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**BY-AMIT KAKKAR SIR**

- Theory
- Explanation
- Derivation
- Example
- Shortcuts
- Previous Years Question With Solution

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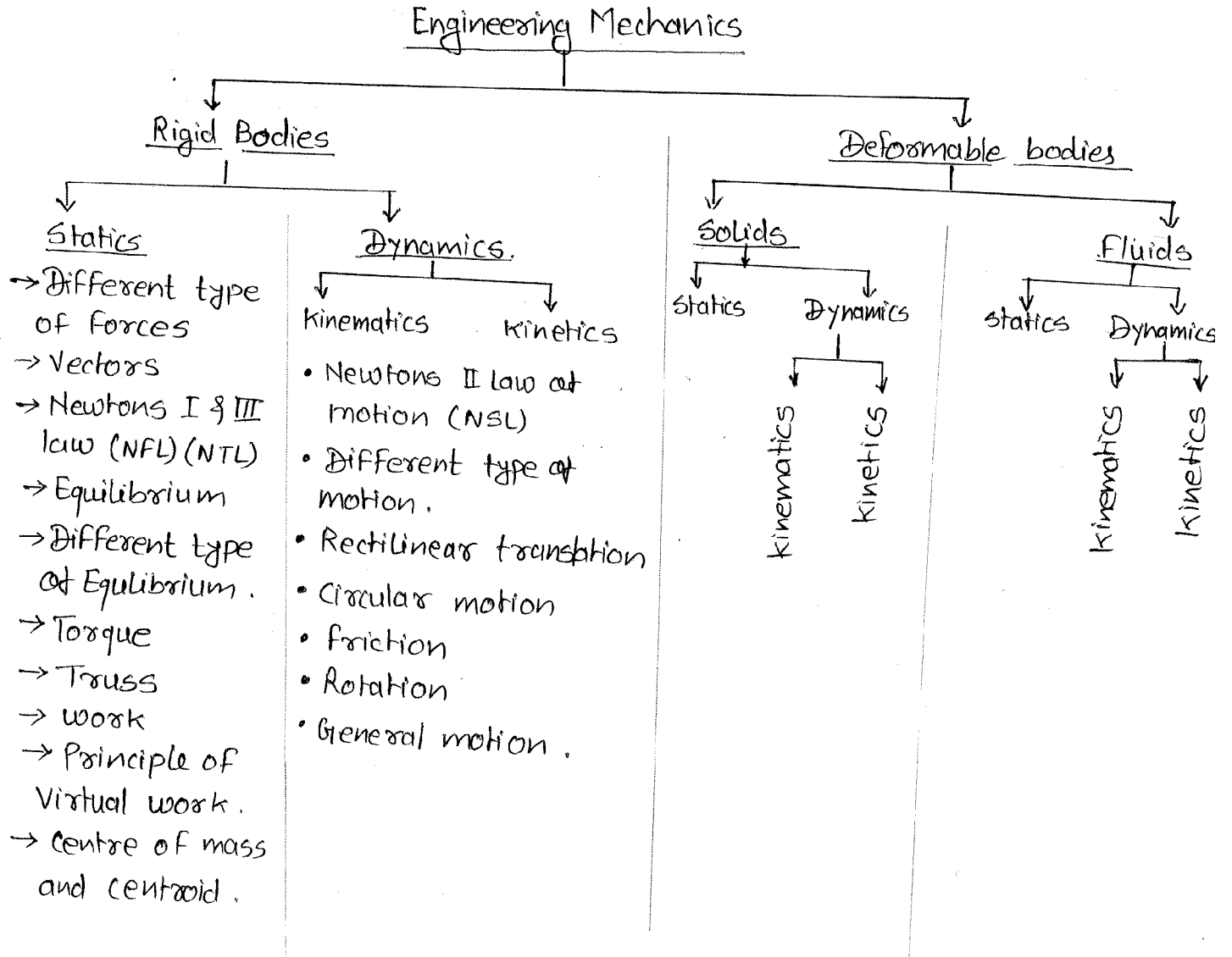
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# \* Engineering Mechanics

→ "It is a science which deals and predicts the condition of the system either at rest or in motion under the action of external force."



# Different ideal concepts in engineering mechanics

## 1) Rigid body

→ whenever loads applied on body, body deforms but if the deformations are negligible wrt size of the body then we can neglect those deformations and we can treat the bodies as a rigid body.

## 2) Continuum

→ Even in solids there is void space between the adjacent molecules and atoms we know that these void spaces are microscopic therefore if the size of body is sufficiently good that means microscopic then we can neglect the void spaces and we can assume adjacent to one molecule there is another molecule hence the entire body is treated as continuous distribution of mass known as continuum.

## 3) Body as a Particles

Real

Real

# Force ( $\vec{F}$ )

→ Action of one body to the other body.

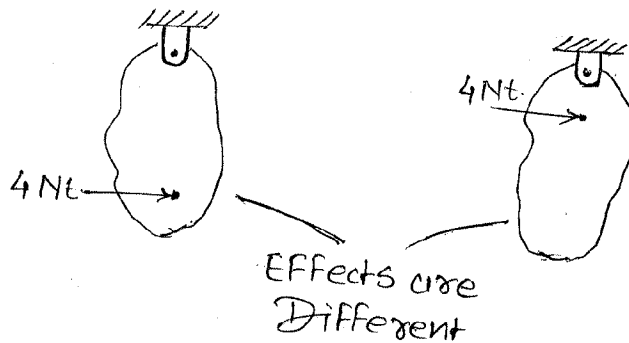
## Vector Quantity

→ Quantities having magnitude and direction.

- when the force is applied on the body this implies that it is applied on some of the particles of body.

