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MD IFTAKHAR KABIR SAKUR

25th BATCH

COMPUTER AND COMMUNICATION ENGINEERING

International Islamic University Chittagong

COURSE CODE: PHY-1201

COURSE TITLE: Physics II

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Physics - Note - 01

1st Semester:-

Mid term + Final

Tuesday
16.07.2020

Date: 18. 07. 20
Saturday

Lecture-01 Lesson-1

Gravity and Gravitation

* Aristotle believed & said that, "a heavier body to reach the ground is less as compared to a lighter body dropped from the same height.

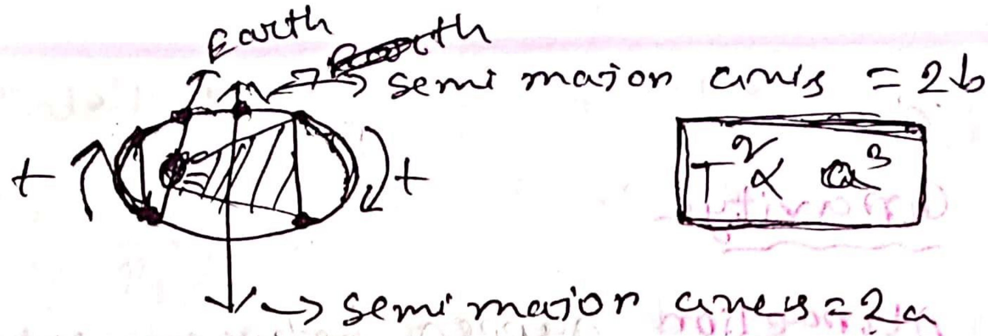
In 1590, Galileo disapproved the idea. He did a public experiment in "pisa" tower with a stone and a paper. ~~The~~ He said that due to a resistance offered by air on the paper, the paper reached after the stone. If that experiment was done in vaccume then both stone and paper would reach on the ~~Flo~~ ground ~~Flo~~ Floor at the same time.

E) Kepler's law of planetary motion:-

1) Every planet moves in an elliptical orbit with the sun being one of its foci (Focus এর plural)

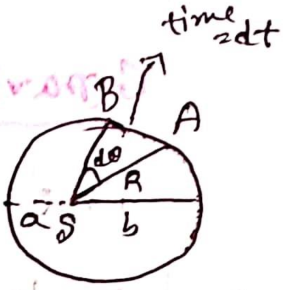
2) The radius vector drawn from the sun to the planet sweeps out equal areas in equal interval of time.
[সমান সময়ে সমান দূরত্ব বা ক্ষেত্রফল অতিক্রম করে] => [Laws of areas]

3) [The periods of planets]:-
The square of the periods of revolution of a planet around the sun is proportional to the cube of the semi major axis of the orbit.
[যখন কোনো গ্রহ সূর্যের কাছ দিয়ে যায় তখন দ্রুত যায়, আর যখন গ্রহ দূর দিয়ে যায় তখন আস্তে গমন করে]



$\boxed{T^2 \propto a^3}$

$\boxed{Q}$



Formula of Kepler's law no. 2 :-

2. Area swept in time dt

$\therefore$ = Area ABS $= \frac{1}{2} R \times R d\theta = \boxed{\frac{1}{2} R^2 d\theta}$

r^2
$r.r$
$\pi\, a.b$

Areal velocity,

$$\frac{\frac{1}{2} R^2 d\theta}{dt} = \frac{1}{2} R^2 \left(\frac{d\theta}{dt}\right) = \frac{1}{2} R^2 \omega$$
= Constant

~~If we~~ So, $\boxed{\frac{1}{2} R^2 \omega}$ is Constant

as a result, $\boxed{\frac{1}{2} M R^2 \omega}$ is also a constant

Total area of elipse

$\pi a b$ [a is semi minor axes
b is semi major axes]

সূর্যের চারদিকে কোনো গ্রহের ঘূর্ণনের সময়,

$$T = \frac{\text{Area}}{\text{Area velocity}} = \frac{\pi a b}{\frac{1}{2} R^2 \omega} = \boxed{\frac{2\pi a b}{R^2 \omega}}$$

3

Gravity:-

Attraction happen between earth & many other objections.

Gravitation:-

The attraction force between any two bodies in the universe is called gravitation.

Derivation of law of gravitation:-

(মাধ্যাকর্ষণ আইন আবিষ্কার)

$$F_1 = M_1 R_1 \omega_1^2 = M_1 R_1 \left[\frac{2\pi}{T_1}\right]^2 \rightarrow \text{Force of planet A} \quad \text{—(i)}$$

$$F_2 = M_2 R_2 \omega_2^2 = M_2 R_2 \left[\frac{2\pi}{T_2}\right]^2 \rightarrow \text{Force of planet B} \quad \text{—(ii)}$$

(i) : (ii)

$$\frac{F_1}{F_2} = \frac{M_1 R_1 \left[\frac{2\pi}{T_1}\right]^2}{M_2 R_2 \left[\frac{2\pi}{T_2}\right]^2} = \left(\frac{M_1}{M_2}\right)\left(\frac{R_1}{R_2}\right)\left(\frac{T_2}{T_1}\right)^2 \quad \text{—(iii)}$$

Kepler's third law,

$$\left(\frac{T_2}{T_1}\right)^2 = \left(\frac{R_2}{R_1}\right)^2$$

Substituting this ~~(iv)~~ in equation (iii)

$$\therefore \frac{F_1}{F_2} = \left(\frac{M_1}{M_2}\right)\left(\frac{R_2}{R_1}\right)^2$$

$$\therefore \frac{F_1 R_1^2}{M_1} = \frac{F_2 R_2^2}{M_2} = \text{Constant}$$

$$\therefore F \propto \frac{M}{R^2} \text{ or, (i) } F \propto M \text{ \& (ii) } F \propto -\frac{1}{R^2}$$

এখানে দূরত্ব বুঝানোতে (−) বসেছে

According to the Newton:-

The Force of attraction must be mutual., a force exerted by ~~the~~ a ~~earth on the body~~. body on the earth must be equal and opposite to the force ~~ext~~ exerted by the earth on the body. Newton reduced the

Kepler's laws into a single law of gravitation.

~~পৃথিবী~~ নিউটনের মতে, বলের আকর্ষণ দুই দিক হতেই সমান হতে হবে। পৃথিবীর উপর কোনো কিছুর আকর্ষণ বলের মান, পৃথিবী হতে ওই বস্তুর উপর দেওয়া ~~ও~~ বিপরীত বলও সমান হতে হবে।

4 Newton's Universal law of gravitation (নিউটনের মহাকর্ষ সূত্র):-

This ~~t~~ law is true not only for the heavenly bodies but also for any two bodies of the Universe.

Law :-

The attraction force between any two bodies in the universe is directly proportional to the ~~square of the~~ product of their masses & inversely proportional to the square of the distance between

Kepler's laws into a single law of gravitation.

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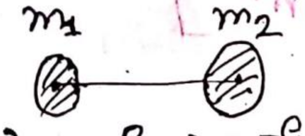


$R \rightarrow$ মধ্যবর্তী দূরত্ব

$F \propto M.m$

Or, $F \propto \frac{1}{R^2}$ (অর্থাৎ $F \propto \frac{Mm}{R^2}$)

$\therefore F = G\frac{Mm}{R^2}$ $[G = 6.67 \times 10^{-11} Nm^2/kg^2]$

According to the newton's second law OF motion $F = ma$.

Here $a = g$, where g is the acceleration due to gravity.

$$\frac{g'}{g} = \frac{r^2}{R^2}$$ [g' = গ্রহের অভিকর্ষজ ত্বরণ
g = পৃথিবীর অভিকর্ষজ ত্বরণ
r = পৃথিবীর ব্যাসার্ধ
R = গ্রহের ব্যাসার্ধ]

বা, $g' = \frac{gr^2}{R^2}$

বা, $g' = \frac{v^2}{R^2} = \frac{\left(\frac{2\pi R}{T}\right)^2}{R^2} = \frac{4\pi^2 R}{T^2}$

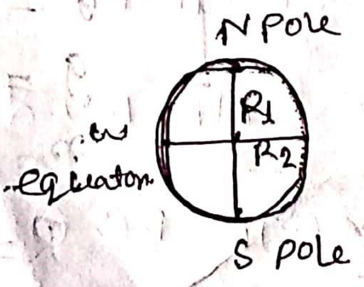
$\therefore \frac{gr^2}{R^2} = \frac{4\pi^2 R}{T^2}$

বা, $R^3 = \frac{gp^2T^2}{4\pi^2}$ বা, $R = \left[\frac{gp^2T^2}{4\pi^2}\right]^{1/3}$

Value of 'g' at the poles and at the equator :-

(মেরু ও অক্ষরেখায় 'g' এর মান)

⇒ The shape of the earth is slightly ellipsoidal (অধ উপবৃত্ত). It is bulging (ফোলা) at the equator (অক্ষরেখায়) and flattened (চেপ্টা) at the poles (মেরু). Its equatorial (নিরক্ষীয়) radius is more than the ~~plo~~ polar radius.



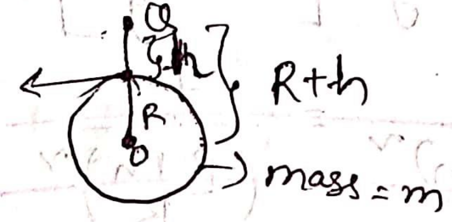
$R_2 > R_1$

$\therefore g = \frac{GM}{R^2}$

$\therefore g \propto \frac{1}{g^2}$

Variation of g with altitude :-

(পৃথিবী পৃষ্ঠের উচ্চতা দিয়ে কোথাও গেলে g এর মান যেভাবে পরিবর্তিত হয়):-



A body of mass (m) when placed at the point P experiences a force (mg) towards the centre of the earth.

$$mg = \frac{GMm}{R^2} \quad ---(i) \qquad \left[\because F = \frac{GMm}{R^2}\right]$$

$$F = mg$$

When the body is at Q, let the acceleration due to gravity be g',

$$\therefore mg' = \frac{GMm}{(R+h)^2} \quad ---(ii)$$

(ii) ÷ (i)

এখানে,

$$\frac{g'}{g} = \frac{GM}{(R+h)^2} \Big/ \frac{GM}{R^2}$$

$$= \frac{R^2}{(R+h)^2} = \frac{1}{\left(\frac{R+h}{R}\right)^2} = \boxed{\frac{1}{\left(1+\frac{h}{R}\right)^2}}$$ —— সূত্র

$\Rightarrow$ পৃথিবী হতে কোনো বস্তুকে যত উপরে নেওয়া যায়, h এর মান ততই কমতে থাকে। কমতে কমতে 0 এর মধ্যে চলে আসে।

$$\therefore \left(\frac{h}{R}\right)^2 = 0.$$

$$\therefore \boxed{g' = g\left(1 - \frac{2h}{R}\right)}$$ —— সূত্র

Therefore the acceleration due to gravity decreases with altitude.

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also Note:-

দ্বিপদী বিস্তৃতি :-

$$(1+x)^{-2} = 1-2x+3x^2-4x^3$$

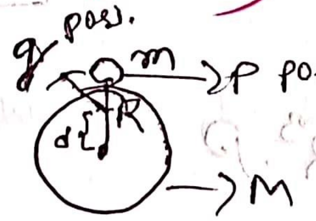
অতএব,

$$\left(1+\frac{h}{R}\right)^{-2} = 1-\frac{2h}{R}+\frac{3h^2}{R}-\dots\dots$$

$$\therefore \left(1+\frac{h}{R}\right) = \left(1-\frac{2h}{R}\right)$$ [বাকি অংশগুলোর মান 0 হয়]

Variation of g with Depth:-

(গভীরতায় g এর মান)



Let g, & g' be the accelerations due to gravity at P & Q respectively. At P the whole mass of the earth attracts the body & at Q it is attracted by the mass of the earth of radius $(R-h)$

$$\therefore mg = \frac{GMm}{R^2}$$

$$বা,\ g = \frac{GM}{R^2}$$

Same,

$$mg' = \frac{GM'm}{\cancel{(R-h)^2}\,(R-d)^2}$$

$$বা,\ \boxed{g' = \frac{GM'}{(R-d)^2}}$$

[M′ এর কারণ হলো পৃথিবীর ভেতরে গেলে একদিকে ব্যাসার্ধ কমলে চারদিকেই কমে যায়। আয়তন ছোট হলে ভর ও ছোট হয়]

[$\rho = \frac{M'}{V}$

বা, $M = \rho V$]

at point P,

তে, $M' = \frac{4}{3}\pi R^3 \cdot \rho$

at point Q,

$$M' = \frac{4}{3}\pi (R-d)^3 \cdot \rho$$

$$\therefore g = \frac{GM}{R^2} = \frac{G\,\frac{4}{3}\pi R^3\cdot\rho}{R^2} = \boxed{\frac{G\cdot 4\cdot\pi R\cdot\rho}{3}} \quad -(3)$$

ρ = ঘনত্ব (পৃথিবীর)

$$\therefore g' = \frac{GM'}{(R-d)^2} = \frac{\frac{4}{3}\pi(R-d)^3\cdot\rho}{(R-d)^2} = \boxed{\frac{4\pi(R-d)\rho}{3}} \quad -(4)$$

ρ is the Density of the earth

(4) ÷ (3)

$$\frac{g'}{g} = \frac{4\pi G\cancel{R\cdot\rho}(R-d)\cdot\rho}{3} \times \frac{3}{4\pi GR\rho}$$

$$= \frac{R-d}{R} = 1 - \frac{d}{R}$$

$$\therefore \boxed{g' = g\left(1 - \frac{d}{R}\right)} \qquad [\because g << R]$$

$$g' = g(0.9\ldots)$$

$g' < g$ (এর মানে হলো, পৃথিবীর যত গভীরতায় যাওয়া যায় ততই g' এর মান কমবে)

গভীরে গেলে ব্যাসার্ধ কমে, কিন্তু তাও অভিকর্ষজ ত্বরণের মান কমে কেনো?

$$\Rightarrow \boxed{\frac{GM}{R^2}} = \frac{G\frac{4}{3}\cdot\pi R^3\cdot\rho}{R^2}$$

এখানে, ভর এর মান কমে R^3 আকারে আর ব্যাসার্ধ কমে R^2 আকারে। যেহেতু ভর ~~বেশ~~ বেশি কমে, তাই অভিকর্ষজ ত্বরণের মান কমে।

Variation of g with Rotation of the earth :-

$$g_\lambda' = g(1 - \omega^2 R\cos^2\lambda)$$

ω = কৌনিক বেগ

R = পৃ. ব্যাসার্ধ

$\cos\lambda$ = কেন্দ্রাতিগ বলের কোণ

g = অভিকর্ষজ ত্বরণ

g' = পরিবর্তিত " "

বিষুব রেখা বরাবর, $\lambda = 90°$;

অর্থাৎ, $\cos\lambda = \cos 90° = 1$

$$\therefore \boxed{g_0' = g - \omega^2 R} \Rightarrow \text{বিষুব রেখা}$$

মেরু অঞ্চলে,

$\lambda = 90^\circ$; অর্থাৎ, $\cos \lambda = 0$.

$\therefore g_{90} = g$.

আহ্নিক গতির ফলে,

বিষুবীয় অঞ্চলে ত্বরণ এর মান সবচেয়ে কম

মেরু ,, (নিরক্ষবৃত্ত ,, অভিকর্ষজ ,,) ,, বেশি।

এর ফলে, আহ্নিক গতির ফলে বস্তুর ওজন বিষুবীয় অঞ্চল হতে মেরু অঞ্চলের দিকে ক্রমশ বৃদ্ধি পায়।

Gravitational Field:-
(মহাকর্ষীয় ক্ষেত্র)

The gravitational force of attraction is perceived (অনুভূত) is called gravitational field.

If the gravitational field at a point is E, the force acting on a mass m is F.

$\therefore F = mE$

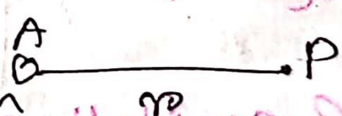
বা, $E = \frac{F}{m}$ ———— (i)

$= -\frac{dV}{dr}$ [also defined as the negative gradient of gravitational potential]

Gravitational potential :-
(মহাকর্ষীয় সম্ভাবনা)

Consider a particle A of mass m, P is a point at a distance r from A. The gravitational intensity at P.

$E = \frac{F}{m} = \frac{GM}{r^2}$ —— (i)



$E = -\frac{dV}{dr}$ —— (ii)

বা, $dV = -E \times dr$

$= -\left(\frac{GM}{r^2}\right) dr$ [(ii) হতে পাই]

~~At Infinity~~ Integration between the limits of infinity and r,

$$V = -\frac{GM}{r}$$

∴ The gravitational potential at a point due to a point mass,

$$= \left(-\frac{GM}{r}\right)$$

Q Gravitational potential energy of a body depends upon:-

(i) The mass of the body at A.

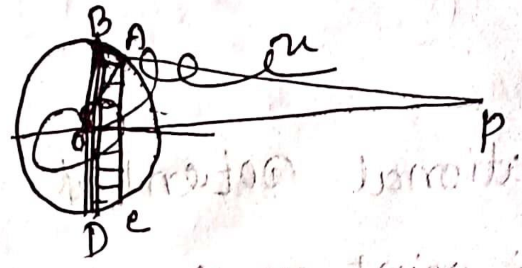
(ii) The mass of the body at BP

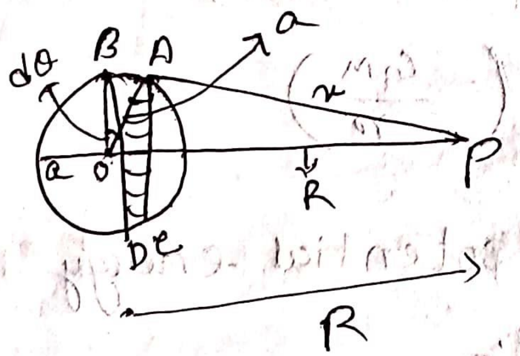
(iii) the distance between two masses.

