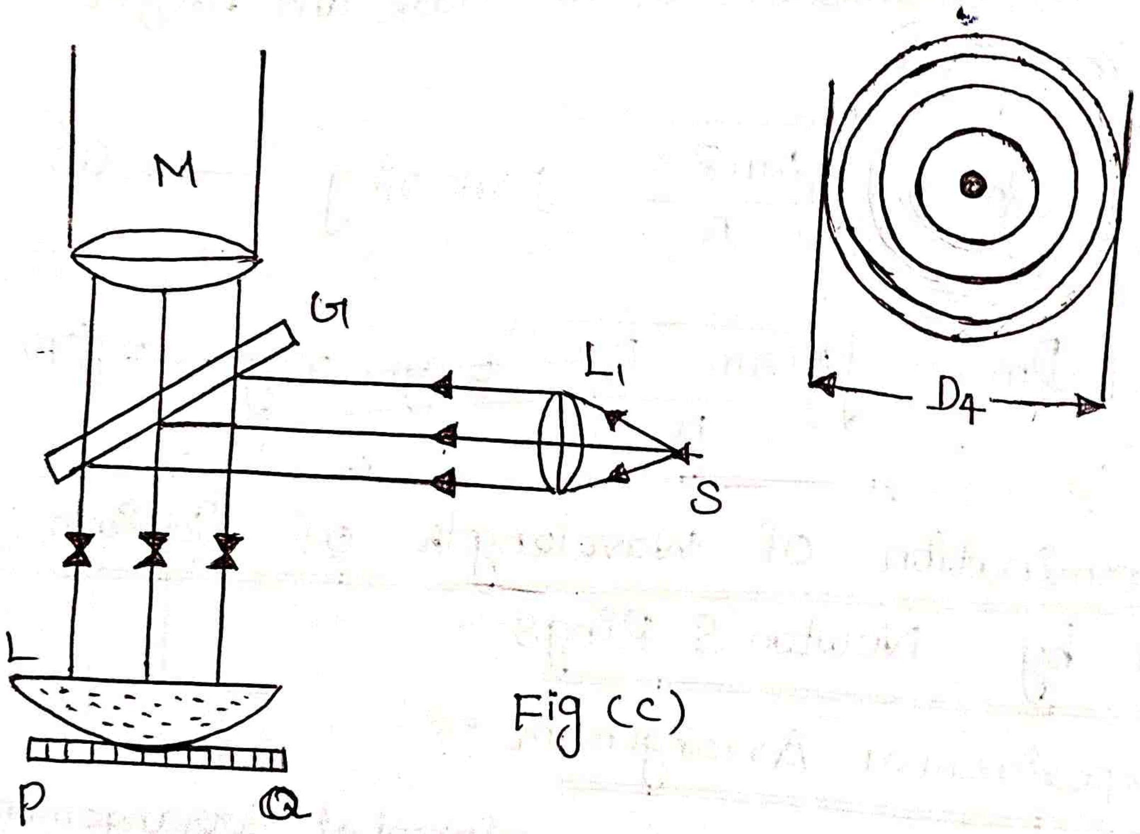


Fig (c)

~~Proce~~ Procedure:

With the help of the travelling microscope, the diameters of a number of dark rings are measured.

The position of the microscope is adjusted to get the centre of Newton's rings at the point of intersection of the cross-wires. The microscope is moved until one cross wire is tangential to the 16th dark ring. The microscope reading is taken.

Then the microscope is moved such that the cross-wire is successively tangential to 12th, 8th and 4th dark rings respectively. The readings are noted in each case. Readings corresponding to the same rings on the other side of the centre are taken.

The readings are tabulated as follows:

No. of ring	Reading of travelling microscope		Diameter of ring	D^2	$D_m^2 - D_p^2$
	Left(a)	Right(b)	$D = a - b$		
16					
12					
8					
4					

Average $(D_m^2 - D_p^2) =$

The average value of $(D_m^2 - D_p^2)$ is found,

For an air film, $n = 1$

$\therefore$ The diameters of pth and mth rings are given by

$$D_p^2 = 4pR\lambda \text{ and } D_m^2 = 4mR\lambda$$

$$D_m^2 - D_p^2 = 4(m-p)R\lambda$$

$$\therefore \lambda = \frac{D_m^2 - D_p^2}{4(m-p)R}$$

The radius of curvature R of the lower surface of the lens is found by Boy's method. Substituting this value of R and the average value of $(D_m^2 - D_p^2)$ with $(m-p) = 8$ in the above equation, λ is calculated.