Then to define force:

- Magnitude
  - Direction
  - Point of application
- } Required.



Whenever the force is applied on the body, then for that force ( $\vec{F}$ ), two bodies will exist.

- One body → which is applying force
- Second body → on which the force is applied.

## Note

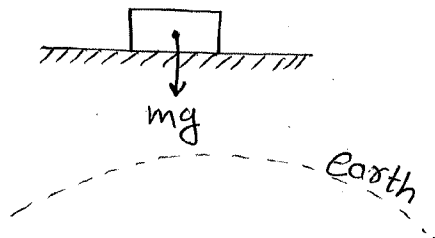
→ If a force is acting on the body, but there is no other body which is applying this force, that force is called Pseudo force (Artificial force)

# Different type of forces

[most frequently appearing in EM]

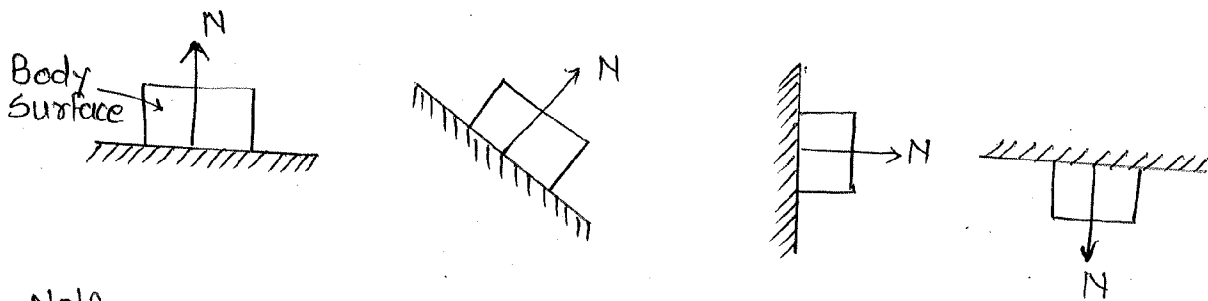
## 1) Weight (w) (mg)

- force acted on the body by the earth.
- It is a body force.



## 2) Normal Reaction (N) :-

- Surface force
- Acts on the body by the surface exactly in the direction perpendicular to the surface.
- It is due to pressing effect between contacting surface.



### Note

- IF the surface are touching but not pressing then,

$$N = 0^{**}$$

## 3) Friction: (Dry friction)

- Surface force
- Along the surface
- It resists the relative motion or tendency or relative motion between the contacting surface.

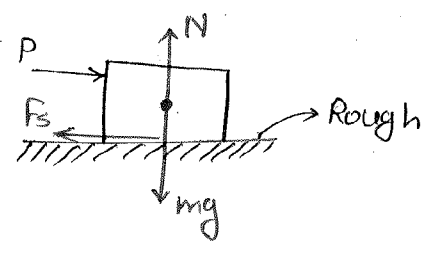
### Static Friction ( $f_s$ )

→ Due to the tendency of relative motion between the contacting surface { no relative motion }.

→ It is a variable friction.

$$0 \leq f_s \leq \mu_s N$$

$\mu_s$  → Coefficient of static friction.



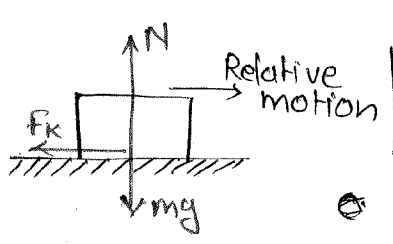
Applied force	Static friction ( $f_s$ )
0	0
1Nt	1Nt
2Nt	2Nt
3Nt	3Nt
⋮	⋮
⋮	⋮
$\mu_s N$	$\mu_s N$

→ Static friction is conservative force

$$\text{Energy loss} = 0 \quad **$$

It is a tendency of relative motion is more than the  $f_{smax} = \mu_s \cdot N$ .

- If relative motion starts friction developed is called kinematic friction ( $f_k$ ) ~~the~~ this friction is developed due to the relative motion between the contacting surfaces.



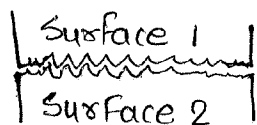
$$f_k = \mu_k \cdot N$$

$\mu_k$  → Coeff. of kinetic friction

Constant friction = Non ~~is~~ conservative force  
Energy loss.

## Coefficient of friction ( $\mu_s, \mu_k$ )

→ Every surface is having surface irregularities

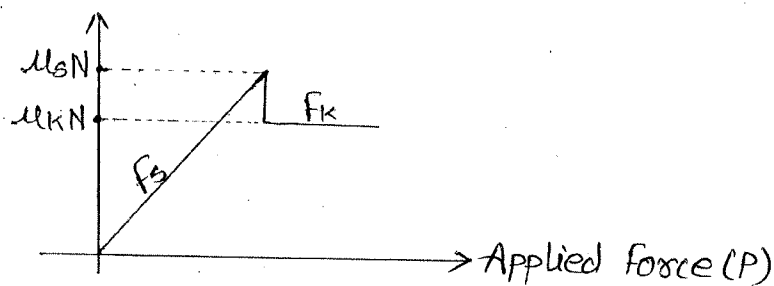


Depends upon

- 1) Surface irregularities
- 2) How irregularities are interlocked.
- 3) No. of interlocking.

" $\mu_s$ " is slightly more than " $\mu_k$ "

→ Because a little bit decrease in strength of interlocking at the moment when relative motion starts.