*** Gravitational potential & field at a point due to a spherical shell:- (गुब्बारा)

⇒

P.T.O





এখানে,

$AB = a\,d\theta \quad [\because s = r\theta]$

Surface area of element AC, BD

$= 2\pi(a\sin\theta)\,a\,d\theta \quad \left[\sin\theta = \frac{r}{a},\ \therefore r = a\sin\theta\right]$

$= 2\pi a^2 \sin\theta\, d\theta$ — (2)

mass of the element,

$m = (2\pi a^2 \sin\theta\, d\theta)\rho$ — (3)

Now,

$AP = x$

P, point এর সাপেক্ষে gravitational potential,

$dv = -\frac{E\,dr}{} \quad$ বা, $E = \frac{dv}{dr}$

$\therefore E = \frac{GMm}{r^2 m} = \frac{GM}{r^2}$

$\therefore dv = -\frac{GM}{r x}$

$= -G\frac{2\pi a^2 \sin\theta\, d\theta\, \rho}{x}$ —— (4)

$\triangle AOP$ এর জন্য,

$x^2 = a^2 + R^2 - 2aR\cos\theta$

এখন, Differentiation করে পাই,

$2x\,dx = 2aR\sin\theta\, d\theta$

বা, $x = \frac{aR\sin\theta\, d\theta}{dx}$ —— (5)

(4) নং equation -এ x এর মান বসাই,

$dv = \frac{2\pi G a^2 \sin\theta\, d\theta\, \rho}{aR\sin\theta\, d\theta}\, dx$

$\therefore dv = -\left(\frac{2\pi G a \rho}{R}\right)$ —— (6)

$V = -\int_{R-a}^{R+a} \frac{2\pi G a \rho}{R}\, dx = \frac{2\pi G a \rho}{R}\left[R+a-R+a\right]$

$$v = -\frac{4\pi a^2 G \rho}{R} \quad \text{—— (7)}$$

আমরা জানি,

ভর, $M = 4\pi a^2 \rho$

$$\therefore v = -\frac{GM}{R} \quad \text{—— (8)}$$

$$F = -\frac{dv}{dR} = -\frac{d}{dR}\left[-\frac{GM}{R}\right]$$

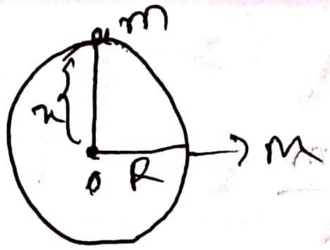
$$= -\frac{GM}{R^2}$$

$$\therefore \vec{F} = -\frac{GM\vec{R}}{R}$$

মুক্তিবেগ
(Escape velocity)

Escape velocity is defined as the valocity with which a body has to ~~to~~ be projected vertically upwards from the earth's gravitational field altogether

(যদি কোনো বস্তুকে gravitational field এর বাইরে নিয়ে যাওয়া হয়)



R = Radius of the earth

M = mass of the earth

m = mass of the object

$$F = \frac{GMm}{x^2} \quad \text{— (i)}$$

$$dw = F \cdot dx$$

$$dw = \left(\frac{GMm}{x^2}\right) dx \quad \text{— (2)}$$

To take the body from earth's surface to Infinity we will get total work (W).

$$W = \int F dx = \int_{\infty} \frac{GMm}{x^2} dx = \int_{R}^{\infty} \frac{GMm}{x^2} dx$$

$$\cancel{= GMm \int_{R}^{\infty} \frac{1}{x^2} dx}$$

$$\cancel{= GMm \left[-\frac{1}{x}\right]^{\infty}}$$

$$\cancel{= GMm \left[-\frac{1}{\infty} + \frac{1}{R}\right]}$$

$$= \left[-\frac{GMm}{x}\right]_{R}^{\infty} = \left[\frac{GMm}{R}\right]$$

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

or, $\frac{1}{2}mv^2 = \frac{GMm}{R}$

$\therefore v = \sqrt{\frac{2GM}{R}}$ — (iv)

Also at the surface ~~ad~~ of the earth,

$mg = \frac{GMm}{R^2}$

$\therefore \boxed{GM = gR^2}$ — (v)

Substituting the value of GM in equation (iv)

$$\boxed{v = \sqrt{2gR}} \quad \text{— (vi)}$$

$\therefore$ The value of g at the earth's surface $= 9.8\ ms^{-2}$

and $R = 6\times106\ m$

$v = \sqrt{2\times9.8\times64\times106}$

$\therefore v = 11.2\times106\ ms^{-2}$

$= \cancel{ttt}\ 11.2\ kms^{-2}$

Date:- 06.08.20
Wednesday 7:55 p.m

Lecture-02

Dynamic of rigid bodies

Dynamic:- (গতিবিদ্যা)

Relating to forces producing motion

The part of mechanics in which motions to the forces associated with it & the proportion of moving object is related is known as dynamics.

Rigid Body (অনমনীয় শরীর(বস্তু))

A body is said to be rigid when it is impossible to change it's shape by the application of a force however large. For practicle purpose all solid bodies are considered as rigid bodies.

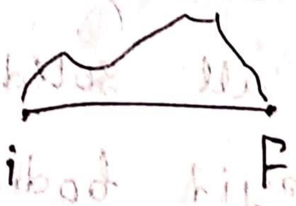
Short Form:-

where two points of a body are fixed or unmovable be though the whole body is movable.

The difference between two points of this body can't move though the ~~do~~ body is movable.

Displacement (সরণ) :-

Displacement is defined as the shortest distance between initial & final position of a body in a particular direction.



Velocity (বেগ) [V]

Valocity is defined as the rate of change of displacement with respect to time. If Δs displacement changes with time Δt,

$\therefore$ velocity, $V = \dfrac{\Delta s}{\Delta t}$ $[ms^{-1}]$

$\therefore$ accelatration, $a = \dfrac{\Delta v}{\Delta t}$ $[ms^{-2}]$

Instantaneous velocity (তাৎক্ষণিক বেগ) :-

It is the limit of the average velocity as the elapsed (অতিক্রান্ত) approaches zero, or the derivative of (s) with respect to t:

$$\text{int } V = \lim_{\cancel{\Delta t \to 0}\ \Delta t \to 0} \frac{\Delta s}{\Delta t} = \frac{ds}{dt}$$

$$\therefore \text{Ins. accelaration, } a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$

$\Rightarrow$ Like average velocity, intantaneous velocity is a vector with dimension of length per ti

ভরবেগ (Mass velocity):-

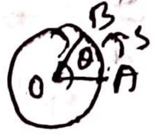
(Momentum)

ভর ও বেগের গুনফলকে ভরবেগ বলে,

$p = mv$

Angular ~~Momentum~~ Displacement :- (θ)

The angle subtended (সম্মুখ) in a particular time interval by an Object or particle at a center of circular path (বৃত্তাকার পথ) along which it is revolving (ঘুরতে থাকা) is called Angular Displacement.



$\theta = s/r$ বা, $\boxed{s = r\theta}$

এখানে θ এর মান অবশ্যই রেডিয়ানে নেওয়া হয়।

রেডিয়ান:-

কোনো বৃত্তের ব্যাসার্ধের সমান চাপ বৃত্তের কেন্দ্রে যে কোন উৎপন্ন করে তাকে রেডিয়ান বলে।

(*)

যদি Rigid Body সম্পূর্ণ বৃত্তাকার পথে একবার ঘুরে আসে তাহলে কেন্দ্রে উৎপন্ন কোন,

$$\theta = \frac{\text{পরিধি}}{\text{ব্যাসার্ধ}} = \frac{2\pi r}{r} = 2\pi \text{ radian}$$

And in Degree,

$$2\pi = 360 \text{ degree}$$

$$\therefore 1 \text{ radian} = \frac{360^\circ}{2\pi} = 57.3^\circ \text{ (প্রায়)}$$

Angular velocity (ω):-

The rate of change of angular displacement with respect to time is called angular velocity (ω)

সময়ের সাথে কৌনিক সরণের অনুপাতকে কৌনিক বেগ বলে।

If $\Delta\theta$ angular displacement changes with time Δt,

$$\boxed{\text{angular velocity, } \omega = \frac{\Delta\theta}{\Delta t}}$$

Instantaneous Angular velocity :-

The angular velocity of a body rotation at any one moment of time is called as instantaneous velocity.

$$\boxed{\omega = \lim_{\Delta t \to 0} \frac{\Delta\theta}{\Delta t} = \frac{d\theta}{dt}}$$

Angular acceleration :-

It is the time rate of change of the angular velocity and is usually designated by α & expressed in radians per second.

Unit system :- SI unit

Symbol :- $rad s^{-2}$

$$\boxed{\alpha = \frac{\Delta\omega}{\Delta t}}$$

Ins. angular acceleration:-

It is the rate of an object rotates in a circular path at a particular moment in time.

$$\boxed{\alpha_i = \lim_{\Delta t \to 0} \frac{d\omega}{dt} \quad [ms^{-2}]}$$

Angular Momentum:- (কৌণিক ভরবেগ)

The angular momentum of a rigid body is defined as the product of the moment of inertia & the angular velocity.

It is analogous (অনুরূপ) to linear (রৈখিক) momentum & is subject to the fundamental constraints (সীমাবদ্ধতা) of the conservation (সংরক্ষণ) of angular momentum principle if there is no external torque on object.

~~Angular veloci~~

কোনো বিন্দু বা অক্ষকে কেন্দ্র করে ঘূর্ণায়মান কোনো কনার ব্যাসার্ধ ভেক্টর এবং ভরবেগের ভেক্টর গুনফলকে ঐ বিন্দু বা অক্ষের সাপেক্ষে কৌণিক ভরবেগ বলে।

moment of momentum $= mvr$

So, Angular Momentum, $L = mvr = m(\omega r)r = mr^2\omega$

$$\boxed{L = I\omega = I\left(\frac{2\pi N}{t}\right)}$$

L = Angular Momentum → $kg\,m^2 s^{-1}$

I = জড়তার ভ্রামক → $kg\,m^2$

ω = কৌণিক বেগ → $rad\,s^{-1}$

N = আবর্তন সংখ্যা

t = সময় (s)

মাত্রা:- ML^2T^{-1}

$L = \vec{r} \times \vec{p}$

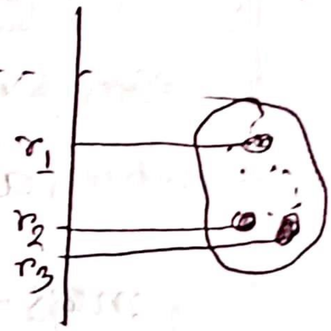
$\vec{p}$ → কনার ভরবেগ

$\vec{r}$ → অবস্থান vector

Moment of Inertia (নিষ্ক্রিয়তা মুহূর্ত) :-
(বা, জড়তার ভ্রামক)

The sum of product of mass & the square of perpendicular distance of each particle of an object from axis of rotation is called moment of inertia of the object.

$$\boxed{\begin{aligned} I &= m_1 r_1^2 + m_2 r_2^2 + m_3 r_3^3 - - - \\ &= \Sigma\, m_1 r_1^2 \end{aligned}}$$



$\therefore \boxed{I = mr^2}$ [জড়তার ভ্রামক)

⇒ কোনো নির্দিষ্ট সরলরেখা থেকে কোনো দৃঢ় বস্তুর প্রত্যেকটি কণার লম্ব দূরত্বের বর্গ এবং প্রত্যেকটির ভর এর গুণফল এর সমষ্টিকে ঐ সরলরেখার সাপেক্ষে ঐ বস্তুর জড়তার ভ্রামক বলে

Note:-

কোনো নির্দিষ্ট অক্ষ বরাবর একক সমকৌণিক বেগে আবর্তনকৃত কোনো দৃঢ় বস্তুর জড়তার

ভ্রামক, সংখ্যাগতভাবে এর গতিশক্তির দ্বিগুণ।
অর্থাৎ,

$\boxed{\text{জড়তার ভ্রামক, } I = 2E}$

Linear (রৈখিক)	Angular (কৌণিক)
S	θ
v	ω
a	α
mass → m	I = moment of Inertia
i	L
Force ← F	T → Torque

$$\boxed{E_K = \frac{1}{2} I\omega^2}$$

Conservation of angular Momentum

(কৌণিক ভরবেগের সংরক্ষণ)

For a body rotating about an axis, change in angular velocity can be constant about (~~a by~~ an external agency called ~~torq~~ torque. In the case of a system when the external torque is zero, the angular momentum of the system remains constant. This is called conservation of angular momentum principle.

এং কোনটি হলে Anguler velocity বেশি হবে।

Shortcut! -

The law of conservation of angular momentum states that, when no external torque acts on an object, no change of angular momentum will occur.

Torque টর্ক

Considering (ধরি), a particle of mass (m) moving about an axis in a circular path of radius (r). Let an external force (F) act on the particle along the tangent to the circular path.

⇒ কোনো বিন্দু বা অক্ষকে কেন্দ্র করে ঘূর্ণায়মান কোনো কণার ব্যাসার্ধ ভেক্টর এবং কণার উপর প্রযুক্ত বলের ভেক্টর ~~গুণফলের~~ গুনফলকে ঐ বিন্দু বা অক্ষের সাপেক্ষে কণাটির উপর প্রযুক্ত টর্ক বলে।

The moment of the Force $= F \cdot r$

The moment of Force is called torque & represented by, τ

$$\therefore \boxed{\tau = F \cdot r = mar = m \cdot \alpha r \cdot r = m\alpha r^2}$$

$$\boxed{\therefore \tau = I\alpha}$$

Hence, Torque is equal to product of moment of inertia & angular acceleration. Torque can also be defined by the rate of change of angular momentum.

$$\tau = \frac{dL}{dt} = \frac{d}{dt}(I\omega)$$

$$= I \cdot \frac{d\omega}{dt} + \omega \cdot \frac{dI}{dt}$$

$$= I \cdot \alpha + 0$$

$$= I\alpha$$

$$\therefore \boxed{\tau = I\alpha}$$

SI unit :- $Kg\,m^2 s^{-2}$

Other units : pound - force - feet, Ibf · inch, ozf · in.

Common Symbols : M

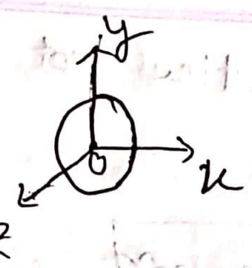
Dimension : ML^2T^{-2}

SI Unit :- newton metre

Perpendicular Axes Theorem:
(লম্ব অক্ষ উপপাদ্য)

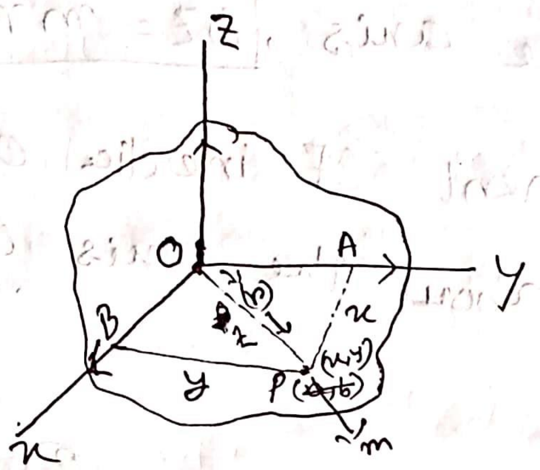
=> The moment of inertia of a ~~place~~ plane laminar body about an axis perpendicular to the plane is equal to the sum of the moments of inertia about two mutually perpendicular axis in the plane of the lamina such that the three mutually perpendicular axis have a common point of intersection.

=> কোনো সমতল পাতের তলে অবস্থিত দুটি পরস্পর লম্ব অক্ষের সাপেক্ষে ঐ পাতের জড়তার ভ্রামকদ্বয়ের সমষ্টি হবে ঐ দুই অক্ষের ছেদবিন্দু দিয়ে এবং পাতের অভিলম্বভাবে গমনকারী অক্ষের সাপেক্ষে পাতটির জড়তার ভ্রামক এর সমান।



$(I_z = I_x + I_y)$

PROOF :-



Considering a plane lamina having the axis ox or oy in the name of Lamina. The axis OZ passes through O & is perpendicular to the plane of the lamina. Let the Lamina be divided into a large number of particles, each of mass(m). Let a particle of mass m be at p with coordinates (x, y) & situated at a distance r from the point of intersection of the axis.

$$r^2 = x^2 + y^2 \quad \text{--- (1)}$$

∴ The moment of inertia ~~at point~~ of the particle P.

about the axis, $\boxed{OZ = mr^2}$ — (1)

The moment of inertia of the whole lamina about the axis OZ is given by,

$$I_z = \sum m r^2 \text{ ——— } (2)$$

The moment of inertia of the whole lamina about the axis Ox,

$$I_x = \sum M y^2 \text{ —— } (3)$$

Similarly, $I_y = \sum M x^2$ — (4)

From equation ~~(1)~~ (1) & (2)

$$I_z = m(x^2 + y^2)$$

$$= mx^2 + my^2$$

$$= I_y + I_x$$ ∴ $I_z = I_x + I_y$

Note:-

[$\sum M_i x_i^2$ = Oy অক্ষের সাপেক্ষে জড়তার ভ্রামক ; $\sum M y_i^2$ - Ox অক্ষের সাপেক্ষে]

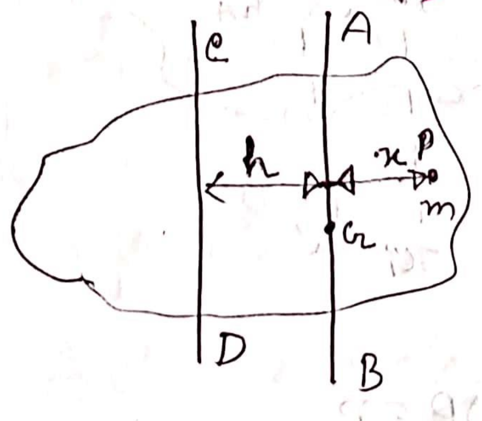
Shortcut:-

The perpendicular axis theorem states that, the moment of inertia of a planar lamina about an axis perpendicular to the plane of the Lamina is equal to the sum of the moments of inertia of lamina about the two axes at right angles to each other, in its own ~~place~~ plane intersecting each other at the point where the perpendicular axis passes through it.

⑮ Parallel axes Theorem :-

(সমান্তরাল অক্ষ উপপাদ্য)

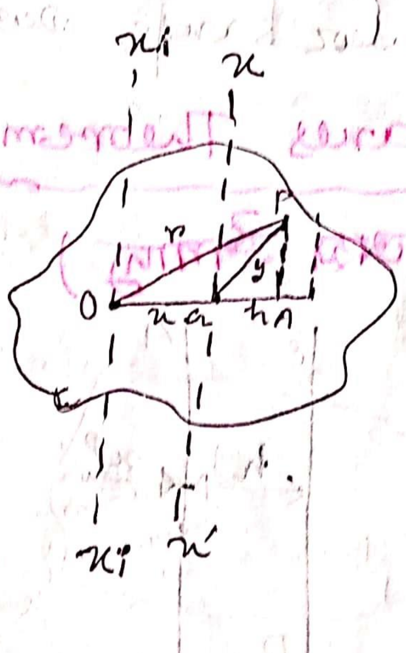
~~The m~~



The moment of inertia of a body

about any axis is equal to the sum of the moment of inertia of the body about a parallel axis passing through the center of ~~g~~ growing & product of the mass of the body & the square of the perpendicular distance between the two parallel axes.

$\therefore I_O = I_G + mx^2$



Here,

$OG = x$ $OP = r$

$GP = y$ $GA = h$

mass OF P, particel is m.

$$I_O = \sum m r^2 \quad \text{—(1)}$$

△OPA -এ,

$$r^2 = OA^2 + AP^2$$

$$= OG^2 + GA^2 \quad \text{—(2)}$$

আবার,

△GPA হতে পাই,

$$GP^2 = GA^2 + AP^2$$

$$\therefore AP^2 = GP^2 - GA^2 \quad \text{—(3)}$$

(2) নং কে (1) নং এ বসাই,

$$= (x+h)^2 + y^2 - h^2$$

$$= x^2 + 2xh + h^2 + y^2 - h^2$$

$$= x^2 + 2xh + y^2 \quad \text{—(4)}$$

(1) নং হতে,

$$I_O = \sum m r^2 = \sum m(x^2 + 2xh + y^2)$$

$$= \sum m x^2 + \sum 2mxh + \sum m y^2$$

$$= mx^2 + I_G + 0 = I_G + Mh^2$$

Cause,

$\sum m y^2 = I_a$

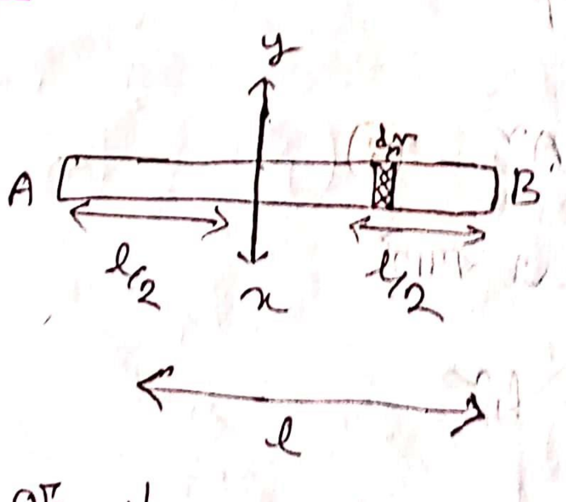
$\sum m h = 0$

$\sum m g h = 0 = mgh$

$\sum m h = 0$ [$\because g$ = constant]

Moment of Inertia (জড়তার ভ্রামক) :-

Proof:-



mass of bar $= M$

Length of bar $= l$

Mass per unit $= \frac{M}{l}$

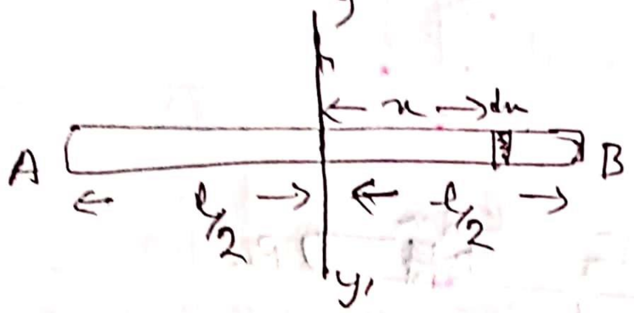
Now,

Take an element of length dx at

a distance x from the axis.