(ii) Diffraction

Introduction

If an opaque object is placed between a source of light and a screen, a sharp shadow is obtained on the screen. This shows that light travels in straight lines. If, however, the size of the ~~so~~ obstacle is small, (comparable to the wave length of light) there is a departure from straight line propagation and the light bends into the geometrical shadow.

This phenomenon of bending of light waves around corners and their spreading into the geometrical shadow of an object is called diffraction.

Plane Transmission Diffraction Grating

An arrangement consisting of a large number of parallel slits of equal width and separated from one another by equal opaque spaces is called ~~a~~ diffraction grating.

Theory :

Consider a parallel beam of light incident normally on a grating XY Fig (a) AB, CD, EF are the transparent slits. Let the width of each slit be a and the width of each opaque portion be b. Then the points distance (a+b) is called the grating constant or grating element. The points in the consecutive slits separated by the distance (a+b) are called the corresponding points. Most of the light issuing from the spaces will go straight on. But as the width of spaces is comparable to the wavelength of light, part of this spreads out in all directions, on leaving the slits.

(i) Suppose a telescope with its axis normal to the grating is placed in the path of diffracted light. Then the rays issuing out normally are brought to focus at a point O lying on the principal axis of the lens L. All the rays reaching O are in phase with each other. Hence the rays reinforce producing a central bright band (central maximum).

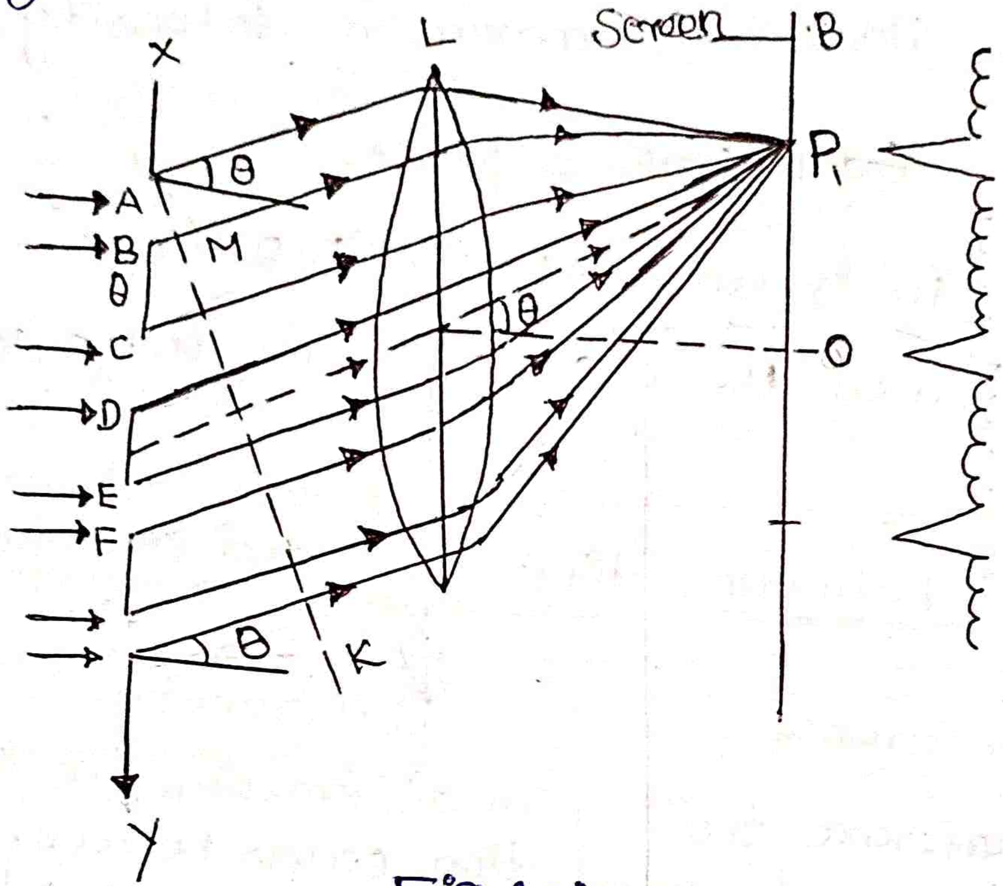


Fig (a)