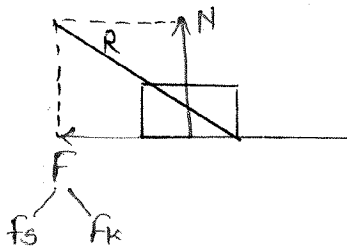


Total Contact force: ( $\vec{R}$ )

$$\vec{R} = \vec{N} + \vec{F}$$

$f_s$       $f_k$

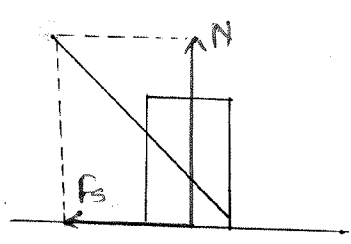
Resultant of friction & normal reaction.





### Angle of static friction ( $\phi_s$ )

→ Angle between the normal reaction and total contact forces when body is at verge of relative motion.



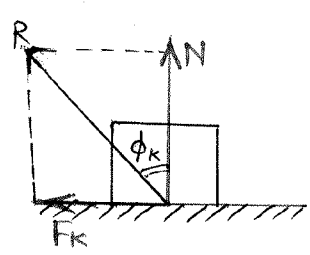
$$R \sin \phi_s = f_{s \max} = \mu_s N$$

$$R \cos \phi_s = N$$

$$\boxed{\mu_s = \tan \phi_s}^{**}$$

### Angle of kinetic friction ( $\phi_k$ )

→ Angle between normal reaction and total contact force when body is in relative motion.



$$R \sin \phi_k = f_k = \mu_k N$$

$$R \cos \phi_k = N$$

$$\boxed{\mu_k = \tan \phi_k}^{**}$$

Note • IF only one coefficient of friction ( $\mu$ )

$$\Rightarrow \boxed{\mu_s = \mu_k = \mu}$$

• IF only one angle of friction ( $\phi$ ) is given.

$$\boxed{\mu_s = \mu_k = \tan \phi_s = \tan \phi_k = \tan \phi = \mu}$$

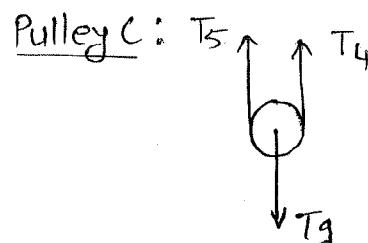
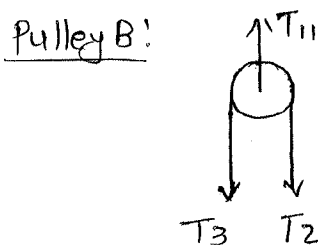
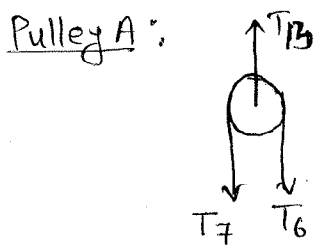
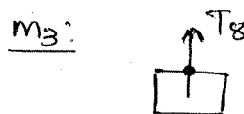
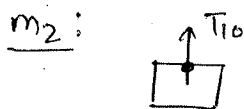
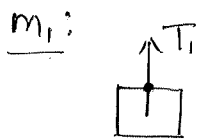
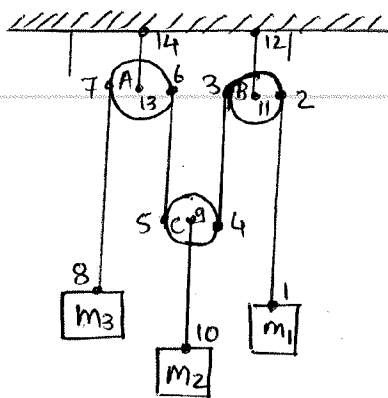
### ↳ Tension (Tension in string):-

→ It is a pulling force.

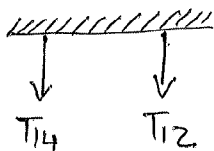
→ Tension always acts along the string.

→ It is always away from the body (system).

Consider the following system.



Support



1-2 Position of string





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~ Session 2021-22 ~

**Faculty : Sagar Dodeja** (Ex. IES)  
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# INTRODUCTION TO ENVIRONMENTAL ENGINEERING

TEACHER – SAGAR DODEJA (IES)  
SR. FACULTY, MADE EASY

These are interactive notes for Made Easy Classroom Students and Made Easy Online Students. These notes contain basic knowledge only and classes need to be attended thoroughly for in-depth explanations and solving Workbook Questions.

All the blank spaces are intentionally left for the students to write during the lectures.

Students should keep a separate copy of 200 pages with them at all times to solve all Workbook questions.

These notes are already tried and tested successfully on thousands of students and the notes provided have ensured maximum output from them.

With these notes, students can focus entirely on concept building and developing problem solving skills as basic theory, diagrams and facts are already written clearly in the notes. This also minimises errors during writing.