Mass of the element $= \left(\frac{M}{L}\right) dx$

$\Rightarrow$



Moment of inertia of the element about the axis yy'

$$= \left[\left(\frac{M}{l}\right) dx\right] x^2$$

Moment of inertia of the bar AB about the axis yy'

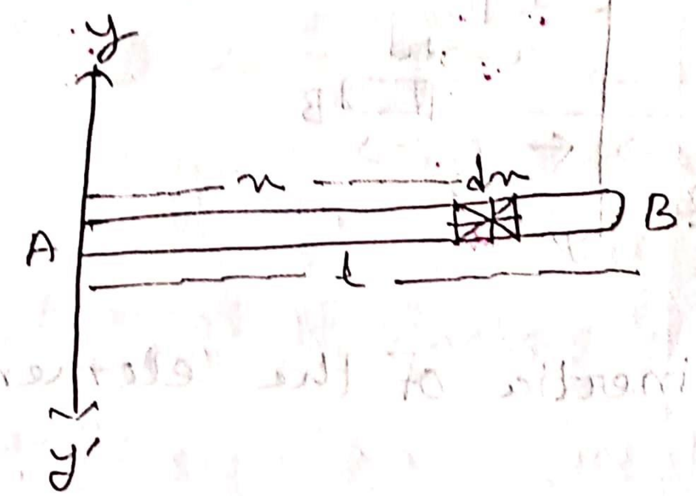
$$= \left[\left(\frac{M}{l}\right) dx\right] x^2$$

Moment of inertia ~~of~~ of the bar AB about the axis yy'

$$I = 2\int_0^{l/2} \left(\frac{M}{l}\right) x^2 dx = \frac{2M}{l}\left[\frac{x^3}{3}\right]^{l/2}$$

$$I = \frac{Ml^2}{12} = MK^2 \text{ or, } MK^2 = \frac{Ml^2}{12} \quad \therefore \boxed{K = \frac{l}{2\sqrt{3}}}$$

④ Moment of inertia of a bar about an axis passing through one end and perpendicular to its length.



Here,

$$I = \int_0^l \left(\frac{M}{l}\right) x^2 \, dx$$

$$\therefore \cancel{I = \frac{Ml^2}{3}} \quad \text{——③}$$

$$\text{or, } I = \frac{M}{l}\left[\frac{x^3}{3}\right]_0^l$$

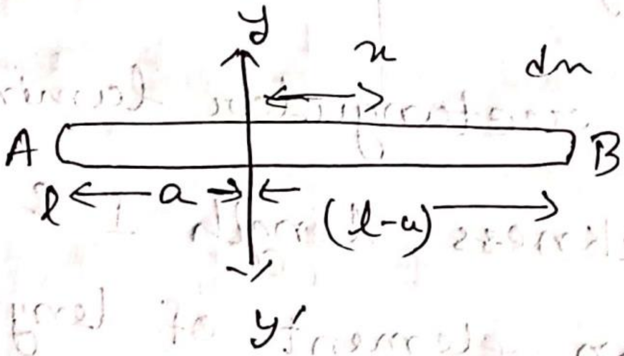
$$= \frac{M}{l}\,\frac{l^3}{3}$$

$$= \frac{Ml^2}{3}$$

But $I = MK^2$ so, $MK^2 = \frac{Ml^2}{3}$

$$\therefore K = \frac{l}{\sqrt{3}} \quad \text{——— (4)}$$

☐ To its length, at a distance from One end:-



Here, $$I = \int_{-a}^{(l-a)} \left(\frac{M}{l}\right) x^2 dx$$

~~Or, $I = \frac{M}{l} \left[\frac{x^2}{3}\right.$~~

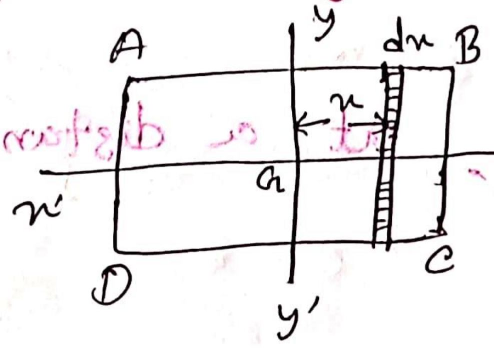
Or, $$I = \int_{l-a}^{-a} \left(\frac{M}{l}\right) x^2 \cdot dx$$

$$= \frac{M}{l} \left[\frac{x^3}{3}\right]_{-a}^{l-a}$$

$$= \frac{M}{l} \left\{\frac{1}{3}\left[(l-a)^3 - (-a)^3\right\}\right]$$

$$\therefore I = M\left[\frac{2}{3} - la + a^2\right]$$

From a regular Lamina:-



=) Consider a rectangular lamina of uniform thickness, length l & breadth b. Consider an element of length dx at a distance x from the axis yy'.

Mass of the lamina $= M$

Area of the lamina $= l \times b$

Mass per unit area $= \left(\frac{M}{l \times b}\right)$

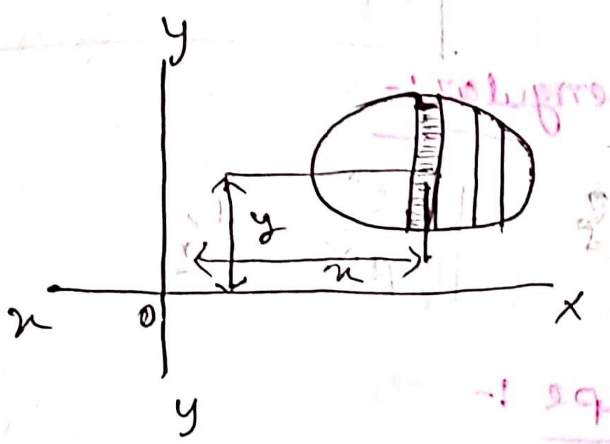
$$\therefore I = \frac{2M}{R^2}\left[\frac{R^4}{4}\right]$$

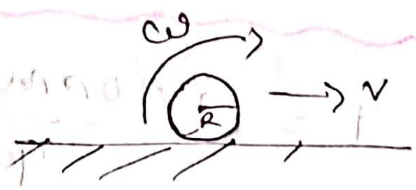
$$= \frac{MR^2}{2}$$

** Moment of inertia of a circular disc about its diameter $\boxed{\frac{MR^2}{2}}$

Routh's Rule :-

In classical Mechanics, the strech rule (sometimes reffered to as Routh's rule) states that the moment of inertia of a rigid ~~subject~~ object is unchanged when the object is streched parallel to an axis of rotation that is a principal axis, ~~proof~~ provided that the distribution of mass remains unchanged except in the direction parallel to the axis





Radius of gyration
(চক্রাবর্তের পরিভ্রমণ).

$$V = \omega R \; ; \; I = MK^2$$

For Bodies :-

Square in Shape or Rectengular :-

$$I = \frac{\{(A \text{ or } M) \times S\}}{3}$$

A = Area of the body
M = Mass of the body
S = Sum of the squares of the couple of semi barring the one (বাদে) about which one the m.o.I being calculated

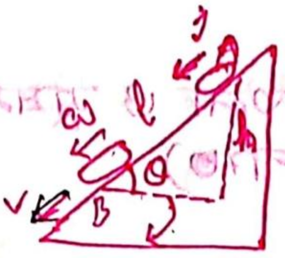
Circular or Rectengular :-

$$I = \frac{\{(A \text{ or } M) \times S\}}{4} \quad \Big| \quad \frac{K^2}{R^2} = \frac{1}{2}$$

Spherical in Shape :-

$$I = \frac{\{(A \text{ or } M) \times S\}}{5} \quad \Big| \quad \frac{K^2}{R^2} = \frac{2}{5}$$

□ কোনো বস্তু ঢাল বেয়ে গড়িয়ে পড়তে থাকলে ত্বরণ :-



Loss $E_p = mgh$

$\sin\theta = h/l$ or, $h = l\sin\theta$

E_p (Loss of potential Energy) $= mgh\sin\theta$ — (1)

Gain in E_k

$= \frac{1}{2}mv^2\left(1+\frac{K^2}{R^2}\right) = Mgl\sin\theta$ — (2)

$= \cancel{mgl\sin\theta}$

or, $v^2 = \dfrac{2gl\sin\theta}{1+\frac{K^2}{R^2}}$ — (3)

Derivative ~~of~~ to t of equation (3)

$2v\dfrac{dv}{dt} = \dfrac{2g\sin\theta}{\left(1+\frac{K^2}{R^2}\right)} \cdot \dfrac{dl}{dt}$

$\therefore a = \dfrac{g\sin\theta}{1+\frac{K^2}{R^2}}$ — (4)

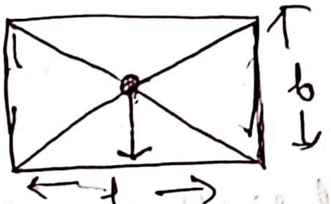
Semi Square

$\angle \rightarrow$ one-eight of 360° circle

For, $a = \frac{2g\sin\theta}{3}$

$= \frac{7g\sin\theta}{5}$

Routh's rule (পাতলা ও সুষম আয়তাকার পাতের):



$I = I_x + I_y$

$= \frac{Mb^2}{12} + \frac{Ml^2}{12}$

$I = \frac{M}{3}\left\{\left(\frac{l}{2}\right)^2 + \left(\frac{b}{2}\right)^2\right\}$

$= \frac{M}{3} \cdot \frac{l^2+b^2}{4} = \frac{M}{12}(l^2+b^2)$

$\frac{1}{n}(m)$ [sum of other two semi squares]

Where,

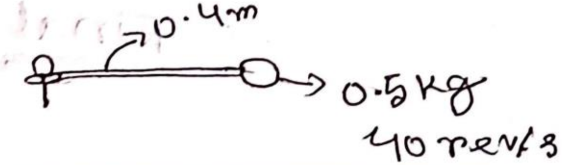
$n=3$ for rectangular body.

$n=4$ for circular/eliptical body.

$n=5$ for ~~sper~~ spherical body.

Rule:- If a body is symmetrically shaped about all its three axes, then the moment of inertia about any three axes which passes

Through the center of gravity of the body can be written as; $I = \{A^{gr} M \times 3) / 5$ - spherical shape



A 0.5 kg mass is whirled in a circle at the end of a string 0.4 m. long, the other end of which is held in the hand. If the mass makes 40 revolutions per second, what is ~~this~~ its angular momentum. If the the number of revolution decreases by one in 20s., Calculate the mean value of the torque on the system.

=>

Date:- August 15, 20
Saturday
11:25

Elasticity
(স্থিতিস্থাপকতা)

Elasticity:-

Elasticity is defined as the property by which a body regains its original position when the forces are withdrawn.

The opposite of elasticity is plasticity. No substance is perfectly elastic or perfectly plastic.

Stress (পীড়ন):-

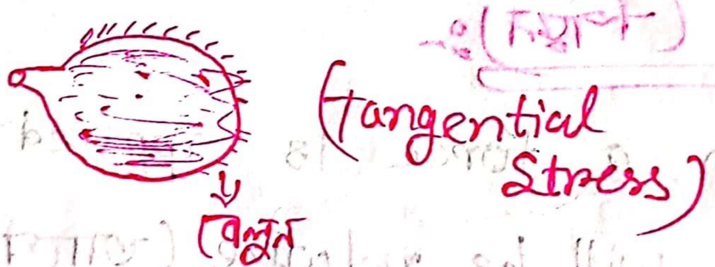
when a force is applied on a body, there will be relative (আপেক্ষিক) displacement of the particles and due to the property of elasticity the particles tend to regain their original position. Stress is defined as the restoring force per unit area.

Normal Stress (লম্বালম্বি পীড়ন) :-
or Longitudinal Stress :-

Restoring force per ~~area~~ unit area perpendicular to the surface is called Normal / Longitudinal stress.

Tangential Stress:- (স্পর্শিনী / স্পর্শক সমান্তরাল এর পীড়ন)

Restoring force parallel to the surface per unit area is called tangential stress. (~~Shearing → ক~~



Strain:- (টান)/(বিকৃতি)

The ratio (অনুপাত) of the change in shape to the original shape is called strain. There are three types of strains:-

Longitudinal / Lateral Strain
(লম্বালম্বি বিকৃতি)

The ratio of change in length to original length is called longitudinal strain.

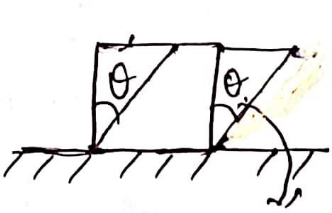
$\left(\frac{l}{L}\right)$

Shearing Strain (বিকৃত কোণ)

Actually, It is defined as the tangent of that angle.

Shear strain is the ratio of the change in deformation (আকৃতির বিকৃতি) to its original length perpendicular (উলম্ব) to the axes of the member due to shear stress. Shear stress is stress in parallel to the cross section of the structural member.

এটা দিয়ে ভূমিকম্পতে মাটির কম্পন মাপা হয়।



Shearing strain.

It has no any unit

Angle of shear measured in radians

Volume strain:-
(আয়তন বিকৃতি)

The ratio of the change in volume to original volume is called volume strain

Formula :- $\left(\frac{v}{V}\right)$

Elastic Limit:-

The maximum stress which a body exhibits the properly of elasticity is called elastic limit.

If the applied force exceeds the maximum stress limit, the body does not regain its original position completely after the external forces are withdrawn.

Hooke's Law:-

It states that within the elastic limit, stress is directly proportional to strain.

(পীড়ন ∝ বিকৃতি)

Stress ∝ Strain

Stress = E · strain [E = constant] → Modulus of elasticity

$\therefore E = \frac{\text{Stress}}{\text{Strain}}$

Or, $\frac{F/A}{l/L} = y$ [Young's Modulus of elasticity]

Or, $\frac{FL}{Al} = y$

$\eta = \frac{F/A}{\theta} = \frac{F}{A\theta}$ [Modulus of Rigidity]

F/A → [~~Normal~~ Tangential Stress] ; [~~normal strain~~] → [Tangential strain] ; θ → [Shearing strain]

$K = \frac{F/A}{v/V} = \frac{FV}{Av}$ [Bulk Modulus of elasticity]

F/A → [Normal Stress] ; v/V → [Volume strain]

poisson's ratio
~~poison's ratio~~

[2] Poisson's Ratio :-

["Whenever a body is subjected to a force in a particular direction, there is a change in dimensions of the body in the other two perpendicular direction this is called lateral strain."]

=> [যখন কোনো বস্তুর উপর বল প্রয়োগ করা হয় ~~কোনো~~ কোনো দিকে তখন ~~উলম্ব বরাবর~~ অন্য দুই অক্ষের এর আকারে পরিবর্তন ঘটে তার একেই বলে উলম্ব বিকৃতি]

Lateral strain is proportional to the size of the body.

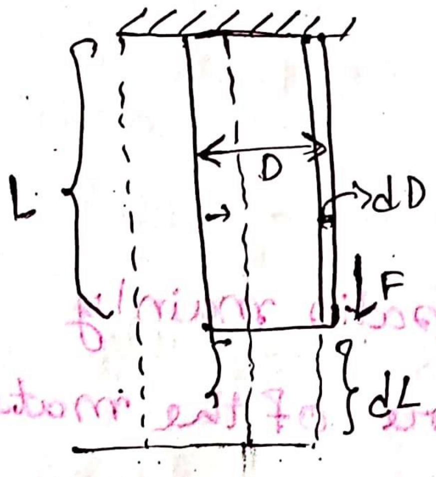
Let the (α) be the longitudinal (অনুদৈর্ঘ্য) strain per unit stress and β be the lateral (পার্শ্বিক) strain per unit stress, within the elastic limit.

$\beta \propto \alpha$

$\beta = \sigma \alpha$

So, $\boxed{\text{poisson's ratio, } \sigma = \dfrac{\beta}{\alpha}}$

* Lateral strain per unit to the longitudinal strain ~~per~~ per unit stress is called poison's ratio.



$$\alpha = \frac{dL}{L}$$ [দৈর্ঘ্য বিকৃতি]

$$\beta = \frac{dD}{D}$$ [প্রস্থের বিকৃতি]

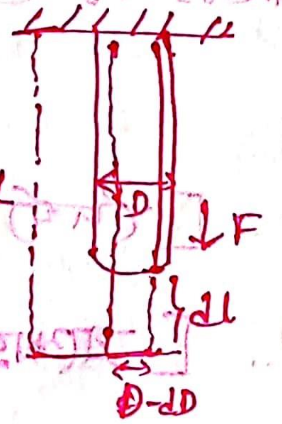
$$So,\ \beta = \frac{dD/D}{\frac{dL}{L}}$$

$$\therefore \sigma = \left(\frac{dD}{dL}\right)\left(\frac{L}{D}\right)$$

The values of σ will varies from 0.2 to 0.4

□ Initial ~~value~~ volume :- (প্রারম্ভিক আয়তন)

Initial value of the wire:



(*) The value of poison's ratio mainly depends upon the nature of the material of the body. σ has no units as it is a ratio of two numbers.

For most of the substances, the value of σ varies between 0.2 to 0.4.

=) If the volume of the wire remained unchanged after the force has been applied, then,

Initial volume of the wire, $v = \pi L D^2$

$$v = \left(\frac{\pi D^2}{4}\right)L \quad \text{--- (ii)}$$

Differentiating equation (ii)

$$dv = \frac{\pi}{4}\left[D^2 dL + 2LD\, dD\right]$$

If, $dv = 0$

Then,

$$D^2 dL + 2LD\, dD = 0$$

$$\frac{dD}{dL} \times \frac{L}{D} = -1/2$$

But,

$$\sigma = -\left(\frac{dD}{dL} \times \frac{L}{D}\right)$$

$$= -(-1/2)$$

$$= 1/2$$ → This is the maximum possible value of poison ratio

$$\sigma = -\left(\frac{dD}{DL}\right)\left(L/D\right)$$

Alternative Method

The relation between Y, η & K :-

The relation between Y, η and K can also be obtained with the help of the following table.