(ii) The rays diffracted at an angle θ with the grating normal reach P_1 on passing through the lens in different phase. Draw AK ~~PNR~~ perpendicular to the direction of the diffracted light. Then CN is the path difference between the rays diffracted from the two corresponding points A and C at angle θ

The path difference $CN = AC \sin\theta$

$= (a+b) \sin\theta$

If this path difference is an even multiple of $\lambda/2$, then the point p will be bright. Hence for maximum intensity, we have

$$(a+b)\sin\theta = \pm m\lambda$$

Here, m is an integer 0, 1, 2, 3 etc

m is called the order of the interference maximum.

Difference between diffraction and interference

S. NO	Interference	Diffraction
1.	In interference, the interaction occurs between two separate wave fronts originating from the two coherent sources	In diffraction, the interaction occurs between the secondary wavelets originating from different points of the exposed parts of same wave front.
2.	The minimum intensity points are perfectly dark in interference pattern	The minimum intensity ~~position~~ points are not perfectly dark in diffraction pattern
3.	In an interference pattern all the ~~[illegible]~~ maxima are of same intensity	In a diffraction pattern the maxima are varying intensity

4	Interference fringes are of the same width	Diffraction fringes are not of the same width
5	In interference a large number of fringes can be observed	In diffraction, only a few fringes can be observed.

Determination of wave length of Light using Transmission Grating (Normal Incidence)

Principle:

If θ is the angle of diffraction for a wave length λ in the mth order then

$$(a+b) \sin\theta = m\lambda$$

Here, $(a+b)$ is called grating element

If the grating element $(a+b)$ and the angle of diffraction θ for order m are determined, then λ can be calculated

(i) Determination of $(a+b)$

On every grating the number of rulings per inch is written. Let N be the number of rulings per inch. Then

Then $(a+b) = 0.0254 / N$ metre

(ii) Determination of Angle of Diffraction θ:

Adjust a spectrometer (Fig a) for work. Illuminate the ~~slit~~ slit with the source whose wave length is required

(i) Take the direct reading of the telescope

(ii) Rotate the telescope by 90° and fix it.

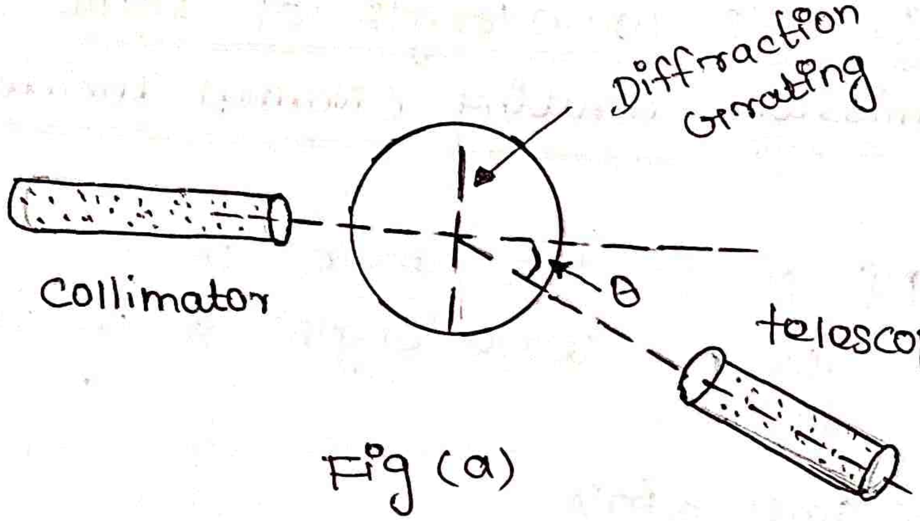


Fig (a)

(iii) Mount the grating on the prism table so that the rules are vertical and the ruled surface is at the centre of the prism table. Rotate the prism table until the image of the slit reflected by the grating coincides with the intersection of the cross-wires in the telescope.