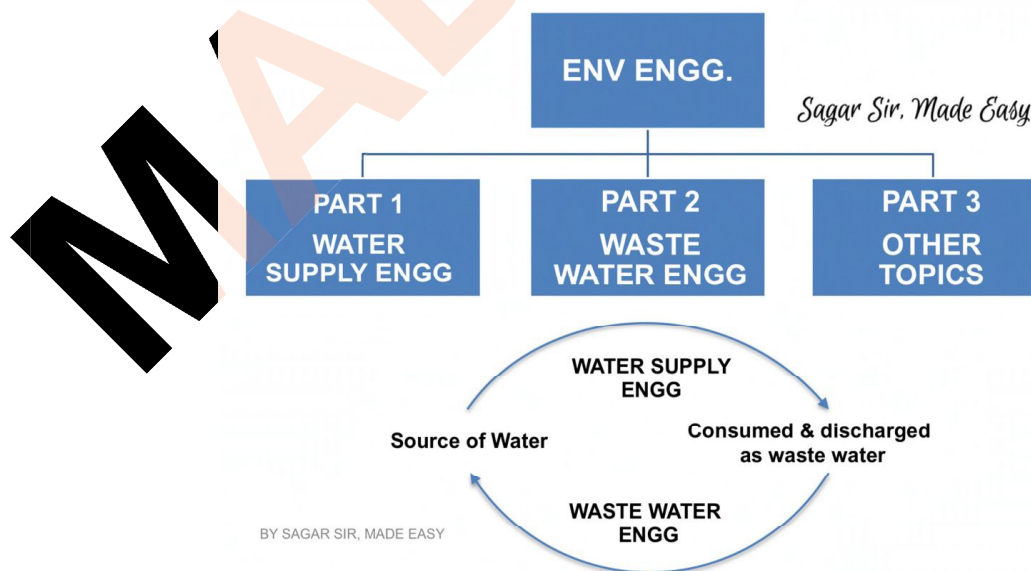
**ENJOY THE LEARNING EXPERIENCE!**

## Weightage in ESE

ESE	OBJECTIVE	CONVENTIONAL	TOTAL
2014	36.67	56	92.67
2015	38.33	56	94.33
2016	33.33	56	89.33
2017	26.72	105	131.72
2018	36	100	136
2019	26	96	122
2020	30	110	140
2021			

## Weightage in GATE

GATE YEAR	MARKS
2016 average	10
2017 average	12
2018 average	11
2019 average	11
2020 average	11
2021 average	15
<b>Average</b>	<b>11</b>



## Flow of Course

### Part 1 Water Supply Engineering

S NO.	DESCRIPTION	INSTRUCTIONS FOR STUDENTS
1	WATER DEMAND - Population Forecasting - Various Types of Demand	-SOLVE WB AS SOON AS IT ENDS
2	SOURCES OF WATER - Focus on Sub Surface Sources - Geological Formations - Well Hydraulics	-SOLVE WB AS SOON AS IT ENDS  <i>Sagar Sir, Made Easy</i>
3.	WATER QUALITY PARAMETERS -Physical, Chemical & Biological Parameters	-REVISE AS MUCH AS POSSIBLE -MEMORIZE KEY POINTS OF IS 10500 -SOLVE WB ALONG WITH CLASS
S.NO.	DESCRIPTION	INSTRUCTIONS FOR STUDENTS
4	TREATMENT OF WATER -General process of treatment - Screening, Aeration, Coagulation, Flocculation, Sedimentation, Filtration & Disinfection -Minor methods of treatment - Lime Soda Process, Ion Exchange, Demineralisation, Nalgonda, Prashanti and other techniques.	-DESIGN DATA NOT REQUIRED FOR GATE. - SOLVE WB TWICE BEFORE EE ENDS
5	WATER DISTRIBUTION -Types of Distribution Networks -Types of Pipes, Valves and Joints -Balancing Reservoir/ Distribution Reservoir Design	-SOLVE WB AS SOON AS IT ENDS  <i>Sagar Sir, Made Easy</i>

Note : All the reforms for water treatment which were extensively adopted by the Water Act of 1974 are also included in the lectures along with the standard GOI Manuals & IS Codes.

## Part 2 Waste Water Engineering

S.NO.	DESCRIPTION	INSTRUCTIONS FOR STUDENTS
6	WASTEWATER MICROBIOLOGY	-MEMORIZE IT BEFORE NEXT CHAPTER
7	QUALITY CHARACTERISTICS OF WASTEWATER	-SOLVE WB AS SOON AS IT ENDS
8	DISPOSAL OF WASTEWATER - Self purification Mechanism in Rivers - Disposal in Land, Sea - Lake characteristics and terminologies	- SOLVE WORKBOOK AS SOON AS IT ENDS <i>Sagar Sir. Made Easy</i>
9	TREATMENT OF WASTEWATER -Primary, Secondary & Tertiary Treatment -Sludge Handling -Oxidation Ponds, Septic Tanks, Imhoff tanks etc.	- SOLVE WORKBOOK QUESTIONS TWICE ALONG WITH CLASS
10	SEWERS AND SEWERAGE SYSTEM - Components and Layout of Sewerage System - Design of sewers - Hydraulic characteristics	- SOLVE WORKBOOK AS SOON AS IT ENDS

## Part 3 - Small but an important portion

CHAPTER NO.	DESCRIPTION
11	SOLID WASTE MANAGEMENT -Sources and classification of Solid Wastes -Municipal Solid Waste Management – Characteristics, generation, collection & disposal - Generation of energy - Characteristic terminologies
12	AIR POLLUTION - Types of pollutants, sources, impacts, control, air quality standards & limits - Air Pollution Meteorology - Lapse Rates, types of atmosphere - Plume behaviour <i>Sagar Sir. Made Easy</i>
13	NOISE POLLUTION Impacts of noise, permissible limits, measurement of noise, & control of noise pollution Various terms such as Leq, Ln etc

## CHAPTER WISE ANALYSIS

CHAPTER NAME	ESE	GATE
WATER DEMAND	2.3%	1%
SOURCES OF WATER	7.2%	5%
WATER QUALITY PARAMETERS	10.3%	18.3%
TREATMENT OF WATER	22.5%	21.9%
CONVEYANCE & DISTRIBUTION SYSTEMS	3.6%	3.1%
WASTE WATER CHARACTERISTICS	5.4%	13%
DISPOSAL OF WASTE WATER	4%	2%
WASTE WATER TREATMENT	17.3%	15.5%
DESIGN OF SEWERS & SEWERAGE SYSTEMS	6.7%	3.5%
MUNICIPAL SOLID WASTE MANAGEMENT	6.45%	4.3%
AIR & NOISE POLLUTION	14.3%	12.4%