Consider a unit cube, which is subjected to outward (বাহ্যিক) elongational (দীর্ঘায়িতকরণ) force [P] on each face. Let (σ) be the poisson's ratio for the material. In the table, the values of applied stress (পীড়ন) & the corresponding (অনুরূপ) strains (বিকৃতি) produced along the three perpendicular (লম্বভাবে) axes are shown. For a stress (P) the longitudinal strain produced $= P/Y$ in its own direction & the corresponding strains in the other two perpendicular directions are $-\frac{\sigma P}{Y}$ & $-\frac{\sigma P}{Y}$

	Stress Along			Strain along		
	Ox	Oy	Oz	Ox	Oy	Oz
	$+P$	0	0	$+P/Y$	$-\sigma P/Y$	$-\sigma P/Y$
	0	$+P$	0	$-\sigma P/Y$	$+P/Y$	$-\sigma P/Y$
	0	0	$+P$	$-\frac{\sigma P}{Y}$	$-\frac{\sigma P}{Y}$	$+P/Y$
volume	$\cancel{PP}$ $+P$	$+P$	$+P$	$P/Y(1-2\sigma)$	$\frac{P}{Y}(1-2\sigma)$	$P/Y(1-2\sigma)$
	Total volume strain :-		$\frac{3P}{Y}(1-2\sigma)$			
Shearing	$+P$	0	0	$+P/Y$	$-\frac{\sigma P}{Y}$	$-\frac{\sigma P}{Y}$
	0	$-P$	0	$+\frac{\sigma P}{Y}$	$-P/Y$	$+\frac{\sigma P}{Y}$
	Sum:- $+P$	$-P$	0	$P/Y(1+\sigma)$	$-P/Y(1+\sigma)$	0

Total Shearing strain: $-2P/Y(1+\sigma)$

Bulk Modulus: (আয়তন গুণাঙ্ক):-

Bulk modulus is used to measure how incompressible (অসংকোচনীয়) a solid is.

Besides the more the value of K (Indicate of Bulk modulus) for a material, the higher is its ~~value~~ nature to be incompressible. For example, the value of K for steel is $1.6 \times 10^{11}\ Nm^{-2}$ & the value of K for glass is $4 \times 10^{10}\ Nm^{-2}$

It is defined as the ratio of the ~~inf~~ infinitesimal (ক্ষুদ্রাতিক্ষুদ্র) pressure increase to the resulting relative decrease of the ~~value~~ volume.

Its Unit is the = pascal.

Formula is $= \frac{dv}{v}$

Shearing Strain (Deformation) :-

tangent of angle; and is equal to the length of deformation at its maximum divided by the perpendicular length in the plane of force.

Now,

B.M., $K = \frac{P}{\text{Strain}}$

So, Strain $= P/K$

or, $\frac{3P}{y}(1-2\sigma) = P/K$

or, $K = \frac{Py}{3P(1-2\sigma)}$

or, $K = \frac{y}{3(1-2\sigma)}$ —— (i)

Now,

Shearing strain $= \frac{P}{\eta}$ [we

From the table,

Shearing strain $= \frac{2P}{y}(1+\sigma)$

So, $\frac{P}{\eta} = \frac{2P(1+\sigma)}{y}$

or, $\eta = \frac{y}{2(1+\sigma)}$ [divided by P]

—— (ii)

So, From (1) & (2),

$$1-2\sigma = \frac{y}{3K}$$

$$1-2\sigma = \frac{y}{3K} \quad \text{— (iii)}$$

$$2+2\sigma = \frac{y}{\eta} \quad \text{— (iv)}$$

$$3 = \frac{y}{3K} + \frac{y}{\eta}$$

or, $3 = y\left(\frac{1}{3K} + \frac{1}{\eta}\right)$

$$\therefore \frac{3}{y} = \frac{1}{3K} + \frac{1}{\eta} \quad \text{— } \cancel{(6)} \rightarrow (5)$$

Limiting values of σ :- $[-1 \leq \sigma < 0.5]$

$$\cancel{\eta = \frac{1}{2(\alpha+\beta)} = \frac{1}{2\alpha(1+\beta/\alpha)}}$$

$$\cancel{\eta = \frac{y}{2(1+\sigma)} \quad \text{— (i)}}$$

From equation (iii) & (iv)

$$y = 3K(1-2\sigma) \quad \text{— } \cancel{(3)}\ (1)$$

$$y = 2\eta(1+\sigma) \quad \text{— } \cancel{(4)}\ (2)$$

$\therefore 3K(1-2\sigma) = 2\eta(1+\sigma)$

when,

$\sigma = +$ (positive) then, K & η = positive (+)

⇒ If the poisson's ratio is a positive quantity

~~Limit~~:- as K & η are always positive

$\cancel{1-2\sigma > 0}$

OR, $\cancel{2\sigma < 1}$

So, $\cancel{-1 < \sigma < 0.5}$ ⇐ Limit

⇒ If the

(b) If the poisson's ratio is a negative quantity, for η & K to be positive,

$(1+\sigma) > 0$

$\sigma > -1$

It means the value ~~t~~ of σ lies between,

-1 & 0.5

Note:-

⇒ In actual practice the value of σ cannot be negative because the body doesn't expand laterally when it expands longitudinally (অনুদৈর্ঘ্যভাবে). And when $\sigma = 0.5$, it means that there is no change in volume and the body is completely incompressible. Therefore, it is not possible.

In practice, the value of (σ) for most of the isotropic ~~sad~~ substances (পদার্থসমূহ) is between 0.2 & 0.4.

η = The modullous of rigidity (মাপাঙ্ক (স্থিতিস্থাপকতার মাপাঙ্ক)

σ = poison's ratio.

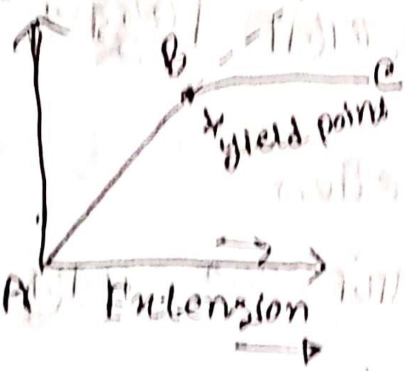
Y = young's modulus.

(শৈথিল্য)

☐ yield point (নমন বিন্দু):-

where a wire (spring) is loaded beyond elastic limit, Hooke's law is no longer obeyed. The extension is more than the corresponding load.

In the above graph B point is yield point.

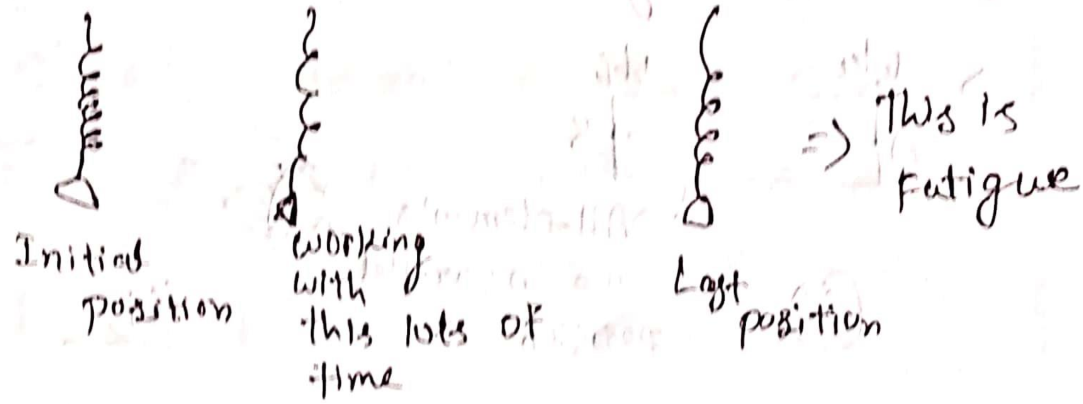


→ If the load is removed, the particle don't regain their position

Note:-
এই স্থানে একটি দেহটি হুকের নীতি মেনে চলবেনা।

4) Elastic Fatigue:-

If a body is continuously subjected to stress & strain it gets fatigued.



5) Bending of Beams:-

A beam is defined as a structure of uniform cross-section, whose length is large comparison to its breadth & thickness.

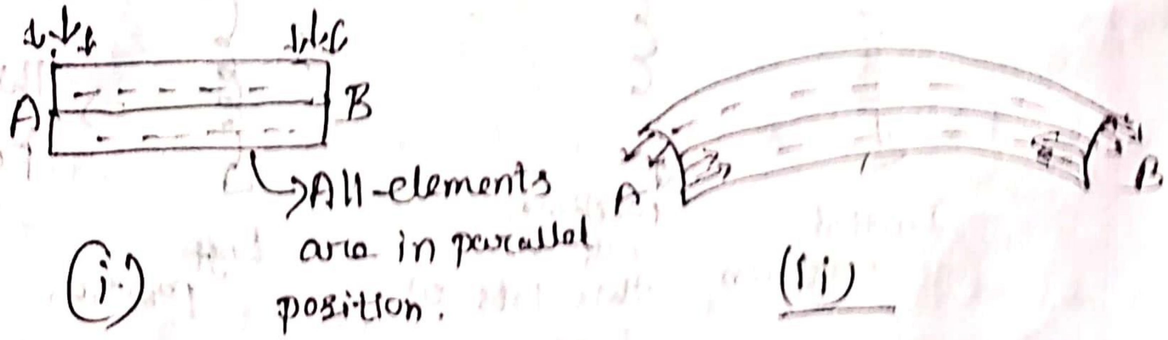
(এটি মেটাল/অন্য কোনো কিছুরও হতে পারে)

Uniform cross-section

[কোথাও সরু, মোটা হতে পারবে না। একদম সমান হতে হবে]

Consider a beam of uniform rectangular cross section. Let the beam be subjected to deforming forces so that it bends.

=>



Position No.(i) :-

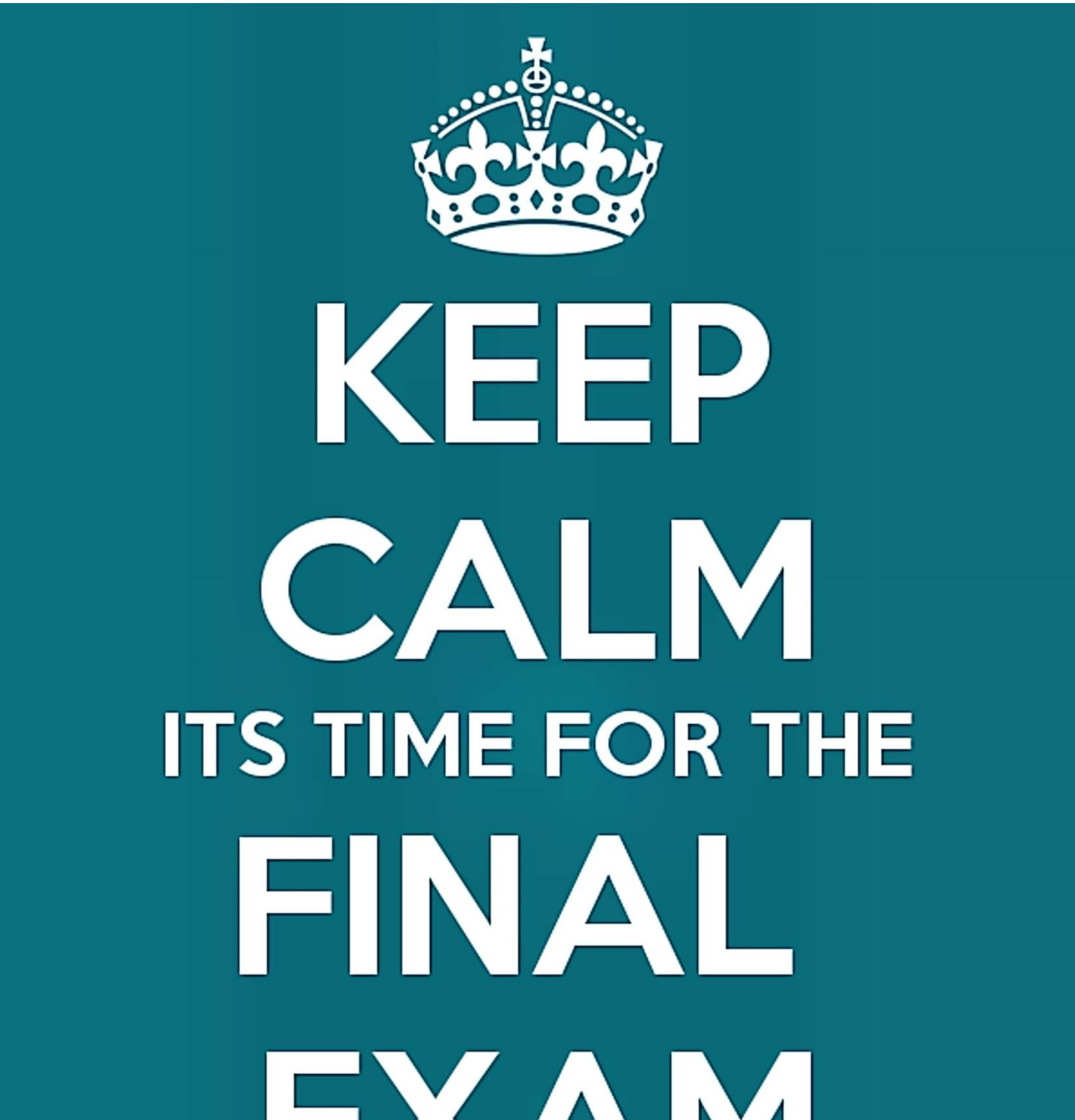
Let, AB beam be subjected to deforming forces, so that it bends. In the initial position of the beam, the various filaments constituting the beam are in parallel layers of equal length. বিভিন্ন অংশগুলো ফিলামেন্ট সমান্তরালে বিদ্যমান।

position No. (ii):-

In the final position, above the layer AB. the filaments are elongated (বড় হয়ে যাওয়া) while below AB they are Compressed (সংকুচিত) The length of the layer AB remains an (পরিবর্তিত হওয়া) altered. It is called the neutral axis. The surface combining the (নিরপেক্ষ) neutral axis is called neutral surface.

Mid Term Finish

Final Starts from Next page


KEEP
CALM
ITS TIME FOR THE
FINAL
EXAM

Final

Lesson:- Surface Tension

~~Adhesive~~ Cohesive Force:-

Mutual attraction between the molecules (অণু) of the same substances (পদার্থ) is called cohesion (সংযোগ).
And the Force is called as Cohesive Force.

Adhesive Force:-

Mutual attraction between the molecules of different substances is called adhesion (আঁঠালো লেগে থাকা)
And the Force is called as Adhesive Force.

Surface Tension:-

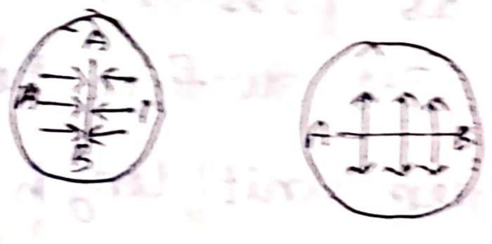
- These forces are effective only when the distance between the neighbouring molecules is extremely small of the order 10^{-7} cm.

- The greatest distance at which the molecules can attract each other is called molecular range.

- A sphere having a radius equal to the molecular range, with the molecule as the centre is called the sphere of influence.
([illegible])

Surface Tension

It is the property of a liquid by which the free surface of a liquid behaves like a streched membrane.



=> Consider an imaginary line AB is dividing the liquid surface ~~the molecules of the liquid~~ in to two parts.

The molecules on one side pull away the molecules on the other side. Therefore, if the liquid was actually separated into two parts with AB as the boundary line, work would have to be done.

production of a large amount of a free surface requires an increase in the potential energy of the liquid. The undisturbed liquid tries to minimize its potential energy. so, it must take a shape in which its free surface area is as small as possible.

Its surface tends to contract and force per unit length acting on either side of the imaginary line drawn on the liquid surface at rest is called as the surface tension.

$$\text{Surface Tension} = \frac{\text{Force}}{\text{Length}}$$

$$\therefore T = \frac{F}{L}$$

- The unit of surface tension in CGS system is ~~de~~ $\boxed{\text{dynes per centimetre}}$

And in rationalised (যৌক্তিকীকরণ)

- MKS system is newtons per metre.

- The dimensions of surface tension are

$$[MT^{-2}]$$

[4] Surface Tension Dependency :-

(i) Temperature (K) :- $T \propto \frac{1}{K}$

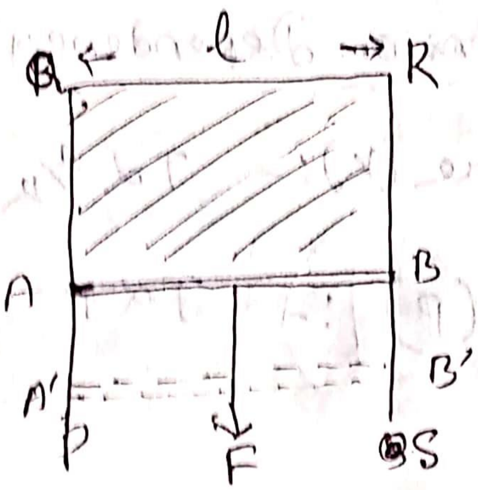
(ii) Density (ρ) :- $T \propto \rho$

(iii) Impurity

Surface Energy & Surface Tension

• As discussed already, a liquid surface contracts spontaneously (স্বতঃস্ফূর্তভাবে). Free energy is associated with it and work must be done to extend the surface.

⇒ Let consider a rectengular frame PQRS



with horizontal wire AB. Dip it in a soap solution (সাবানের দ্রবণ/ফেনা). A film is formed across the ~~surface tension~~ ABRQ. The wire AB is <u>pulled up</u> (উঠবে) due to surface tension of the film. To keep the wire equilibrium (সুস্থিত) and in its position, a Force has to be applied downwards. Let the total Force be F.

So, F is equal to $w_1 + w_2$

w_1 = weight of the wire

w_2 = Extra weight to be used

F will hold the wire at rest in any position, regardless (নির্বিশেষে) of the are of the surface.

When the wire AB is pulled downwards through a distance δx, the area of the Film is increased. The molecules in the bulk of the liquid move into the surface layers.

- It is assumed that the temperature remains constant

$\boxed{\text{work done} = F \times \delta x}$ So, $w = F \cdot \delta x$

• Total increase in the surface area of the liquid film

$= 2(l \times \delta x)$

Where l is the length of the wire AB

∴ work done per unit area $= \dfrac{F \cdot \delta x}{2l \cdot \delta x}$

$= \dfrac{F}{2l}$

(*) The work done per unit area gives the increase in potential energy per unit area of the film.

(*) The increase in energy per unit area is called surface energy.

Also the force, $F = T \times 2l$

Here, T is the surface tension.

$\therefore T = \dfrac{F}{2l}$

[#], It seemed that the temperature remain const. throughout the process. Actually the film gets cooled when it is streched.

Therefore extra energy has to be supplied to restore the original temperature of the film.

$S = T + H$ — (i) [H = The quantity of heat absorbed per unit area from atmosphere]

Or, $T = S - H$ — (ii) [(S−H) = The mechanical part of the surface eng./ ~~and~~ The amount of work done in increasing the surface area of the film by one unit]

If the process is Adiabatic (রুদ্ধতাপীয়), $H = 0$

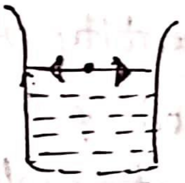
From eqⁿ (ii)

$T = S$

The units of free surface energy in CGS system is: ergs per ~~unit~~ sq cm

in MKS system:- Joules per sq. metre.

Pressure Difference Across a Spherical Surface :-



(i)

(i) when the liquid surface is plane, the resultant force of surface tension on a molecule is zero.

(ii) when the liquid surface is Convex(উত্তল), the resultant force is outward.