Take the reading of the prism table

iv) Rotate the prism table by 45° in the proper direction so that the plane of the grating is normal from the collimator and fix the prism table

In this position, the grating is normal to the incident light (Fig (b))

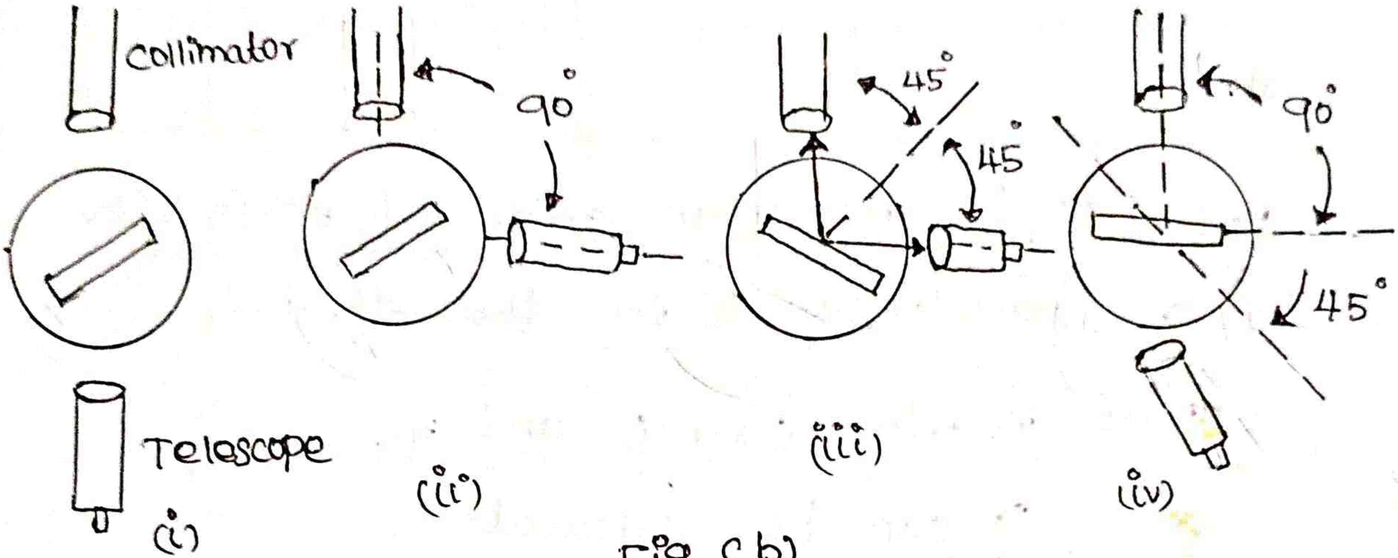


Fig (b)

Bring the telescope to take the direct reading. Get first order spectrum in the telescope. Make the cross-wire coincide with the various spectral lines one after another. Take the reading in each case. The difference between this and the direct reading gives the angle of diffraction.

The angle of diffraction may be found for the spectrum on the other side of the normal as well as for other orders of spectra.

The readings are tabulated as shown below

Order	Colour	Vernier Reading		2θ	θ	λ
		Left	Right			
I						
II						

Let θ be the mean angle of diffraction for a wavelength λ in the mth order

Thus knowing (a+b) θ and m.

λ can be calculated.