## Reference Books

- GOI Manuals
  - Environmental Engg – Peavy, Rowe & Tchobanoglous
  - Environmental Engg – Metcalf & Eddy
  - Water Supply Engg - S K Garg
  - Waste Water Engg – S K Garg
  - Environmental Chemistry - Sawyer, McCarty, Parkin
  - Environmental Engineering - Davis & Cornwell
- Sagar Sir, Made Easy*
- *Everything related to GATE & ESE will be covered in class itself. If anything else is required, above materials can be referred.*

## MANUALS

- GOI Manual on Water Supply & Treatment, 1999
- GOI Manual on Sewerage and Sewage treatment (Part A, B & C), 2013
- GOI Manual on Municipal Solid Waste Management, 2016

*Note : All manuals are developed by CPHEEO (Central Public Health & Environmental Engineering Organization) under MoUD (Ministry of Urban Development)*

*Download link : <http://cpheeo.nic.in/> Sagar Sir, Made Easy*

Apart from GOI Manuals, there will be references to various IS Codes in the lectures



start of

**WATER  
SUPPLY  
ENGINEERING**

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# CHAPTER 1

## WATER DEMAND

### CONTENTS

Students should write this after chapter completion. This provides with overall view & acts as a tool for active recalling.

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## CHAPTER 1 WATER DEMAND.

Water Demand — Water Demand implies water quantity estimation. The quantity of water required for municipal uses for which the water supply scheme has been designed requires the following data —

1. Forecasted population.
2. Rate of consumption (l/c/d or m<sup>3</sup>/d/capita)

### Design Period

The quantity of water is worked out for requirement of future population. Water supply system involves huge investment because the such as dams, reservoirs, canals and costly structures such as distribution network, various and vast structures units etc. which cannot be easily replaced or modified.

The future period for which the water supply scheme is designed to cater for the future population is known as Design Period.

Design Period is not very high nor very low. Why?

PART 1

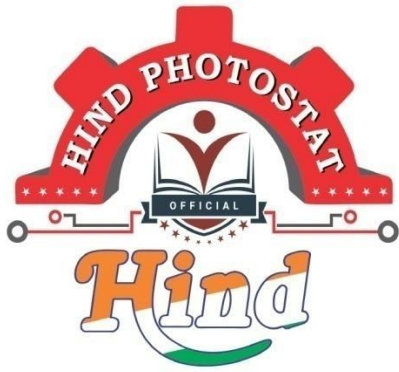
Population Forecasting → Mathematical Methods  
 → Graphical Methods.

Mathematical Methods.

1. Arithmetic Increase Method.
2. Geometric Increase Method.
3. Incremental Increase Method.
4. Decreasing Rate of Growth Method.

## 1. Arithmetic Increase Method (AIM)

- This method is based on the assumption that the population increases at a constant rate from the last known population. An average increase in population ( $\bar{x}$ ) is considered to compute the future population.
- It is used for those cities which are sufficiently large and are already established.



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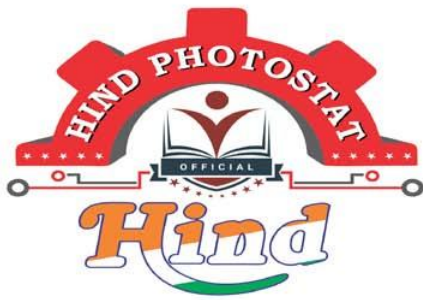
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1. KE E /E /
2. E /E /
- D, E /E /
4. / E /E /
- /E DE /KE E /E /
6. KD /

**,GATE, TEST @**

❖ -W / & D /

❖ GATE

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**, YADAV, KD D, &K E /KE, -GRAW, D, W KE...K s**

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# R.C.C

8826630002 MK. Singh.

## GATE + ESE

- ① Basic properties
- ② Working stress method (SRB/WSM) - concepts
- ③ Limit state method (LSM) - concepts
  - a) Single Reinforced
  - b) Doubly Reinforced
  - c) T/L sections.
- ④ Shear & Torsion
- ⑤ Bond & Dev. Length
- ⑥ Beam & Lintels
- ⑦ slab
- ⑧ Column
  - a) Material Properties
  - b) Analysis of stress
  - c) Losses
  - d) slope & Deflection
  - e) Design of PSC member.

## ESE syllabus → addition to GATE + ESE

- ⑩ foundation
- ⑪ stair case
- ⑫ Retaining wall
- ⑬ Water Tank
- ⑭ Masonry structure
- ⑮ Earthquake Engineering

QUESTION 1

- 1) The number of ways of selecting 3 items from 10 items is  ${}^{10}C_3 = 120$
- 2) The number of ways of selecting 3 items from 10 items is  ${}^{10}C_3 = 120$
- 3) The number of ways of selecting 3 items from 10 items is  ${}^{10}C_3 = 120$
- 4) The number of ways of selecting 3 items from 10 items is  ${}^{10}C_3 = 120$
- 5) The number of ways of selecting 3 items from 10 items is  ${}^{10}C_3 = 120$
- 6) The number of ways of selecting 3 items from 10 items is  ${}^{10}C_3 = 120$
- 7) The number of ways of selecting 3 items from 10 items is  ${}^{10}C_3 = 120$
- 8) The number of ways of selecting 3 items from 10 items is  ${}^{10}C_3 = 120$
- 9) The number of ways of selecting 3 items from 10 items is  ${}^{10}C_3 = 120$
- 10) The number of ways of selecting 3 items from 10 items is  ${}^{10}C_3 = 120$