(iii) when the liquid surface is Concave(অবতল), the resultant force is inward.

Thus for curved liquid surface the Pressure on Concave side is greater than on the Convex side.

The difference of pressure depends upon the surface tension of the liquid and the radius of curvature of its surface.

/

Example :- A liquid drop of radius R breaks up into 64 small drops, Calculate the

Main Formula :-

Change in energy / Energy required = (Surface Tension) × (Increase in Area)

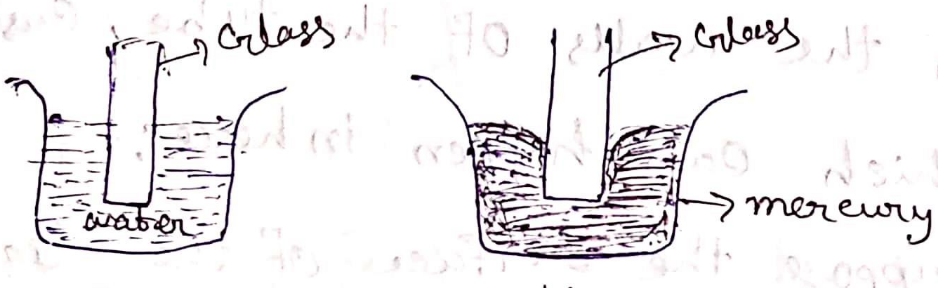
$= T \times A =$

$= \cancel{C4T} \times$

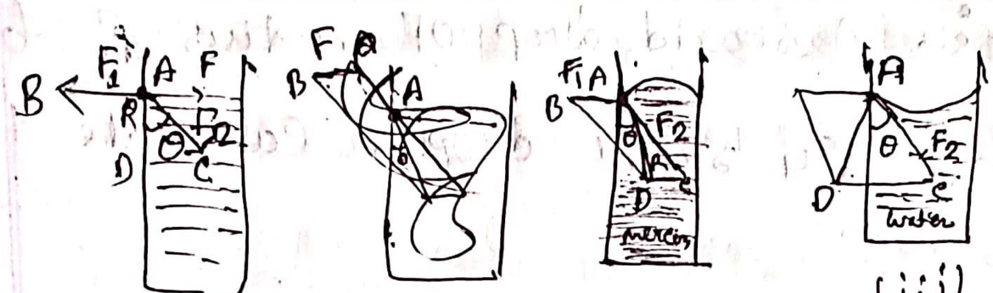
(বাকি ম্যাথ পরে হবে)

Angle of Contact

সংস্পর্শ কোণ



(a) (b)



(i) (ii) (iii)

=) Considering a liquid in a glass tube.

The molecule, at A experiences,

(i) Force of adhesion ([illegible]) F_1 between it(A) & the glass molecules.

(ii) Force of cohesion ([illegible]) F_1 between it and the molecules of the liquid.

F_1 acts along AC making an angle of 45° with the walls of the tube, cases which can happen in here:-

1. Suppose the surface of the liquid is horizontal as shown in (i) F_2 is the Force of cohesion acting along AC.

The component of F_2 along AE is $F_2 \sin\theta$.

F_1 is the force of ~~ch~~ adhesion along AB.

$$\boxed{F_1 = F_2 \sin\theta}$$

Thus the molecule A does not experience any force in the horizontal direction.

The only force ~~in~~ is in the vertical direction and is equal to $F_2 \cos\theta$

where, $\theta = 45^\circ$

And the Angle of contact is 90°

$P_r V_r = P_a V_a + P_b V_b$ or, $P_r \times \frac{4}{3}\pi r^2 = P_a \times \frac{4}{3}\pi a^2 + P_b \times \frac{4}{3}\pi b^2$

or, $\boxed{P_r r^2 = P_a a^2 + P_b b^2}$

$F_p = \cancel{P} = \left(\frac{4T}{r}\right) + P$

$P_a = P + \left(\frac{4T}{a}\right)$

$P_b = P + \left(\frac{4T}{b}\right)$

$\therefore T = \frac{P(r^2 - a^2 - b^2)}{4(a^2 + b^2 - r^2)}$

Capilarity (কৈশিকতা)

When a capillary tube (কৈশিক নালি) of fine bore (সূক্ষ্ম ছিদ্র) is dipped (ডুবানো হয়) in water, water rises in the tube.

A tube with a line bore is called a capillary tube.

~~On the~~ But if the same tube is dipped in mercury, there is depression of mercury level in the tube.

The property of rise or depression of a liquid inside a capillary tube is called Capillarity. It is one of the most important effects of surface tension.

In general, the liquids that wet the glass, rise inside the capillary tube ~~with~~ while these which do not wet the glass show a depression inside the capillary tube.

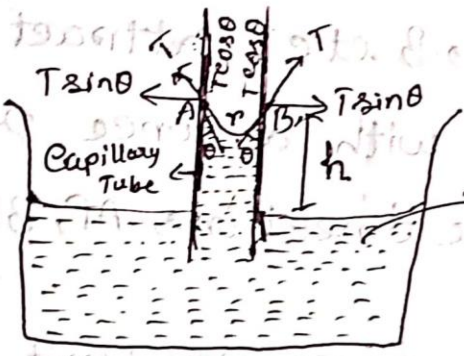
Expression for surface tension:

......[To be continued]

Surface Tension

.... এর পর)

1. Expression for surface Tension :-
(তলের প্রসারণের অভিব্যক্তি)



=> Consider a capillary tube of radius r dipped in water. Due to surface tension. The water rises inside the capillary tube.

h = height of water

The meniscus is concave. (point A, B)

T acts tangential to the surface with the wall of the capillary tube.

The Force per unit length, T refers to the

Force experienced by the molecule at A. due to,

1) The force of adhesion due to glass molecules.

2) The force of cohesion due to liquid molecules. at A, B etc attract the liquid molecules with a force per unit length T in the directions AP, BQ etc.

⇒ ~~To~~ Resolve the force per unit length T along AB into two rectangular components.

(i) $T\cos\theta$ ~~Co~~ acting vertically upwards.

(ii) $T\sin\theta$ acting in the horizontal direction.

(*)

Force per unit length $= T\cos\theta$

Circumference $= 2\pi r$

Total upward force $= T\cos\theta \times 2\pi r$

This upward force balances the weight of the liquid column in the capillary tube.

Height of the liquid column $= h$

volume of the liquid in the meniscus (অনুমোচন)

$= (\pi r^2 \times r -$

$= \frac{\pi r^2}{3}$

volume of the liquid in the column

$$= \pi r^2 h + \frac{\pi r^2}{3} = \pi r^2 \left(h + \frac{r}{3}\right)$$

Density of the liquid $= \rho$

Weight of the liquid $= \pi r^2 (h + r/3) \rho . g$

Equating (i) & (ii)

$$2\pi r\, T\cos\theta = \pi r^2 (h + r/3)\, \rho \cdot g$$

$$= 4 \text{ or, } T = \frac{r(h + r/3)\rho g}{2\cos\theta}$$

when the angle of contact is zero,

$$\cos\theta = 1$$

$$\text{or, } T = \frac{r(h + r/3)\rho g}{2}$$

Determination of surface Tension:-

(তলের টান নির্ণয়)

Surface tension of water can be determined experimentally using capillary method.

The height of the liquid column & the internal diameter of the capillary tube is found with the help of a travelling microscope.

For a particular tube, the radius is r, the height of water is h and the density of water is ρ. Then the surface tension of water at room temperature

$$T = \frac{r(h+\frac{r}{3})\rho g}{2\theta\cos\theta}$$

Taking, $\theta = 0$, $\cos\theta = 1$

$$T = \frac{r(h+r/3)\rho g}{2}$$

Surface tension of water can be determined...

In the actual experiment, three capillary tubes of different diameters are taken and the mean value of surface tension is calculated.

This method suffers from a number of drawbacks.

1) The angle of contact has been taken to be zero, because it can't be measured inside the tube.

2) The tube may not be of uniform area of cross-section.

(iii) The tube may not be cleaned.

Example of Capilarity:-

(1) A pen nib is split at the tip to provide the narrow capillary and the ink is drawn up to the tip continuously.

(2) In oil lamps & stoves, oil is drawn up through the capillaries of the wick.

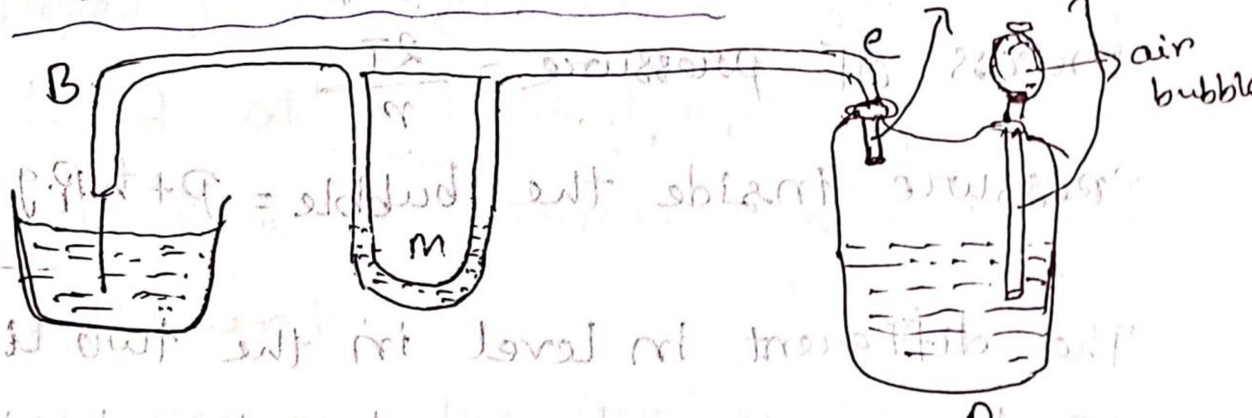
(3) pores in the blotting paper act as capillaries. when the blotting paper is kept in contact with ink, the ink absorbed.

(4) walls get damped in rainy season due to the absorption of water by the bricks by capillary action.

5] Leaves, trunk & branches of a tree possess fine capillaries. Sap & water rises even up to the top most leaves by capillaryes action.

[6] Sandy soils are dry whereas clay soils are damp. The interspaces between the particles of the clacy form finer capillaries and water rises to the surface quickly.

[7] Determine surface tension of a liquid by ~~ger~~ Jarger's Method :-



~~The apparatus (7~~

D is woulf's bottle; On one side it is fitted

with a thistle funnel and other side it is connected to a tube BC. The tube BC is fitted with a manometer M. The end of the tube BC is joined to a capillary tube. Two capillary tube One is from C & the other is inside the liquid ~~water~~ which surface tension is to be ~~determined~~ determined.
~~Ex~~ Stop cock is opened the pressure of bottle increases
Here,

Excess of pressure inside the bubble

$$= \frac{2T}{r}$$

The pressure of the liquid column

$$= h\rho g$$

Atmospheric pressure $= P$

Excess of pressure $= \frac{2T}{r}$

pressure inside the bubble $= P + h\rho g + \frac{2T}{r}$ —— (1)

The different in level in the two limbs of the manometer when the bubble just bursts $= H$

Density of the liquid in the manometer

$= \rho_2$

Pressure of air in the manometer,

$$P_2 = P + H\rho_2 g \quad \text{—(ii)}$$

Equating (i) and (ii)

$$P + h\rho_1 g + \frac{2T}{r} = P + H\rho_2 g$$

$$\frac{2T}{r} = (H\rho_2 - h\rho_1)g.$$

$$T = \frac{gr}{2}(H\rho_2 - h\rho_1)$$

The radius (r) of the capillary tube is measured with a Travelling microscope

This method can be usefully employed (i) to find the surface tension of a liquid at various temperatures.

(ii) to find the surface tension of molten metal and

(iii) to compare the surface tension of two Liquids at the same temperature.

Math problem's solve

[1] A Liquid drop of radius (R) breaks up into 64 small drops. Calculate the change in Energy.

⇒ Let,
the surface tension of the liquid be T.

Radius of the bigger drop = R

Surface area of the bigger drop = $4\pi R^2$

Volume of the bigger drop = $\frac{4}{3}\pi R^2$

Let, the radius of each small drop be; r

$$\therefore \frac{4}{3}\pi R^3 = 64 \times \frac{4}{3}\pi r^3$$

$$R^3 = 64 r^3$$

$$\therefore \cancel{R = 8r}$$

$$\therefore \cancel{r = \frac{8}{R}} \; \frac{R}{8}$$

$$\therefore r = \frac{R}{4}$$

Surface area of each small drop,

$= 4\pi r^2$

$= 4\pi \left(\frac{R}{\cancel{8}4}\right)^2 = 4 \cdot \pi \frac{R^2}{\cancel{64}16} = \frac{\pi R^2}{4}$

Surface area of 64 small drops,

$= \frac{64 \times \pi R^2}{\cancel{16}4} = 16\pi R^2$

Increase in surface area =

$16\pi R^2 - 4\pi R^2$

$= 12\pi R^2$

Change in energy = (Surface tension) × (Surface Area)

$= T \times 12\pi R^2$

$= 12\pi R^2 T$

(Ans)

(2) Calculate the amount of energy needed to break a drop of petrol of volume $10^{-6}\ m^{3}$ into a thousand millions drops of equal size. Surface Tension of petrol is $26 \times 10^{-3}\ Nm^{-1}$.

$\Rightarrow$ Let, The radius of patrol's drop be $= R$

The volume of a drop of petrol $= 10^{-6}\ m^{3}$

The surface tension of petrol, $T = 26 \times 10^{-3}\ Nm^{-1}$

we will convert it into thousand million drops $= 10^{9}$

~~What~~ Amount of energy needed = ?

Here,

$$\frac{4}{3}\pi R^{3} = 10^{-6}$$

$$\text{Or} \quad R^{3} = \frac{3 \times 10^{-6}}{4\pi}$$

$$\text{Or,} \quad R = \left(\frac{3}{4\pi}\right)^{1/3} \cancel{\times 10^{-2}\ m.}$$

$$= 1.465 \times 10^{-3}$$

~~If let~~, r

Also,

The radius of small drops = r

So, volume of 10^9's drop of petrol

be $= \frac{4}{3}\pi r^3 \times 10^9$

Here,

$\frac{4}{3}\pi R^3 = \frac{4}{3} \times \pi r^3 \times 10^9$

~~Or, $1.32 \times 10^{-8} = \frac{4}{3} \times \pi r^3 \times 10^9$~~

~~Or~~, or, $R^3 = 10^9 \times r^3$

or, $r^3 = \frac{R^3}{10^9} = \frac{(1.465 \times 10^{-3})^3}{10^9}$

or, $r^3 = 3.144 \times 10^{-18}$

or, $r = 5.32 \times 10^{-9}$

Increase in surface area

$A = 10^9 \times 4\pi r^2 - 4\pi R^2$

$= \cancel{10^9 \times} 4\pi \, (10^9 r^2 - R^2)$

$= 4\pi \{10^9 (5.32 \times 10^{-9})^2 - (1.465 \times 10^{-3})^2\}$

$= 4\pi$

[Q] Calculate the work done in spraying a spherical drop of mercury of radius $10^{-3} m$ into a million drops of equal size. Surface tension of mercury $= 550 \times 10^{-3}\ Nm^{-1}$.

=> Here,

The radius of mercury, $R = 10^{-3} m$.

Total drops $= 10^6$

So,

$$\frac{4}{3}\pi R^3 = 10^6 \times \frac{4}{3}\pi r^3$$

or, $R^3 = 10^6 \times r^3$

or, $R = 10^2 \times r$.

Or, $r = \frac{R}{100} = \frac{10^{-3}}{10^2} = 10^{-3} \times 10^{-2}$

$= 10^{-5} m$.

Increase in surface area

$$A = 10^6 \times 4\pi r^2 - 4\pi R^2 = 4\pi(10^6 \times r^2 - R^2)$$

$$A = 4\pi\left\{10^{6}\times(10^{-5})^{2} - (10^{-3})^{2}\right\}$$

$$= 4\pi \times 99\times10^{-6}\ m^{2}$$

$$= 1.244\times10^{-3}$$

work done = $T \times A$

$$= 550\times10^{-3} \times 1.244\times10^{-3}$$

$$= 6.842\times10^{-4}$$

[4] Calculate the amount of energy needed to break a drop of water diameter 2×10^{-3} m. into 10^{9} droplets of equal size. Surface tension of water $72\times10^{-3}\ Nm^{-1}$.

⇒ Here,

The diameter is $= 2\times10^{-3}$ m

so, Radius, $R = 10^{-3}$ m.

Droplets of equal size $= 10^{9}$

Surface Tension, $T = 72\times10^{-3}\ Nm^{-1}$

So,

$$\frac{4}{3}\pi R^3 = 10^9 \times \frac{4}{3}\pi r^3$$

Or, $R^3 = 10^9 \times r^3$

Or, $r^3 = \frac{R^3}{10^9}$

Or, $r = \frac{R}{10^3} = \frac{10^{-3}}{10^3} = 10^{-3-3} = 10^{-6}$ m.

Also,

Increase in surface Area,

$$A = 10^9 \times 4\pi r^2 - 4\pi R^2$$

$$= 4\pi (10^9 \times r^2 - R^2)$$

$$= 4\pi \{10^9 \times (10^{-6})^2 - (10^{-3})^2\}$$

$$= 4\pi ((10)^{9-12} - 10^{-6})$$

$$= 4\pi (10^{-3} - 10^{-6})$$

$$= 1.255 \times 10^{-2}$$

Excess pressure,

1side (Inside/Outside) = $\frac{2T}{r}$

2sides (Both inside+ outside) = $\frac{4T}{r}$ $\boxed{}$

∴ Amount of energy = $A \times T$

$= (1.255 \times 10^{-2} \times 72 \times 10^{-3})$ J

$= 9.039 \times 10^{-4}$ J.

(Ans)

Excess pr.

$\boxed{P}$ An air bubble of radius 0.1 mm is situated just below the surface of water. Calculate the gauge pressure (excess of pressure) inside the air bubble. Surface Tension of water = 7.2×10^{-2} N/m.

⇒ Excess of pressure = $\frac{2T}{r}$

$= \frac{\cancel{0.1 \times 10^{3}}\ (\cancel{0.1 \div 10^{3}})}{}$

$= \frac{7.2 \times 10^{-2} \times 2}{(0.1 \div 10^{3})} = 1.44 \times 10^{3}$

$= 1440$ Nm^{-2}

(Ans)

(1) In an experiment for determining the surface tension of water by capillary rise, a capillary ~~rise~~ tube of diameter 1 mm is used. The height of water in the capillary tube was found to be 3 c.m. Calculate the surface tension of water. Take density of water 10^3 Kgm^{-2}.

Note:- (তাত্ত্বিক চাপ)

$$\boxed{\begin{aligned} &\text{Excess pressure} = h\rho g \\ &\therefore \frac{2T}{r} = h\rho g \end{aligned}}$$

The pressure of liquid column

Here,

Diameter = 1 mm

Radius, $r = 0.5\ m.m = \frac{0.5}{1000}$

$= 5\times10^{-4}\ m.$

The height of water, $h = 3\ c.m$

$= 3\times10^{-2}\ m.$

Density of water, $\rho = 10^3$ Kgm^{-2}

So, the difference in water level,

$$h = (h_1 - h_2)$$

$$= \cancel{(29.39 - 14.694)\,m}$$

$$= \cancel{14.696\,m}$$

$$= (2.939 - 1.47) \times 10^{-3}$$

$$= 1.469 \times 10^{-3}\,m.$$

(Ans)

4 A glass tube of internal radius 5×10^{-1} m is dipped vertically into a vessel containing mercury such that the lower end of the tube is 10^{-2} m. below the surface of mercury. Calculate the gauge pressure of air inside the tube to blow a (ফাঁপা) hemispherical bubble at the lower end of the tube. Surface tension

of mercury = 3.5×10^{-1} Nm^{-1}. Density of mercury = 1.36×10^{1} $Kg\, m^{-3}$.