Polarisation of Light

Suppose ordinary light is incident normally on a pair of parallel tourmaline crystal plates P_1 and P_2 (Fig (1)) cut parallel to their crystallographic axis

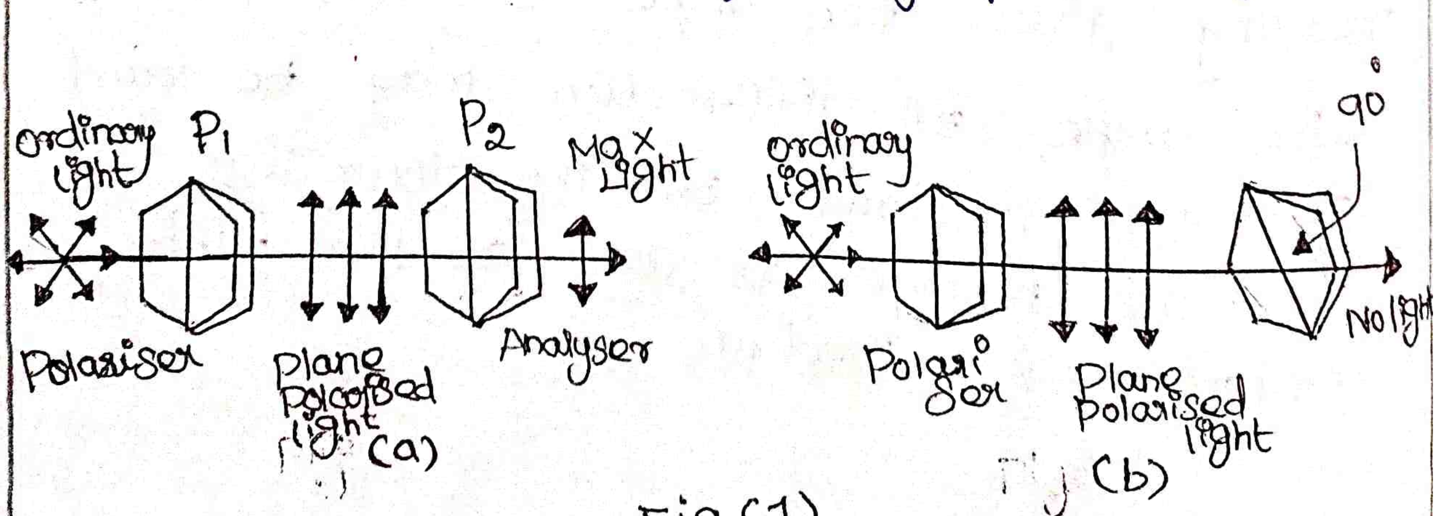


Fig (1)

The emergent light shows a variation in intensity as P_2 is rotated. The intensity is maximum when the axis of P_2 is parallel to that of P_1 [(Fig 1 (a)]

The intensity is minimum when the axis of P_2 is at right angles to the axis of P_1 [Fig (1) (b)]

This shows that the light emerging from P_1 is not symmetrical about the direction of propagation of light. but its vibrations are confined only to a single line in a plane perpendicular to the direction of propagation, such light is called polarised light.

OPTICAL ACTIVITY

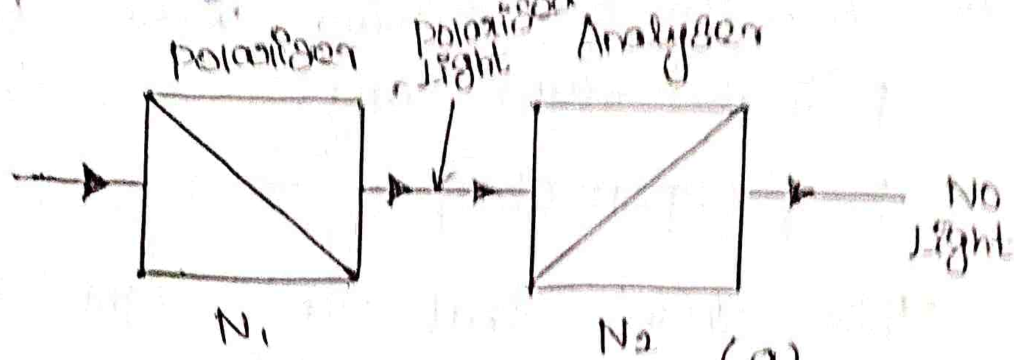
Introduction

The property of rotating the plane of vibration of polarised light by certain crystals and other substances is called optical activity.

Substance which rotate the plane of polarisation are known as optically active substances.

Substances like cinnabar, sodium chlorate, sugar crystals, turpentine oil. sugar solution, quinine sulphate solution etc. are optically active.