QUESTION 2

- 1) The number of ways of selecting 3 items from 10 items is  ${}^{10}C_3 = 120$
- 2) The number of ways of selecting 3 items from 10 items is  ${}^{10}C_3 = 120$
- 3) The number of ways of selecting 3 items from 10 items is  ${}^{10}C_3 = 120$
- 4) The number of ways of selecting 3 items from 10 items is  ${}^{10}C_3 = 120$
- 5) The number of ways of selecting 3 items from 10 items is  ${}^{10}C_3 = 120$



## Important in codes

- ① IS 456 - 2000 : Design of RCC structures.
- ② IS 1893 : Earthquake Resistant design of structure.
- ③ IS 13920 : Design & ductile detailing of RCC structures.
- ④ IS 3370 : Pt I to IV - Design of water tanks.
- ⑤ IS 1343 : Pre stressed concrete.
- ⑥ IS 1905 : Design of load bearing walls (masonry wall)

## Important in Handbooks

### Design Handbooks :-

- \* 1 SP 16 → 1980 Design Aids for RC to IS 456
- \* 2 SP 23 → 1982 Handbook - Concrete mixes
- \* 3 SP 24 → Explanatory handbook - IS 456 - 1978
- \* 4 SP 34 → Handbook - Concrete Reinforcement and Detailing.

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# BASIC Properties of Cement Concrete and steel

## RCC (Reinforced Cement concrete) :-

- ① Cement concrete - \* mainly for compression  
- \* Tensile strength is very low.
- ② Steel Reinforcement - \* for resisting mainly tension  
- \* as well as compression

## Cement concrete

\* → Mixture of Water, Cement, Sand (fine Aggregate), Stone (Coarse Aggregate) & Admixtures.

\* Cement concrete with Reinforcement is called Plain Cement concrete.

Cement Mortar = Cement + Sand + Water

Cement concrete = Cement + Sand + Water + Stone aggregate  
+ admixture.

## Cement concrete →

Cement concrete reinforced by steel is called RCC (Reinforced cement concrete).

Plain cement concrete (PCC) is without steel

## ① Water for concrete → P<sub>w</sub>

\* Water fit for human are good for concrete

\* Water used for concrete should be clean &

→ free from oil, salts, sugar, organic materials etc.

→ that may not harm concrete.

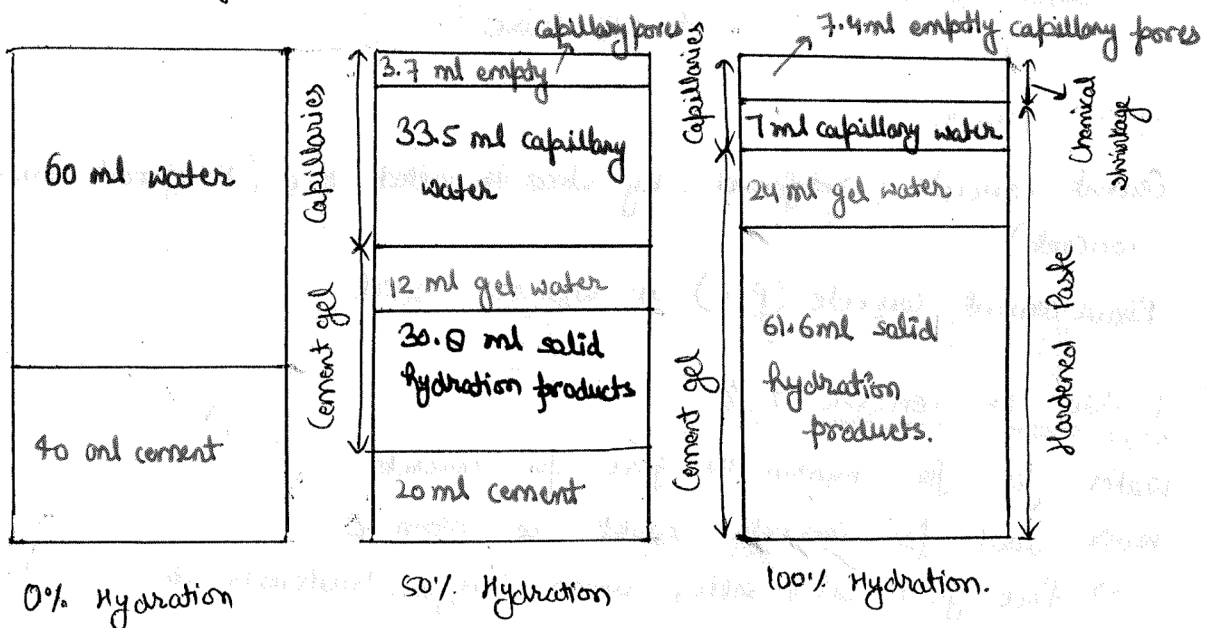
\* Sea water should not be used for RCC.

\* Salt of sea water is harmful for concrete.

- \* In extreme case it may be used for PCC
- \* The pH value of water shall not be less than 6
- \*  $\text{pH} < 6 \rightarrow$  Highly acidic :- Not acceptable
- \*  $\text{pH} = 6 \rightarrow$  acidic :- Acceptable
- \*  $\text{pH} = 7 \rightarrow$  Neutral :- Best water for concrete.
- \*  $\text{pH} > 7 \rightarrow$  Slightly alkaline water is also acceptable.

### Water in Cement concrete is for :-

- ① Combined water  $\rightarrow$  Chemically combined water with the cement for hydration. it is non-evaporable.
- ② Gel water  $\rightarrow$  Held physically or adsorbed on the surface area of the 'cement gel'. A fraction of gel water is evaporable.
- ③ Capillary water  $\rightarrow$  Occupies the 'capillary pores' that constitute the space in the cement paste. This water is easily evaporated.