=> Here,

Internal radius of the glass tube, $r = 5 \times 10^{-4}$ m.

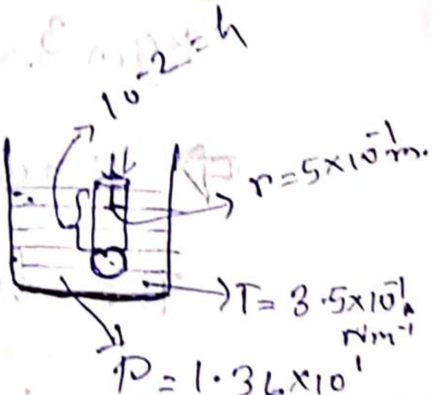
Lower end of that tube, $h = 10^{-2}$ m.

Surface tension of mercury, $T = 3.5 \times 10^{-2}$ Nm^{-1}

Density of mercury, $\rho = 1.36 \times 10^{4}$ Kgm^{-3}

Gravity, $g = 9.8$ ms^{-2}

Gause pressure = ?



Gause pressure $= \frac{2T}{r} + h\rho g$

$$= \frac{2 \times 3.5 \times 10^{-2}}{5 \times 10^{-4}} + 10^{-2} \times 1.36 \times 10^{4} \times 9.8$$

$$= \frac{2 \times 3.5 \times 10^{-1} + (5 \times 10^{-4})(10^{-2} \times 1.36 \times 10^{4} \times 9.8)}{5 \times 10^{-4}}$$

$= \cancel{2.7328}$ 1472.8 Nm^{-2}

(Ans)

□ In a capillary tube water rises to a height of 0.1 m. In the same capillary tube mercury is depressed by 3.42×10^{-2} m. Angle of contact for water = 0. Angle of contact for mercury = 135°. Calculate the surface tension of mercury given the surface tension of water as $72 \times 10^{-3}\ Nm^{-1}$. Density of mercury = 13.6×10^{3} Kgm^{-3}.

⇨ Here, Density of, $\rho_1 = 1000\ Kgm^{-3}$

The height of water, $h_1 = 0.1$ m.

The depression of mercury $= 3.42 \times 10^{-2}$ m.

Angle of contact,

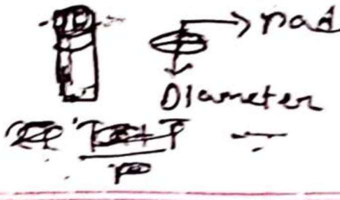
For water, $\theta_1 = 0°$

For mercury, $\theta_2 = 135°$

Surface Tension of water $T_w = 72 \times 10^{-3}$ N/m

Density of mercury, $\rho_2 = 13.6 \times 10^{3}\ Kgm^{-3}$

(Depression তাই মান হবে negative)



The surface tension of mercury = ~~T~~, $T_2 = ?$

Note:-

মূলসূত্র, $\dfrac{2T}{r} = h\rho g$

কিন্তু এখানে, Angle of contact θ বা θ আসবে এর মানও যুক্ত হবে। অর্থাৎ, $\boxed{\dfrac{2T \times \cos\theta}{r} = h\rho g}$

So,

For water, $T_1 = \dfrac{h_1 \rho_1 g \cdot r}{2\cos\theta_1}$ —— (i)

For mercury, $T_2 = \dfrac{h_2 \rho_2 g r}{2\cos\theta_2}$ —— (ii)

Here,

$$\frac{T_2}{T_1} = \left(\frac{h_2}{h_1}\right) \times \left(\frac{\rho_2}{\rho_1}\right) \times \left(\frac{\cos\theta_1}{\cos\theta_2}\right)$$

$$\text{Or, } T_2 = T_1 \left(\frac{h_2}{h_1}\right) \times \left(\frac{\rho_2}{\rho_1}\right) \times \left(\frac{\cos\theta_1}{\cos\theta_2}\right)$$

$$\text{Or, } T_2 = 72 \times 10^{-3} \times \frac{-3.42 \times 10^{-2} \times 13.6 \times 10^{3} \times \cos 0^\circ}{0.1 \times 1000 \times \cos 135^\circ}$$

Or, $T_2 = \cancel{4.73 \times 10^{-7}}\ 4.73 \times 10^{-1}$ (Ans)

13. In Jaeger's experiment, a capillary tube of internal diameter 5×10^{-4} m. dips 3×10^{-1} m inside water contacted in a beaker. The difference in level of water manometer when the bubble is released in 0.09m. Calculate the surface tension of water.

⇒ Here, Density of P_1 & P_2 = 10^3 Kgm^{-3}

The diameter of a capillary tube = 5×10^{-4}m.

Radius, r = 2.5×10^{-4}m

Height of water, $h = 3\times10^{-2}$m.

The difference in level of water manometer, H = 0.09m.

Surface Tension, T = ?

We know,

$$\frac{2T}{r} + hP_1 g + P = P + HP_2 g$$

Or, $\frac{2T}{r} = H\rho_2 g - h\rho_1 g$

Or, $T = \frac{r(H\rho_2 g - h\rho_1 g)}{2}$

Or, $T = \frac{(2.5\times10^{-4})(0.09\times10^3\times9.8 - 3\times10^{-2}\times10^3\times9.8)}{2}$

Or, $T = \frac{(2.5\times10^{-4}\times9.8)}{2}\times(0.09\times10^3 - 3\times10^{-2}\times10^5)$

$= \cancel{0.1102}$

$= \cancel{1.102\times10^{-1}\ N/m}$

$= 0.0735\ Nm^{-1}$

Or, $73.5\times10^{-3}\ Nm^{-1}$

(Ans)

viscous → সান্দ্র
Incompressible → অসংনম্য

Lesson - 02 (Final)

Fluid Dynamics and viscosity

1. Eq^n of c
2. B. Theorem
3. viscosity
4. Stoke's law.

— o —

Introduction:-

(Everything related to water)

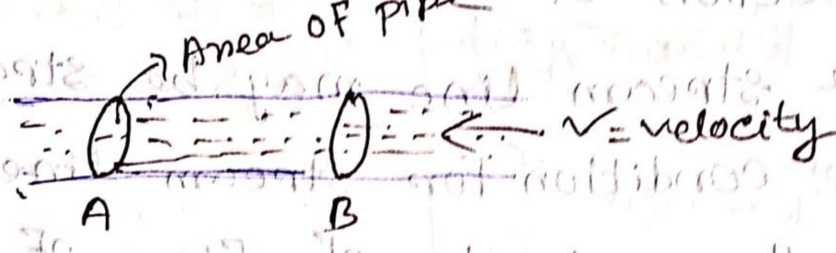
In the case of a liquid at rest, the hydrostatic pressure at any point inside the liquid is given by,

$P = h\rho g$ | h = height of water.

→ This is only for Liquid

A fluid in motion possesses various forms of energy like kinetic energy, potential energy and gravitational energy. In the case of ideal liquids, it is assumed that the viscous forces are completely absent and the liquid is highly incompressible.

Stream Line Motion and Rate of Flow:-



v = velocity of water

a = Area of ~~pressure~~ pipe / Area of cross section

যেহেতু পানি flow হচ্ছে সমবেগে,

$s = vt$

$l = vt$, ~~or $l = va$~~

$\Rightarrow$ ~~set~~ volume of liquid per unit time,

$\Rightarrow \frac{vta}{t} \Rightarrow va \Rightarrow$ (velocity of flow × area of cross section)

- যদি কোনো লাইনের সব জায়গায় সমানভাবে liquid Flow হয় তবে সেটাই Stream line or steady. Stream line motion হলে upper surface এর velocity সবচেয়ে বেশি এবং Lower surface এর velocity সবচেয়ে কম হয়।

In case of stream line motion, at any instant, the tangent to curve gives the direction of the flow of the liquid.

The stream line may be straight or curved.

The condition for stream line motion depends on the velocity of flow of the liquid.

অতিক্রম

If the velocity does not exceed a certain limiting value called the critical velocity.

IF the velocity is not higher than the critical velocity, the flow is said to be stream line.

And if it is higher than critical velocity the motion is said to be turbulent.

For laminar flow, Reynold's number R should be less than 2000. According to Reynold, the critical velocity of a liquid is given by,

$$\boxed{R_e = \frac{v_c \rho D}{\eta}}$$

$v_c =$

or, $\boxed{v_c = \dfrac{Re\,\eta}{\rho D}}$

v_c = Critical velocity of Flow
Re = Reynold's number
ρ = Density of the ~~fluid~~ fluid
D = Diameter of the tube
η = Coefficient of viscosity of the liquid

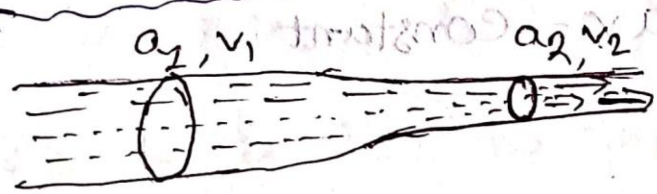
Renold এর নাম্বার যত বাড়বে, velocity ও তত বাড়বে।

Terbulent Flow: the path of the particles during their motion is zig-zag. তারা একই layer এ Flow হয় না, এই particles গুলো ভিন্ন ভিন্ন layer-এ Flow হয়।

Example:-

The Flow of river's water is a stream line motion in ~~natural~~ general time.

Equation of Continuity:-



এই জায়গায় অর্থাৎ a_1 এর area of pipe বড় কিন্তু a_2 ছোট। আর ছোট ~~ক~~ cross section

এত velocity বেশি।

এখানে,

$$\boxed{\begin{array}{c} a_1 > a_2 \\ v_2 > v_1 \end{array}}$$ ← velocity

আর এটাই হলো, equation of continuity। → ধারাবাহিকতা

As there is no accumulation (সঞ্চয়) of the liquid at any point, the amount of liquid flowing per second is the same at all cross-sections of the tube.

Amount of liquid flowing per second, $A = a_1 v_1$

Amount of " " " ", $B = a_2 v_2$

So, $\boxed{a_1 v_1 = a_2 v_2}$ ⇐ The equation of Continuity.

In general, av = constant

[1] Energy of a liquid in Motion:-

1] Liquid যখন গতিশীল থাকে তখন তার মধ্যে ৩ ধরনের শক্তি বা energy থাকে।

সাধারণত আমরা জানি, (1) Kinetic energy $= \frac{1}{2}mv^2$

But the Kinetic energy per unit weight is called velocity head and is equal to

$$\Rightarrow \frac{\frac{1}{2}mv^2}{mg} \Leftarrow \boxed{w = \text{weight} = mg}$$

(*) This energy is due to the position motion of the Liquid.

$$\text{or, } \frac{\frac{1}{2}v^2}{g} \text{ or, } \frac{v^2}{2g}$$

Liquid -এর ক্ষেত্রে যেকোনো ~~কিছু~~ energy per unit weight এ Calculation করতে হয়।

$$\text{so, } \boxed{\text{velocity head} = \frac{v^2}{2g}}$$

2] Potential Energy:-

This energy is due to the position of the liquid with respect to the ground level.

Exerted → কৰ্মাগ্ৰ

So, we know, $P.E = mgh$

So, potential head $= \frac{mgh}{mg} = h$

The potential energy per unit weight

3| pressure Energy:-

The energy is due to the pressure exerted (কৰ্মাগ্ৰ) on the liquid while it is flowing.

This energy is $= \underset{\text{pressure}}{P}\underset{\text{volume}}{V}$

So, The pressure energy per unit weight

$\Rightarrow \frac{PV}{mg}$

But we, $\rho = \frac{m}{V} \therefore \frac{1}{\rho} = \frac{V}{m}$

So, $\boxed{\text{pressure head} \Rightarrow \frac{P}{\rho g}}$

So, now if we add all ~~three ener~~ values of three energies, we will get $\boxed{\text{total energy per unit mass}}$ at any point is given by :-

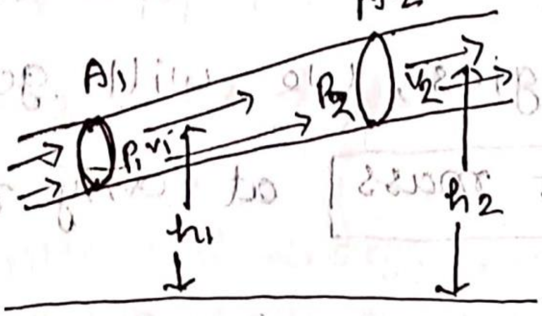
$$\boxed{\left(\frac{v^2}{2} + gh + \frac{P}{\rho}\right)}$$ [when the flow is the stream line]

If we calculate with total energy per unit weight :-

$$\boxed{\left(\frac{v^2}{2g} + h + \frac{P}{\rho g}\right)} \Rightarrow \boxed{\text{Constant}}$$

Bernoulli's Theorem :-

Liquid এর Flow যদি steady বা non-turbulent হয় তবে energy গুলোর যোগফল সমান হবে।



The motion of the liquid is stream line. Let the pressure of the liquid at the cross-section at $A_1 = a_1$ and at $A_2 = a_2$. The velocity of flow of the liquid at A_1 is v_1 and A_2 is v_2.

work done per second on the liquid

entering A_1, $W_1 = P_1 a_1 v_1$

leaving A_2, $W_2 = P_2 a_2 v_2$

We know
work, $W = FS$
w. done per time, $\frac{W}{t} = \frac{FS}{t}$
Also,
pressure, $P = F/A$ or, $F = PA$
so, $\frac{W}{t} = \frac{PAS}{t}$ $\Rightarrow [S/t = v]$
$= PAV$

$\therefore$ Net work done on the liquid,

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

But, $a_1 v_1 = a_2 v_2$ [~~Cause it is in stream line~~] [equation of continuity]

$$\therefore W = (P_1 - P_2) a_1 v_1 = (P_1 - P_2) a_2 v_2$$

This work done on the liquid contributes for the changes in kinetic energy & gravitational energy.

$\boxed{\text{Note}}$:-

gravitational energy :-

From potential energy, $P = mgh$

we also know, $m = \rho v \to \underline{v = \text{volume}}$. $[\rho = m/v]$

we know, volume, $v = a \cdot l$ (area · length)

now, $\frac{mgh}{t} = \frac{\rho v g h}{t}$ $[\because m = \rho v]$

Now, $= \frac{\rho \cdot al \cdot gh}{t} \Rightarrow \rho a g h \cdot \frac{l}{t} \Rightarrow \rho a g h \cdot v$
velocity

এখানে, work done per time unit হল (কাজ)

Now, change in gravitational energy, $E_1 = (a_1 v_1)\rho g \cdot (h_2 - h_1)$

Kinetic energy, $E_2 = \frac{1}{2} m v^2$ ⇐ (This is what we know)

$= \frac{1}{2} \rho \cdot a_1 v_1 \cdot v^2$ ↳ total velocity

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

So, $W = E_1 + E_2$

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

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

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

Or, $\frac{v_1^2}{2} + gh + \frac{P_1}{\rho} = \text{constant}$ ——— (ii)

This equation represents Bernoulli's equation

Dividing equation (ii) by g,

$\left(\frac{v^2}{2g}\right) + h + \left(\frac{P_1}{g\rho}\right) = \text{constant}$

Here,

$\frac{v^2}{2g}$ = The velocity head

h = gravitational head

$\frac{P}{g\rho}$ = pressure head.

Special case :- venturimeter :-

When it is a horizontal pipe,

h is constant,

$$\frac{v^2}{2} + \frac{P}{\rho} = \text{constant}$$

or, $P + \frac{1}{2}\rho v^2 = \text{constant}$

P = Static pressure

$\frac{1}{2}\rho v^2$ = Dynamic pressure

~~Viscosity (सान्द्रता)~~

A venturimeter is a horizontal tube. It has different cross sections at A and B. It is used to find the rate of flow of a liquid when the motion of the liquid crossing through any cross-section of the pipe is constant.

It means that, the amount of liquid crossing per second at A is equal to the amount of liquid crossing per second at B. But

$$\cancel{\frac{P_1}{\rho} - \frac{P_2}{\rho}} \quad \frac{P_2}{\rho} - \frac{P_1}{\rho} = gx - gh - gx$$
$$= -gh$$

the area of cross section at A is large.

7. Law of hydrostatic pressure:-

The difference in pressure between two points A and B can be calculated by applying Bernoulli's principle.

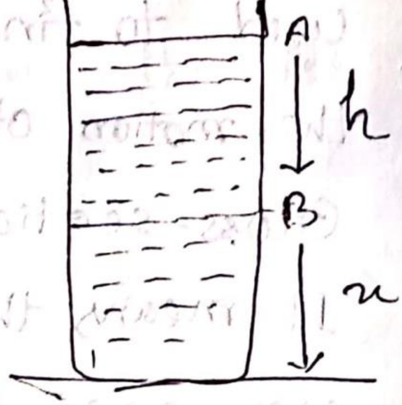
The liquid in the vessel is at rest. Therefore, $v = 0$. The total energy per unit mass at A,

$$= g(h+x) + \frac{P_1}{\rho} \quad \text{--- (i)}$$

Total energy per unit mass at B,

$$= gx + \frac{P_2}{\rho} \quad \text{--- (ii)}$$

Equating (i) & (ii)



$$g(h+x) + \frac{P_1}{\rho} = gx + \frac{P_2}{\rho}$$

$$\boxed{P_2 - P_1 = g\rho h}$$

8) Blowing of Roofs:-

Due to wind, Storm or cyclone, the roofs are blown off. When a high velocity wind blows over the roof, there is considerable lowering of pressure on the roof.

As the pressure on the lower side of the roof is higher, roofs are easily blown off without damaging the walls of the building.

(A) (B) (C)

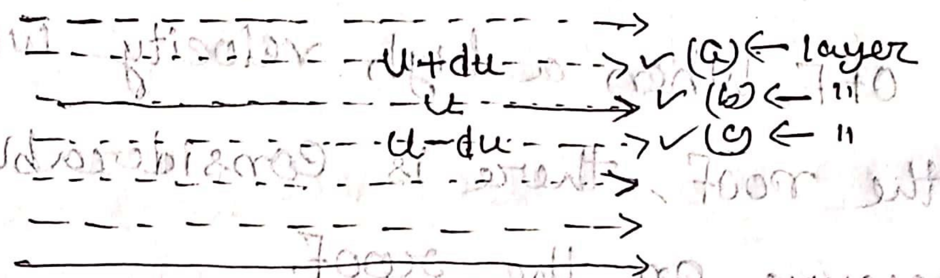
Due to wind, storm or cyclon the roofs are blown off.

lowering of pressure on the roof

lower side of the roof has high pressure. So, roofs are easily blown off without damaging the building.

Streamline → Fluid Flow but free from turbulent.

Viscosity (श्यानता)



⇒ whenever a liquid flows on a horizontal surface, the velocities of the different layers of the liquid parallel to the fixed surface are different and increase with the distance from the fixed surface.