If we take two crossed Nicols N_1 and N_2 the light incident on N_1 does not pass through N_2 [Fig 1(a)]



(a)

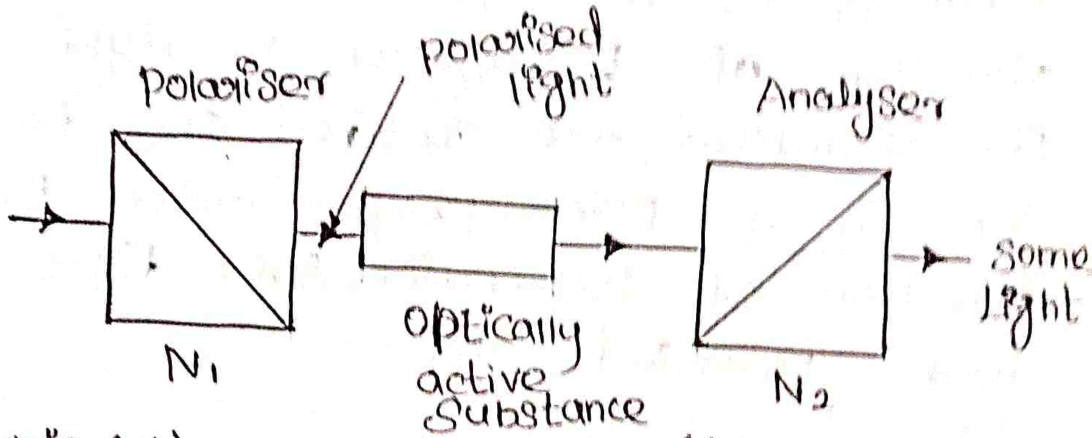


Fig (1) (b)

But if we introduce some particular substance (such as sugar solution, quartz crystal etc) between these crossed nicols N_1 and N_2 [Fig (1) (b)] then some light begins to pass through N_2. The light is, however, again completely cut off if N_2 is rotated through a certain angle.

This shows that the light emerging from the quartz crystal is still plane.

polarised. But its plane of polarisation has been rotated by the quartz crystal through a certain angle. Thus quartz is optically-actived.

There are two type of optically-active substance. Those which rotate the plane of polarisation clockwise (looking against the direction of light) are called "dextro-rotatory" or "right-handed" while those which rotate anti-clockwise are called "laevo-rotatory" of "left-handed". Quartz occurs in both forms. Cane Suger is dextro whereas fruit sugar is laevo.

The angle through which the the plane of polarisation is rotated by the substance is called an angle of rotation θ.

Biot's Laws for Rotatory Polarisation

(i) The angle of ~~ratio~~ rotation θ of the plane of polarisation, for a given wave length, is directly proportional to the length (l) of the optically-active substance traversed ie $\theta \propto l$

(ii) For solution angle of rotation θ for a given path length is proportional to the concentration (c) of the solution i.e, $\theta \propto C$

iii) For Solutions, angle of rotation θ for a given path length.

(iii) The rotation produced by a number of optically-active substances is equal to the algebraic sum of individual rotations. The anti-is or anti-clock wise and clock-wise rotations are taken with opposite sign.

$$\theta = \theta_1 + \theta_2 + \theta_3 + \cdots$$

iv) The angle of rotation is approximately inversely proportional to the square of wave length of light employed

i.e, $\theta \propto \frac{1}{\lambda^2}$

Specific Rotatory power

The specific rotatory power of Solution at a given temperature and for a given wave length, is defined as the rotation (in degree) produced by 1 decimeter length of the Solution when its concentration is 1 gm/cc

unit : deg. $dm^{-1}(gm/cc)^{-1}$

$$\boxed{\theta = \alpha c l}$$

Here θ is the rotation produced in degrees, l is the length of the Solution

Here in decimetre (10 cm) and c is the concentration in gm/cc

Laurent's Half-Shade polarimeter

Construction: Its optical parts are shown in Fig (a) Light from a monochromatic source S is rendered parallel by a convex lens. L and falls on the polarising Nicol P which converts it into plane polarised light. This light passes through a half-shade devide H and then through the analyser containing the solution. The transmitted light passes through the analyser A. The light emerging from the analyser is observed through a telescope G. The analyser Nicol A. can be rotated about the axis of the tube and its position can be read on circular scale S.