Q Maximum limit of suspended matter in water

- a) 200 mg/Litre
- b) 2000 mg/L ✓
- c) 3000 mg/L

Q Maxm limit of Organic matter in water

- a) 200 mg/L ✓
- b) 2000 mg/L
- c) 3000 mg/L

Permissible Limits of Solids in water

<u>Tested for</u>	<u>Permissible Limits</u>
* Organic	200 mg/L
* Inorganic	3000 mg/L
* Sulphates	400 mg/L
* Chlorides	2000 mg/L — for PCC 500 mg/L — for RCC
* Suspended matter	2000 mg/L

## ② Cement

① OPC ordinary Portland cement →

- a) 33 grade OPC
- b) 43 grade OPC
- c) 53 grade OPC

② Rapid Hardening cement — Becomes hard rapidly

③ Portland Pozzolana cement — Use Pozzolana

④ Hydrophobic cement — water repellent

⑤ Low Heat cement — Produce less heat

⑥ Sulphate resisting Portland cement.

### ③ Aggregates →

a) Fine Aggregates = Sand (up to 4.75 mm size)

b) Coarse Aggregates = Stone chips of mixed sizes  
4.75 mm to 20 mm or  
4.75 mm to 40 mm.

\* Size  $> 4.75$  mm & larger

\* Angular are better than rounded aggregates.

\* for RCC - 20 mm aggregates are generally used.

→ (size 20 mm or less - mixed sizes)

→ Well graded stone aggregates are better

→ Uniformly (poorly) graded not suitable.

\* 10 mm size - for closely placed steel sections.

\* 40 mm size - for PCC etc.

### Classification of aggregates →

① Fine aggregate → sand and/or crushed stone

→  $< 4.75$  mm

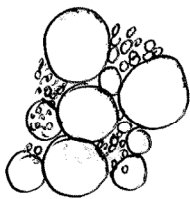
→ Fine aggregate usually 35% to 45% by mass or volume of total aggregate etc.

② Coarse aggregate → Gravel & crushed stone

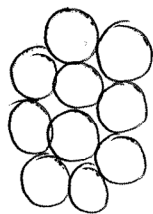
→  $> 4.75$  mm

→ Typically b/w 9.5 & 37.5 mm

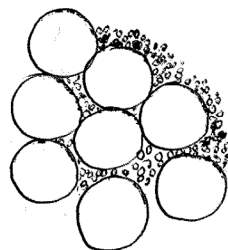
### Types of Aggregates :-



Well Graded



Poorly Graded

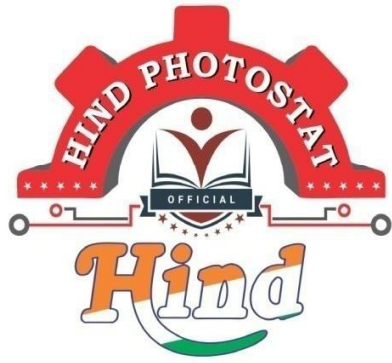


Gap Graded

**NOTE**

→ Concrete Pump used for Pumping concrete.

Concrete vibrator used for proper compaction of concrete.



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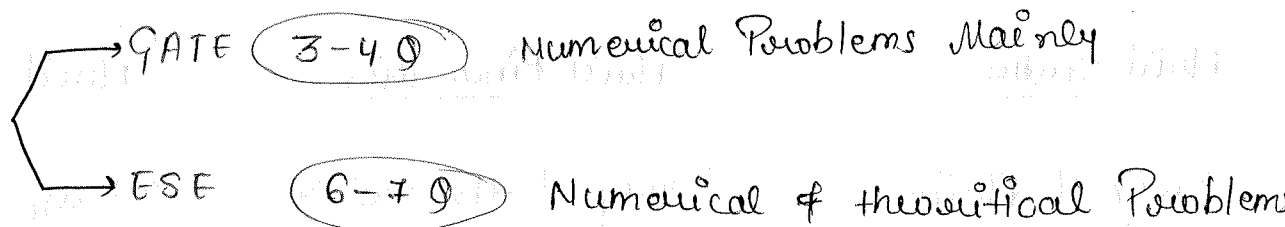
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# fluid Mechanics



## Text Books

fluid Mechanics & Hydraulic Machines — R K BANSAL

Hydraulics And fluid Mechanics — P N MODI  
SM SETH

fluid Mechanics — CENGEL  
CIMBALA

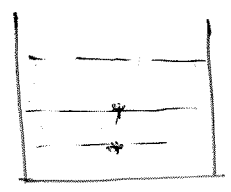
## Syllabus

1. Introduction & properties of fluids
2. Pressure & its measurement
3. Hydrostatic force on surfaces
4. Buoyancy & flotation
5. fluid kinematics
6. fluid Dynamics
7. Dimensional Analysis
8. Pipe flow
9. Laminar flow
10. Boundary Layer theory
11. Turbulent flow in pipe
12. flow over submerged Bodies.

- class workbook
- Previous Gate Problems
- Previous ESE Problems
- TEST SERIES

fluid statics

"Study of fluid when it's in static condition."



fluid kinematics

"Study of the motion of fluid without considering the cause of motion."

Eq<sup>n</sup> used -

$$\vec{v} = \frac{d\vec{s}}{dt} = \frac{d\vec{s}}{dt}$$

$$\vec{a} = \frac{d\vec{v}}{dt}$$

fluid Dynamics

"Study of the motion of fluid with considering the cause of motion."