If the motion of the liquid is streamline, the layer of the liquid in contact with the fixed surface is stationary (स्थिर). The velocity of any layer increases with the distance from the fixed layer. If any two layers are considered, the upper layer tends to accelerate the motion of the lower layer and the lower layer tends to retard the motion of the upper layer. The

& two layers together tends to destroy their relative motion. As if there is a backward tangential force. (যদি তরলের গতি স্বাভাবিক হয় অপরিবর্তনশীল স্তরের সাথে থাকা তরল হয় স্থির। যতই অপরিবর্তনশীল স্তর হতে দূরত্ব বাড়ে ততই স্তরের তরলের বেগ বৃদ্ধি পায়। যদি দুইটি ~~স্তরের~~ স্তরকে ধরা হয়, উপরের স্তরটি নিচের স্তরের বেগকে বৃদ্ধি করতে চাইবে এবং নিচের স্তরটি উপরের স্তরের বেগকে কমাতে চাইবে। এর কারন, একে অপরের গতিকে নিজে নিজের গতির সমান করতে চাইবে। ~~যেনো তাদের এর আপেক্ষিক~~ তারা একে অপরের আপেক্ষিক গতিকে ধ্বংস করতে চাইবে)।

An external force is ~~required~~ required to overcome this backward drag and to maintain the relative velocity between the different layers of the liquid. ~~This pr~~

This ~~prog~~ property by virtue (গুণ) of which a liquid opposes the relative motion between the different layers is called viscosity or internal friction.

Generally thin liquids like alcohol, water, spirit etc. are less ~~viscosity~~ viscous. Whereas, thick liquids like coal tar, castor oil, glycerine etc, are more viscous.

- According to Newton, the backward tangential force F on any layer is dependent on,

(i) $F \propto A$, the area of the layer.

(ii) $F \propto \frac{du}{dx}$, the velocity gradient at the layer,

$$F \propto A \cdot \frac{du}{dx}$$ → [Distance এর সাথে তার velocity এর পরিবর্তন]

Or, $F = -\eta A \frac{du}{dx}$

Here,

(i) η is the coefficient of viscosity of the fluid ~~and~~ ~~$\frac{du}{dx}$~~

(ii) $\frac{du}{dx}$ is called the viscosity gradient or change of velocity with distance.

(iii) The negative sign shows that the Force is acting opposite to the direction of velocity.

(*) η is called the coefficient (गुणांक) of viscosity of the fluid ~~and~~ and $\frac{da}{dx}$ is called the velocity with distance. The negative sign ~~allows~~ shows that the force is acting opposite to the direction of velocity.

If, $A = 1$ & $\frac{du}{dx} = 1$ then, $F = -\eta$

Therefore, the coefficient of viscosity is defined as the tangential force required to maintain a unit velocity gradient between two layer of area one unit each.

Units, If $A = 1$ sq cm,

$$\frac{du}{dx} = \frac{1\ cm/s}{1 cm}$$

and $F = 1$ dyne, then [তাহলে CGS unit

$$\eta = \frac{F}{A \cdot \frac{du}{dx}} \rightarrow \frac{dyne}{cm^2 \cdot s^{-1}}$$

Numerically, $\eta = 1$ poise

The coefficient of viscosity (সান্দ্রতার গুনাঙ্ক) of a liquid is one poise, if a force of 1 dyne is required to maintain a velocity gradient of one unit between two layers of area 1 sq cm each.

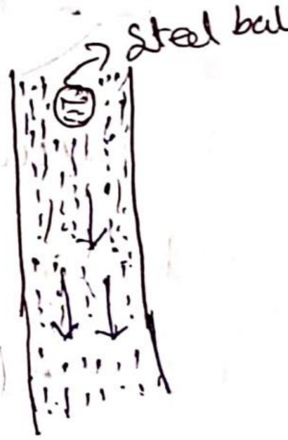
Dimensions of coefficient of viscosity:-

$$[\eta] = \frac{[F]}{[A]\left[\frac{du}{dx}\right]} = \frac{[MLT^{-2}]}{[L^2][T^{-1}]} = [ML^{-1}T^{-1}]$$

Unit of η in SI is $Kg/m\text{-}s$ or $N\text{-}s/m^2$

Stoke's law:-

when a small ball is left gently on the surface of a long vertical column of a viscous liquid, the ball moves vertically downward. Initially, the ball is accelerated due to gravity. The motion of the ball is opposed by the viscosity of the liquid. Consequently, the resultant force acting on the ball becomes zero and it moves with a constant velocity called the terminal velocity v.



The resistive force F, acting on the ball depends on,

(i) The radius of the ball, r

(ii) The terminal velocity, v

(iii) Coefficient of velocity, η.

Expressing dimensionally, $F \propto r v \eta$

$$[F] = K[r^a][v^b][\eta^c] \quad \text{--- (i)}$$

$$[MLT^{-2}] = [L]^a [LT^{-1}]^b [ML^{-1}T^{-1}]^c$$

$$[MLT^{-2}] = [M]^c [L]^{a+b-c} [T]^{-b-c}$$

$$[M]^1 \quad [L]^1 \quad [T]^{-2}$$

Equating the powers.

$c = 1$,

$-b - c = -2$

~~$b = 1$~~

$b = 1$

$a + b - c = 1$

$a = 1$

Substituting these values in equation (i)

$$F = K r v \eta$$

But , $\boxed{K = 6\pi}$ → [মুখস্থ রাখতে হবে] → K = ধ্রুবক

Force, $\boxed{F = 6\pi \eta r v}$

Coefficient of viscosity of a liquid can be determined by Stoke's formula, Suppose,

Radius of the ball = r

Terminal velocity = v

Coefficient of viscosity = η

Density of the ball = ρ

Density of the liquid = σ

weight = mg

Net weight of the ball = $\frac{4}{3}\pi r^3(\rho - \sigma)g$ —— (ii)

Upward force due to viscosity = $6\pi\eta r v$

$$6\pi\eta r v = \frac{4}{3}\pi r^3(\rho - \sigma)g \quad \text{—— (iii)}$$

Terminal velocity, $v = \dfrac{2r^2(\rho - \sigma)g}{9\eta}$

Co. viscosity, $\eta = \dfrac{2r^2(\rho - \sigma)g}{9v}$

Hence η can be determined.

Stoke's law is applicable to determine to coefficient of viscosity of highly viscous liquids.

Describe with liquid's law, what happens when someone jumps with parachute:-

The body of jumper, & The the direction of parachute is the reason why someone lands succes

বাতাস যা প্যারাসুট আটকে থাকে তার direction উপরের দিকে।

এখন উভয়ের ~~velocity~~ reaction যখন same হবে তখন সেটা একটা fixed velocity তে পড়তে থাকবে আর সেটাকে আমরা বলি Terminal velocity, এজন্য ~~অর~~ এমন মনে হবে যে সে নির্দিষ্ট বেগে স্থিরভাবে land করবে।

Math Solve

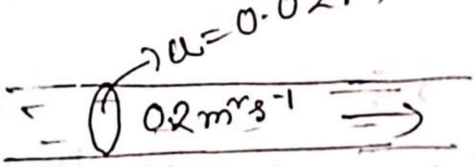
$\rho = \frac{V \times a}{t}$

Example:- 7.1 :- (Theory : Stream line Motion and Rate of Flow)

(অনুভূমিক)

Water Flows through a horizontal pipe line of varying cross section at the rate of $0.2\ m^3 s^{-1}$. Calculate the velocity of water at a point where the area of cross section of the pipe is $0.02 m^2$.

=>



Here,

Area of cross section $= 0.02 m^2$

Rate of Flow $= 0.2\ m^3/s$

velocity $= v$?

We know,

Ratio of Flow $= av$

or, $v = \frac{\text{Ratio of Flow}}{a}$

$= \frac{0.2}{0.02} = 10\ ms^{-1}$

(Ans)

*** [7.2] A pitot tube is fixed on the wing of an aeroplane to measure the speed of the aeroplane. The tube contains a liquid of density 800 kgm^{-3}. The difference in level between the two limbs is 0.5m. Density of air = 1.293 $kg\,m^{-3}$. Calculate the speed of the aeroplane.

⇨ Here,

The density of liquid, $\rho_1 = 800\ kgm^{-3}$

The difference in level between two limbs, $H = 0.5m$.

Density of air, $\rho_2 = 1.293\ kg/m^3$

velocity of plan, $v = ?$

We know,

$$\frac{1}{2} \rho_2 \times v^2 = \rho_1 \times H \times g$$

$$\text{or, } v^2 = \frac{2\rho_1 \times H \times g}{\rho_2}$$

or, $v = \sqrt{\frac{2P_2 \times H \times g}{P_1}} = \sqrt{\frac{2 \times 8000 \times 0.5 \times 9.8}{1.292}}$

$= 77.87 \; ms^{-1}$

(Ans)

Example 7.4:-

Calculate the speed at which the velocity head of a stream of water is equal to 0.5m of Hg.

(Note:- The standard atmospheric pressure of 760 mm in Height exerted when the mercury density is 13.6 cm Ho of Hg. So, the pressure of any gas is the pressure exerted by it on the walls of the container that can rise the mercury to 13.6 cm in the barometer.)

Sol

=> We know,

Velocity head $= \frac{v^2}{2g}$

0.5 m of Hg $= 0.5 \text{ m} \times 13.6$ m of water

Or, $v^2 = V.H \times 2g \times 13.6$

Or, $v = \sqrt{V.H \times 2 \times g \times 13.6}$

Or, $v = \sqrt{0.5 \times 2 \times 9.8 \times 13.6}$

Or, $v = 11.54\ ms^{-1}$

(Ans)

A railway engine is fitted with a tube whose one end is inside a reservoir of water in between the rails. The other end of the tube is 4m above the surface of water in the reservoir. Calculate the speed with which the water rushes out of the ~~proper~~ upper end, if the engine is moving with a speed of $108\ Km\ hr^{-1}$.

⇒ As the train is moving,

So there are both kinetic & potential

energy available.

So,

$mgh_1 + \frac{1}{2} m v_1^2 = mgh_2 + \frac{1}{2} m v_2^2$

Here,

or, $gh_1 + \frac{1}{2} v_1^2 = gh_2 + \frac{1}{2} v_2^2$

~~or, $g(h_1 - h_2) = \frac{1}{2}(v_1^2$~~

or, $\frac{1}{2} v_1^2 = g(h_2 - h_1) + \frac{1}{2} v_2^2$

or, $v_1^2 = 2g(h_2 - h_1) + v_2^2$

or, $v_1 = \sqrt{2g(h_2 - h_1) + v_2^2}$ —— (i)

Here,

$v_1 = ?$

~~$(h_2 - h_1) = 4$ m.~~ $(h_1 - h_2) = 4$ or, $(h_2 - h_1) = -4$

$g = 9.8\ ms^{-2}$

$v_2 = 108\ Km/hr = \frac{108 \times 1000}{3600} = 30 ms^{-1}$

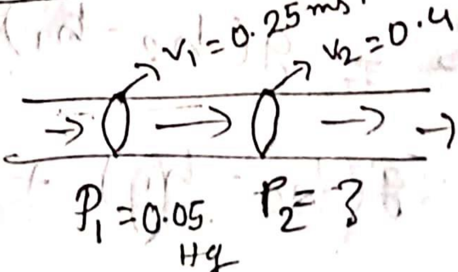
So, $v_1 = \sqrt{2 \times 9.8 \times -4 + (30)^2} = 28.66\ ms^{-1}$

(Ans)

Example - 7.7 :-

Q) Water flows through a horizontal pipe line of varying cross-section. At a point where the pressure of water, is 0.05m of Hg. the velocity of flow is $0.25 ms^{-1}$. Calculate the pressure at another point where the velocity of flow is $0.4 ms^{-1}$. Density of ~~weight~~ water is $10^3 kgm^{-2}$.

$\Rightarrow$



$\rho = 10^3 kgm^{-2}$

Here, $v_1 = 0.25 ms^{-1}$; $v_2 = 0.4 ms^{-1}$ $\rho = 10^3 kgm^{-2}$

pressure of water, $P_1 = 0.05 Hg$

$= 0.05 \times 13.6 \times 10^3 \times 9.8 \ Nm^{-2}$

$= 6664 \ Nm^{-2}$

we know,

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

Question:- 0.05 m of Hg

Nm^{-2}

$\cancel{Or, P_2 = P_1 + \frac{1}{2}(v_2^2 - v_2^2) \cdot \rho}$

$\cancel{Or, P_2 = 6664 + \frac{1}{2}\{(0.25)^2 - (0.4)^2\} \cdot 10^3}$

$\cancel{Or, P_2 =}$

$\cancel{Or, \frac{P_1}{\rho} = \frac{P_2}{\rho} + \frac{1}{2}v_2^2 - \frac{1}{2}v_1^2}$

$\cancel{Or, \frac{P_1}{\rho} = \frac{P_2}{\rho} + \frac{1}{2}(v_2^2 - v_1^2)}$

$$Or, \frac{P_2}{\rho} = \frac{P_1}{\rho} + \frac{1}{2}v_1^2 - \frac{1}{2}v_2^2$$

$$Or, \frac{P_2}{\rho} = \frac{P_1}{\rho} + \frac{1}{2}(v_1^2 - v_2^2)$$

$$Or, P_2 = P_1 + \frac{1}{2} \cdot \rho (v_1^2 - v_2^2)$$

$$Or, P_2 = 6664 + \frac{1}{2} \times 10^3 \{(0.25)^2 - (0.4)^2\}$$

$$Or, P_2 = 6664 - 48.75$$

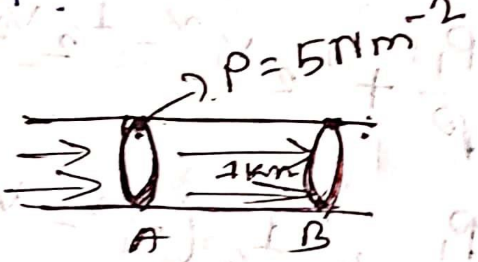
$$Or, P_2 = 6615.25\ Nm^{-2}\ \text{(Ans)}$$

$$Or, \cancel{P_2 = \frac{6615.25}{13.6 \times 10^3}}$$

Example :- 7.8 :-

In a horizontal pipe line of uniform area of cross section, the pressure falls by $5\ Nm^{-2}$ between two points separated by a distance of 1 km. What is the change in Kinetic energy per kg of the oil flowing at these points? Density of oil = $800\ kgm^{-2}$

$\Rightarrow$



According to Bernoulli's principle,

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

As the pipe line is horizontal,

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

As there are two points,

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

|

Or, $\frac{(P_1 - P_2)}{\rho} = \frac{1}{2}(v_2^2 - v_1^2)$ —— (i)

Here,

$P_1 - P_2 = 5 Nm^{-2}$ $\frac{1}{2}(v_2^2 - v_1^2)$ = Changes in kinetic energy.

$\rho = 800 kgm^{-2}$

∴ Change in kinetic energy per k.g,

$$\frac{1}{2}(v_2^2 - v_1^2) = \frac{(P_1 - P_2)}{\rho}$$

$$= \frac{5}{800} \, J/Kg$$

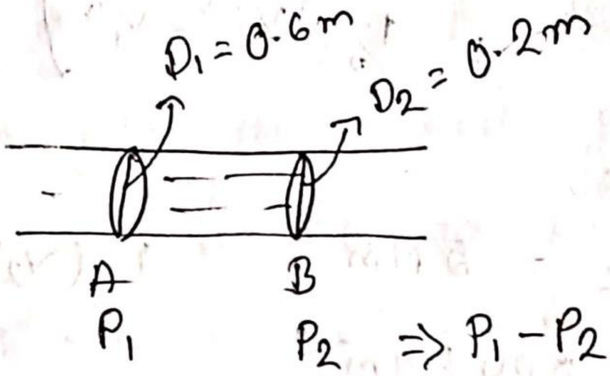
$$= 6.25 \times 10^{-3} \, J/Kg$$

(Ans)

$\boxed{\text{Example:- 7.10}}$ (সমস্যা আছে)

Water is flowing through a horizontal pipe line. At two points A and B. The diameters are 0.6m and 0.2m. The pressure difference between the points A and B is 1 metre column of water. Calculate the volume of water flowing per second.

Ans:-



$\Rightarrow P_1 - P_2 = 1$ metre column of water

kgm^{-3}

Here,

Diametre, $D_1 = 0.6m.$

$D_2 = 0.2m.$

The pressure difference, $(P_1 - P_2) =$

$= 1$ metre column of water.

$= 1 \times 10^3 \times 9.8$

$= 9.8 \times 10^3 \ Nm^{-2}$

The volume of water, $V = ?$

$\Rightarrow$ ~~For A~~,

Rate of Flow $= a_1 a_2 \sqrt{\dfrac{2(P_1 - P_2)}{\rho(a_1^2 - a_2^2)}}$

Here, $a_1 = \dfrac{\pi \times (0.6)^2}{4} = 0.09\pi m^2$

$a_2 = \dfrac{\pi (0.2)^2}{4} = 0.01\pi m^2$

5

$P_1 - P_2 = (1 \times 10^3 \times 9.8)\ Nm^{-2}$

$a_1^2 - a_2^2 = 8 \times 10^{-8}\ \pi^2$

The horizontal range,

$l = v \times t = v \times \sqrt{\frac{2h_2}{g}} = (\sqrt{2gh_1})\sqrt{\frac{2h_2}{g}}$

$= 2\sqrt{h_1 h_2}$

$h_2 = H - h_1$

$l = 2\sqrt{h_1(H-h_1)}$

$l^2 = 4h_1H - 4h_1^2$

~~De~~ Differentiating,

$2l\left(\frac{dl}{dh_1}\right) = 4H - 8h_1$

For l to be maximum, $\frac{dl}{dh_1} = 0$

$\therefore 4H - 8h_1 = 0$

$h_1 = \frac{H}{2}$

$h_2 = H/2$

and, Therefore, for the range of the liquid to be maximum, the orifice must be at half the height of the liquid column.

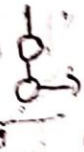
Example - 7.11 :-

(a) Find the limiting velocity of a rain drop. Assume, diameter = 10^{-3} m.

Density of air relative to water = 1.3×10^{-3} kgm^{-3}

Coefficient of viscosity of air = 1.81×10^{-5} S.I Units

Density of water, = 10^{3} Kgm^{-3}



$\Rightarrow$ According to Stoke's law,

$$6\pi\eta r v = \frac{4}{3}\pi r^3(\rho-\sigma)g.$$

$$\text{Or, } v = \frac{2r^2(\rho-\sigma)g}{9\eta}$$

$$= \frac{2r^2\rho\{1-(\sigma/\rho)\}g}{9\eta}$$

Here, $r = 5\times10^{-4}$ m.

$\rho = 10^{3}$ Kgm^{-3}

$\sigma/\rho = 1.3\times10^{-3}$

$\eta = 1.81\times10^{-8}$ S.I. Units.

$$v = \frac{2\times(5\times10^{-4})^2\times10^3(1-1.3\times10^{-3})9.8}{9\times1.81\times10^{-3}}$$

$= 30.04$ ms^{-1} (Ans)

Lecture-03 (Final)

Thermodynamics
(তাপগতিবিদ্যা)

Thermodynamic System:-

A thermodynamic system is a body of matter and/or radiation Confined (সীমাবদ্ধ) in space by walls with defined permeabilities, which separate it from its surroundings.