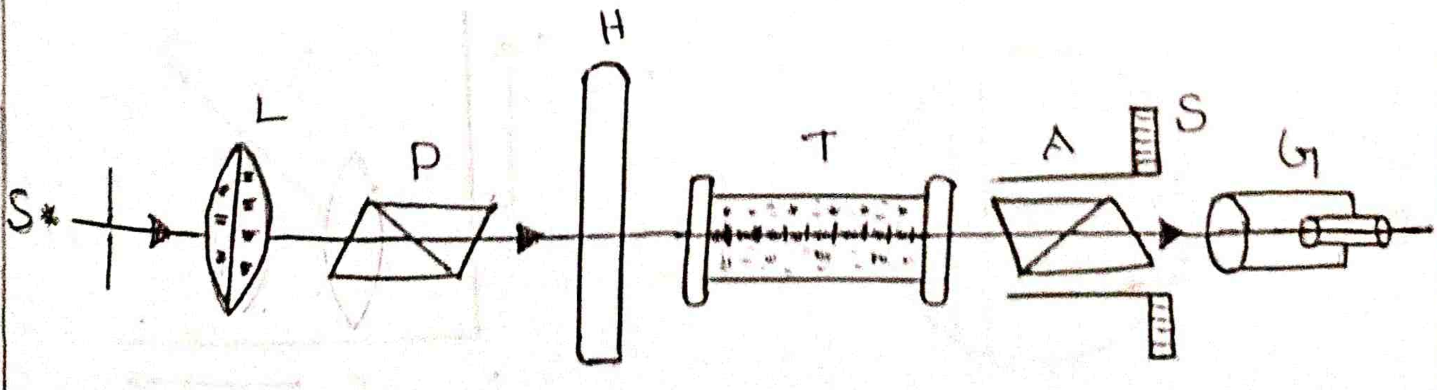


Fig (a)

Determination of Specific Rotatory Power of Sugar Solution

The tube is first filled with water.
The analyser A is adjusted to obtain the condition of equal brightness of the two halves of the field of view. The position of the analyser is read on the circular scale (R_0).

The tube is filled with sugar solution of known concentration. Now the analyser is rotated to obtain equally illuminated position of the field is view again Fig (a) The position of the analyser is again read on the scale (R_1)

Now, $R_1 \sim R_0 = \theta$ = angle of rotation
The direction of rotation of the analyser gives the sense of rotation of the plane of polarisation by active substance.

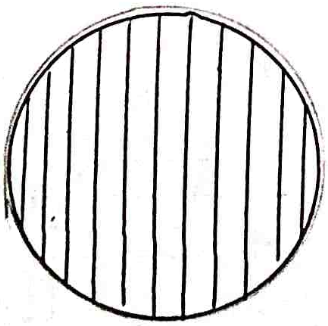


Fig (a)

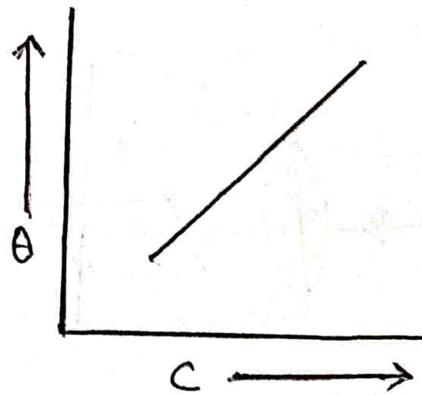


Fig (b)

In actual experiment, the angle of rotation is determined for various concen-tration of the sugar solution. A graph between concentration c of the sugar solution and angle of rotation θ is plotted. The graph is a straight line Fig(b)

From the graph, the ratio θ/c is determined. The specific rotation of sugar is calculated from the relation,

$$\alpha = \frac{\theta}{lc}$$

Here, l is the length of the tube in decimetre, θ is the rotation in degrees and c is the concentration of solution in gm/cc