The surroundings may Include other thermodynamic systems, or physical systems that are not thermodynamic systems. (অর্থাৎ, পরিবেশের যতটুকু নিয়ে আলোচনা করা হয় বা আলোচনা করা যায় সেটাই সিস্টেম)

Systems are classified as Follows:-

Isolated System (বিচ্ছিন্ন ব্যবস্থা):

If there is no interchange of energy or matter between the system and surroundings

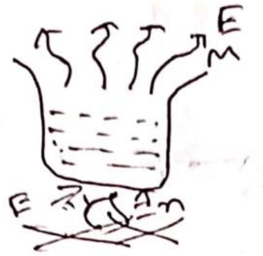
then the system is called isolated system.
(দ্রব্য ও শক্তি কোনটাই পরিবর্তন হতে না পারলে তাকে
Isolated system বা বিচ্ছিন্ন ব্যবস্থা বলে)

Closed system (বদ্ধ সিস্টেম):-

If ~~to~~ no energy or matter ~~co~~ crosses the boundary, then the system is called closed system.
(শক্তি ও দ্রব্য দেওয়া যায় কিন্তু তা আর বের হতে পারে না তাকে বদ্ধ সিস্টেম বলে)

Open system: (উন্মুক্ত সিস্টেম)

If there is an interchanges of energy or matter between the system and surroundings, then the system is called open system. (ভর ও শক্তি উভয়ই দেওয়াও যায় আবার নেওয়াও যায়)



Thermodynamic Process

A thermodynamic process is the ~~er~~ energetic development of a thermodynamic system proceeding (এগিয়ে যায়) from an initial state to a final state.

Different thermodynamic processes are:-

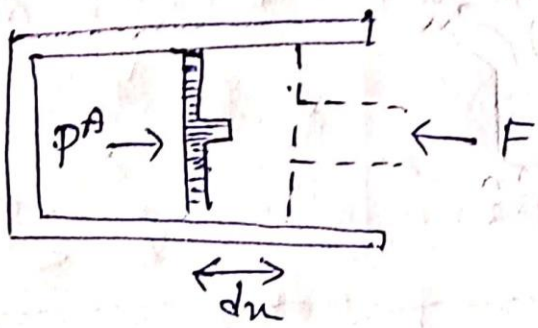
1. Isochoric process (সমআয়তন প্রক্রিয়া):

If during a process, the volume is constant then the process is called isochoric process.

2. Isobaric process (সমচাপ প্রক্রিয়া):-

যে তাপগতীয় প্রক্রিয়ায় সিস্টেমের চাপের কোনো

পরিবর্তন হয় না তাকে সমচাপ প্রক্রিয়া বলে।



3. Isothermal process (সমোষ্ণ প্রক্রিয়া):-

If during a process the temperature is constant then the process is called isothermal process.

An isothermal process is a change of a system, in which the temperature remains constant ($\Delta T = 0$). This typically occurs when a system is in contact with an outside thermal reservoir, and the change occurs slowly enough to allow the system to continually adjust to the temperature of the reservoir (জলাধার) through heat exchange.

system whereas, if the temperature of the system is slightly greater than that of the surroundings there will be a flow of heat in the opposite direction, such process is therefore reversible process where no dissipative force is present.

Irreversible process:-

If there is a finite temperature difference between system and surroundings the direction of the heat flow can't be reversed by an infinitesimal change in temperature of the system and the process is irreversible.

⊞ Concept of 1st law of Thermodynamics:-

Scientist named Joule discovered this.

1st law of thermodynamics:-

When heat is supplied to any system then a part of that helps to increase the internal energy of the system and the remaining part of the energy is used by the system to do external work on the environment.

(যখন কোনো সিস্টেমে তাপশক্তি সরবরাহ করা হয় তখন সেই তাপশক্তির কিছু অংশ সিস্টেমের অভ্যন্তরীণ শক্তি বৃদ্ধিতে এবং বাকি অংশ দ্বারা সিস্টেম তার পরিবেশের দ্বারা উপর বাহ্যিক কাজ সম্পাদন করে)

Explanation:-

(1) $\Delta U = U_2 - U_1$

The change in internal energy.

here,

U_1 = Internal energy of the system.

If Q amount of heat is added to the system then U_2 will become the internal energy.

Thus the first law of the thermodynamics gives,

(2) $Q = \Delta U + W$ => It is the mathematical form of the first law of thermodynamics.

For infinitesimal reversible process, the first law takes the form,

$$\boxed{\begin{aligned} dQ &= dU + dW \\ \text{or, } dQ &= du + \underset{\text{চাপ}}{p}\,\underset{\text{আয়তন}}{dv} \end{aligned}}$$

here,
dQ = সিস্টেম কর্তৃক শোষিত তাপ
du = অভ্যন্তরীণ শক্তি বৃদ্ধি
dw = System কর্তৃক কৃত কাজ

Application of First law of thermodynamics

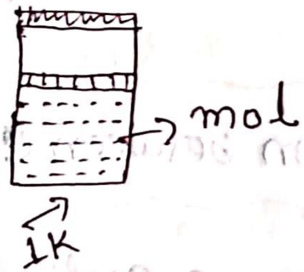
Molar specific Heat :- (মোলার তাপধারণ ক্ষমতা)

The amount of heat needed to increase the temperature one Kelvin of one mole gas is called molar specific heat.
(কোনো পদার্থের এক মোলের এক কেলভিন বৃদ্ধি করতে প্রয়োজনীয় তাপকে ঐ পদার্থের মোলার আপেক্ষিক তাপ বা মোলার তাপধারণ ক্ষমতা বলে।)

Molar specific heat at constant pressure :-

(স্থির চাপে গ্যাসের মোলার আপেক্ষিক তাপ) [Cp]

At constant pressure, the amount of heat needed to increase the temperature one Kelvin of one mole gas is called molar specific heat. [1 mol গ্যাসের temp. 1K (কেলভিন) বাড়াতে গেলে স্থির চাপে যতটুকু তাপ দিতে হয় তাই হলো Cp]



Formula :-

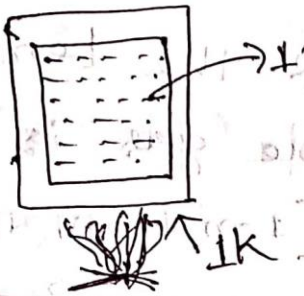
$$C_p = \frac{\Delta Q}{m \Delta T}$$

Molar specific heat at constant volume :- (Cv)

(স্থির আয়তনে মোলার আপেক্ষিক তাপ)

The amount of heat needed to increase the temperature one Kelvin of one mole gas is called molar specific heat.

(1 mol গ্যাসের Temperature স্থির আয়তনে 1K বাড়াতে গেলে যে পরিমান তাপ দেওয়া লাগে তাকে Cv বলে)



$$C_v = \frac{dQ}{m\,dT} \quad \text{or,} \quad C_v = \frac{\Delta Q}{m\Delta T}$$

Relation between C_p and C_v

Let us consider a cylinder containing one mole gas. A Fictionless piston is attached to the cylinder.

P = pressure ; v = volume ; T = Temperature

U = Internal Energy of gas.

Formulas:-

$dQ = dU + Pdv$ —— ①

$dU = C_v\,dT$ —— ②

we know that, the amount of heat needed to increase the temperature one Kelvin of one mole gas is called molar specific heat at constant volume, C_v ~~and increase in temperature dT~~ pressure,

so, $C_p = \frac{dQ}{dT}$

or, $dQ = C_p dT$ —— (3)

If R is the molar gas constant, then for one mole gas we get,

$PV = RT$

or, $PdV = RdT$ —— (4)

From (2), (3) and (4) we put those values into equation (1),

$C_p dT = C_v dT + R dT$

or, $C_p = C_v + R$

or, $\boxed{C_p - C_v = R}$

(1) $dQ = dU + PdV$

(2) $C_V dT + PdV = 0$

(3) $dT = \frac{PdV + VdP}{R}$

(4) $C_V\left(\frac{PdV + VdP}{R}\right) + PdV = 0$

(5) $VdP + \gamma PdV = 0$ [where, $\gamma = (C_P/C_V)$]

(6) $\frac{dP}{P} + \gamma \frac{dV}{V} = 0$

(7) $\ln P + \gamma \ln V =$ Constant

(8) $\ln P + \ln V^\gamma =$ "

(9) $\ln(PV^\gamma) =$ "

(10) $PV^\gamma =$ "

Here,

$C_P > C_V$ [Always]

So,

$C_P - C_V = R$ —(i)

$\frac{C_P}{C_V} = \gamma$ —(ii)

R is a Constant = 8·314

γ,

$$\left.\begin{array}{lll} 1 \text{ পরমাণুক} & = & 1\cdot67 \\ 2 \quad " & = & 1\cdot41 \\ 3 \quad " & = & 1\cdot33 \end{array}\right\} \text{value of } \gamma.$$

Second law of Thermodynamics

To Convert ~~temp~~ thermal power into others we need an engine here. This is what we call as Thermo-engine.

Different scientist have stated the law in different forms:-

1] Carnot's Statement :-

No engine can be built which can extract a fixed amount of heat and will convert totally into work.

2] Clasius's Statement :-

It is impossible for a self acting machine unaided by external agency, convey heat from one body at a lower temperature to another body at a higher temperature

3. Planck's Statement :-

It is impossible to contract an engine which can extract heat continuously from a source of heat and completely transform into work.

4) Kelvin's Statement :-

Continuous flow of energy can't be obtained from an object cooling it than the coolest part of its surroundings.

Heat Engine and Efficiency of Heat Engine

(তাপীয় ইঞ্জিন এবং তাপীয় ইঞ্জিনের দক্ষতা)

Heat Engine :-

Any mechanism for the conversion of

heat into mechanical power is called a heat engine or any suitable device which can convert heat into mechanical work is called heat engine.

Efficiency of heat Engine:-

$$\eta = \frac{W}{Q}$$

The efficiency of heat engine is defined as the ratio of work done during a cycle to the heat absorbed during the cycle.

Thus if W is ~~be~~ the amount of work obtained from heat engine in one cycle at the expense of amount of heat, Then its efficiency η is defined as,

$$\eta = \frac{W}{Q} = (Q_1 - Q_2)/Q_1$$

$$= 1 - (Q_2/Q_1)$$

Carnot's Heat Engine and its Efficiency :-

French scientist Sadi carnot discovered this in 1824.

In carnot's heat engine :-

A system carried through a carnot cycle is the prototype of all cyclic heat engines. Features that is common is, They receive an input of heat at one or more higher temperatures, do mechanical work on their surroundings, and reject at some lower temperature.

When any working substance is carried through a cyclic process, there is no change in its internal energy in any complete cycle and from the first law the net flow of heat Q into the substance in any complete cycle is equal to the workdone W by the engine per cycle,

$W = Q_1 - Q_2 = Q$

Here,

Q_1 = The heat flowing in the system per cycle

Q_2 = The heat flowing out of the system per cycle.

Thermal efficiency :-

[যা কাজ করার জন্য ব্যবহৃত হয় (Output)]

$$\eta = \frac{\text{work output}}{\text{heat input}} = \frac{\text{heat converted into work per cycle}}{\text{heat drawn from the heat source into the system per cycle}}$$

যা Supply হয় (Input)

$$= \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1} \quad \text{--- (1)}$$

[For carnot's engine the heat flowing in or out of the system is proportional to the temperature to the heat reservoir]

$Q \propto T$

or, Q/T = constant

If T_1 and T_2 are the temperature of the source and sink respectively, then

$$(Q_1/T_1) = Q_2/T_2$$

So, $\boxed{\dfrac{Q_1}{Q_2} = \dfrac{T_2}{T_1}}$

From equation ① we get,

$$\eta = 1 - \cancel{\frac{T_1}{T_2}}\ \cancel{\frac{T_2}{T_1}}\ \frac{T_1}{T_2}$$

$$\text{or, } \eta = \cancel{\frac{T_2 - T_1}{T_2}}\ \frac{\cancel{T_1 - T_2}}{\cancel{T_2}\, T_1}\ \frac{T_2 - T_1}{T_2}$$

As efficiency (কার্যদক্ষতা) is expressed in term of percentage,

$$\eta = \frac{(T_2 - T_1)}{T_1} \times 100\%$$

In the same way,

$$\eta = \left(1 - \frac{Q_2}{Q_1}\right) \times 100\%$$

Note:- As, ~~$T_1 > T_2$~~ $T_2 > T_2 - T_1$, so we can't get 100% from any engine.

If the difference between the source of heat and the receiver of heat ~~will~~ is much then the efficiency will be much too. But ~~wouldn't~~ won't be much more than 20% or 25%, sometimes 50%.

Entropy

The disability of converting energy of a system or unavailability of energy to convert into work is entropy.
(কোনো সিস্টেমের শক্তির রূপান্তরের অক্ষমতা বা ~~অসম্ভাব্যতাকে~~ বা রূপান্তরের জন্য শক্তির অপ্রাপ্যতাকে এনট্রপি বলে)

* It has not been possible to measure the absolute magnitude of entropy. If anybody absorbs or rejects ~~heat heat~~ heat then its entropy is changed.
* The change of entropy is measured by the rate of absorption or rejection of heat by the system with respect to temperature.

(কোনো সিস্টেমের তাপমাত্রার সাপেক্ষে গৃহীত বা বর্জিত তাপ পরিবর্তনের হার দ্বারা এনট্রপির পরিবর্তন পরিমাপ করা হয়।)

If any system absorbs or rejects dq amount of heat at Temperature T then the change of entrophy

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

| dq = গৃহীত বা বর্জিত তাপ
| T = বস্তুর তাপমাত্রা

$$\therefore \Delta S = \frac{dQ}{T} = \frac{0}{T} = 0$$

অর্থাৎ, রুদ্ধতাপীয় প্রক্রিয়ায় এনট্রপি স্থির।

Change of Entropy

1) Change of entropy in reversible adiabatic process :- (প্রত্যাগামী রুদ্ধতাপীয় প্রক্রিয়ার)

By definition, the heat absorbed in a reversible adiabatic is zero,

$$dq_1 = 0$$

Hence for such a process entropy change is given by,

$$ds = \frac{dQ_r}{T} = 0$$

where, S = Constant

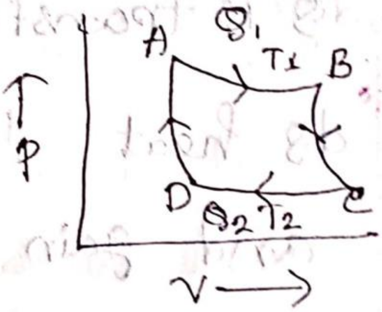
As the S is a constant and such process is called isentropic.

~~Re~~ Change of Entropy in Reversible thermal process :-

(প্রতিবর্তী প্রক্রিয়ায় এনট্রপির পরিবর্তন)

In reversible isothermal process the temperature remains constant and for such a process

$$S = \int \frac{dQ}{T}$$



In AB,

The entropy ~~im~~ increases $= \frac{Q_1}{T_1}$

In CD, " $= \frac{Q_2}{T_2}$

$\therefore$ Entropy changes, $\Delta S = \frac{Q_1}{T_1} - \frac{Q_2}{T_2}$

But in reversible, process,

$$\Delta S = \frac{Q_1}{T_1} - \frac{Q_2}{T_2}$$

But in reversible, $\frac{Q_1}{T_1} = \frac{Q_2}{T_2}$

$$\therefore \Delta S = \frac{Q_1}{T_1} - \frac{Q_1}{T_1} = 0$$

$\therefore$ Entropy didn't change.

Changes of Entropy in irreversible process:-

Let ~~two~~ the temperatures of two objects are respectively T_1 and T_2. If $T_1 > T_2$ then heat will flow from the warm object to the cold object.

dQ is transfered from warm to cold one.

dQ heat is losed by warm object and gain by cold object,

Therefore,

$-\frac{dQ}{T_1}$ = Decrease of entropy of warm object

$\frac{dQ}{T_2}$ = Increase of entropy of cold object.

Changes in Entropy, $\Delta S = \left(-\frac{dq}{T_1}\right) + \left(\frac{dq}{T_2}\right)$

Since, $T_1 > T_2$

$dS > 0$

So, irreversible entropy is always positive.

Heath Death of the Universe

Everything in nature tries to acquire the state of equilibrium (संतुलन).

As the systems, or when objects stop sharing temperature between them is called as thermal equilibrium.

As the systems proceed towards the equilibrium their entropy also increases. The entropy of a system becomes maximum when we do not get any works from it.

Since everything in nature wants to attain equilibrium so the entropy of nature is gradually ~~increaze the~~ increasing.

So, the entropy of the universe when it will attain the heighest point then everything will attain the same temperature.

As a result heat energy will not be possible to convert into mechanical energy.

It is said to be as the heat death of the universe.

The Third Law of Thermodynamics

"The entropy of a system approaches a constant value as its temperature approaches absolute zero."

This is because a system at zero temperature exists in its ground state, so that its entropy is determined ([illegible]) only by the degeneracy (অবক্ষয়) of the ground state.

Math Solve

① A quantity of air ~~&~~ at 27 C and atmospheric pressure is suddenly compressed to half its original volume. Find the final pressure and temperature.

=> Here,

Initial pressure, $P_1 = 1$ atm

Initial Temperature, $T_1 = 27$ C

$= (27 + 273)$ K

$= 300$ K

$\gamma = 1.4$

Let,

Initial volume, $V_1 = V$

Final volume, $V_2 = V/2$

Final pressure, $P_2 = ?$

Final Temperature, $T_2 = ?$

=> We know that,

During sudden compression the process is adiabetic.

Hence,

$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$

or, $P_2 = \frac{P_1 V_1^{\gamma}}{V_2^{\gamma}}$

or, $P_2 = \left(\frac{1 \times V}{V/2}\right)^{1.4}$

$\frac{1\times V}{1} \times \frac{2}{V}$

$= (2)^{1.4} = 2.639$ atm

Again,

$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$

or, $T_2 = T_1 \left(V_1^{\gamma-1} / V_2^{\gamma-1}\right)$

or, $T_2 = 300 \times (V)^{1.4-1} \times \frac{1}{\left(\frac{V}{2}\right)^{1.4-1}}$

or, $T_2 = 300 \times (V)^{1.4-1} \times \left(\frac{2}{V}\right)^{1.4-1}$

or, $T_2 = 300 \times (2)^{1.4-1}$

$= 395.852K = 122.85C.$

(Ans)

Problem-2 :-

Find the efficiency of the carnot's engine working between the steam point and the ice point solution:-

=> Here,

Initial Temperature, T_1 (Steam point) $= 100C$

$= (100+273)K = 373K$

Final Temperature, T_2 (Ice point) $= 0°C = (0+273)K$

$= 273K$

Efficiency, $\eta = ?$

we know that,

$$\eta = 1 - \left(\frac{T_2}{T_1}\right)$$

$$= 1 - \frac{273}{373}$$

$$= \frac{100}{373}$$

i.e. $= \frac{100}{373} \times 100\% = 26.8\%$

(Ans)

Problem-03:-

A Carnot's engine whose temperature of the source is 400K takes 200 calories of heat at this temperature and rejects 150 Calories of heat to the sink. What is the temperature of sink? Also Calculate the efficiency of the engine?

⇒ Here,

Initial heat, $Q_1 = 200$ Cal

Final heat, $Q_2 = 150$ Cal

Initial Temperature, $T_1 = 400K$

Final Temperature, $T_2 = ?$

⇒ We know that,

$$\frac{Q_1}{Q_2} = \frac{T_1}{T_2} \quad \text{or, } T_2 = \frac{T_1 \cdot Q_2}{Q_1}$$

$$\text{or, } T_2 = \frac{400 \times 150}{200} = 300K$$

Again,

Efficiency, $\eta = 1 - (T_2/T_1)$

$= 1 - (300K/400K)$

$= \frac{1}{4} = 0.25 \times 100\%$

$= 25\%$

(Ans)

(4) If a system absorbs 1100 J heat and work is done 300 J on the system, Find the internal energy of the system.

=> Here, Heat, $Q = 1100 J$

work done, $W = 300 J$

Internal energy, $U = ?$

We know that,

$U = Q - W$

$= (1100 - 300) J$

$= 800 J$

(Ans)