Eq<sup>n</sup> used

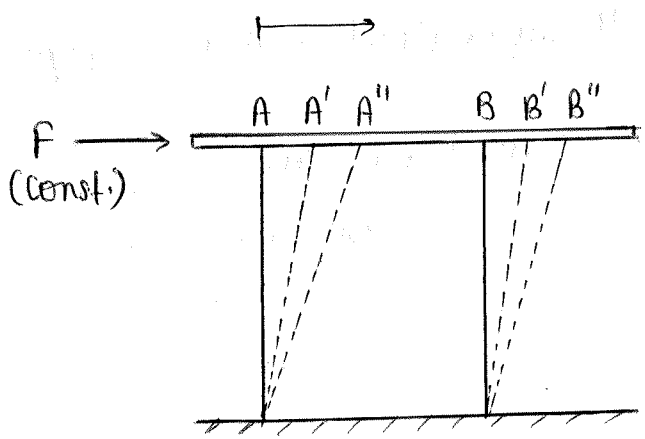
$$\vec{F} = \frac{d(m\vec{v})}{dt}$$

In General

- Solid
  - Liquid
  - Gas
- } fluids

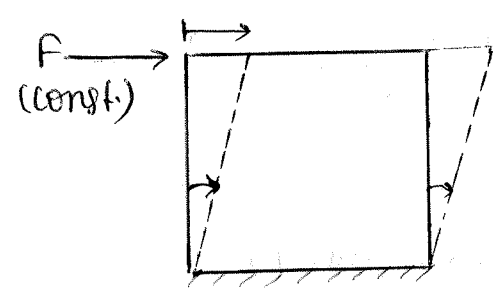
fluid

continuous Deformation



solid

fixed Deformation



"In fluids, rate of deformation is important."

1. "fluid is a substance that deforms continuously under the application of tangential force, no matter how small it is."
2. Liquid And Gases both having a very important property of continuous deformation under the application of tangential force.

### fluid as a Continuum

In Macro Systems, when the inter molecular distances are negligible as compare to dimension of the system we can assume that adjacent to one molecule there is another molecule without any space therefore the entire fluid mass system can be treated as continuous distribution of mass and such continuous mass of fluid is known as Continuum.

$$\text{Knudsen No. (kn)} = \frac{\lambda}{L}$$



$\lambda$  = mean free path

$L$  = characteristic Dimension

$kn < 0.01$	—	"Continuum is Valid"
$0.01 < kn < 0.1$	—	"Slip flow"
$0.1 < kn < 10$	—	"Transition flow"
$kn > 10$	—	"free Molecular flow"

Not in our Study

\* fluid properties such as density etc. can be defined as continuous function of space variable.

\* Continuum is invalid at very low pressure (at high elevations).

## fluid Properties

1] Density ( $\rho$ ) :- It's defined as mass per unit vol<sup>m</sup> of a substance.

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

$V$  = Volume

units:-

in MKS /  $\text{kg/m}^3$

in CGS /  $\text{gm/cm}^3$

$$1 \text{ gm/cm}^3 = \frac{10^{-3}}{10^{-6}} \text{ kg/m}^3$$

$$1 \text{ gm/cm}^3 = 1000 \text{ kg/m}^3$$

2] Specific weight :- It's defined as weight per unit vol<sup>m</sup> of a substance.  
(OR)  
weight Density

$$\text{weight density} = \frac{m \cdot g}{V}$$

$$= \rho \cdot g$$

unit:-

in SI

$$\text{N/m}^3$$

### 3] Specific Gravity (G):-

$$S = \frac{\text{Density of fluid substance}}{\text{Density of std. fluid substance}}$$

for liquids

Std. fluid  $\Rightarrow$   $H_2O$  at  $4^\circ C$

$$\rho_w = 10^3 \text{ kg/m}^3$$

eg.  $S_{Hg} = 13.6$

$$\frac{\rho_{Hg}}{\rho_w} = 13.6$$

$$\rho_{Hg} = 13.6 \times 10^3 \text{ kg/m}^3$$

for gases

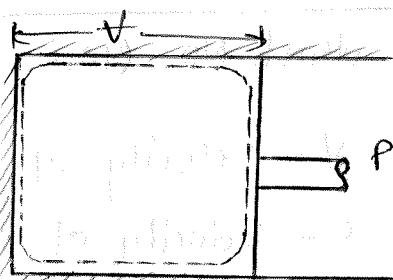
Std. fluid  $\Rightarrow$  Air

4] compressibility ( $\beta$ ):- It's defined as the reciprocal of Bulk Modulus of elasticity.

$$\beta = \frac{1}{K}$$

$K$  = Bulk Modulus of Elasticity

$$K = - \frac{dP}{\left(\frac{dV}{V}\right)}$$



constant  $m = \rho \cdot V$

Diff<sup>n</sup> it

$$d(m)^0 = \rho \cdot dV + V \cdot d\rho$$

$$- \rho dV = V d\rho$$

$$\boxed{-\frac{dv}{v} = \frac{d\rho}{\rho}}$$

$$k = \frac{dP}{d\rho/\rho} \quad \text{(@)}$$

$$\boxed{k = \rho \cdot \frac{dP}{d\rho}}$$

$$\boxed{\beta = \frac{1}{\rho} \frac{d\rho}{dP}}$$

If density is not changing w.r.t. pressure -

$$\frac{d\rho}{dP} = 0$$

$$\boxed{\beta = 0} \quad (\text{Incompressible})$$

If density is changing w.r.t. pressure -

$$\frac{d\rho}{dP} \neq 0$$

$$\boxed{\beta \neq 0} \quad (\text{compressible})$$

for liquids

$$T = 20^\circ\text{C}$$

$$P = 1 \text{ atm}, \quad \rho_0 = 998 \text{ kg/m}^3$$

$$P = 100 \text{ atm}, \quad \rho_0 = 1003 \text{ kg/m}^3$$

$$\% \text{ change} = \frac{1003 - 998}{998} \times 100$$

$$= 0.5$$

$$\boxed{\beta \approx 0}$$

Generally, liquids are treated as Incompressible.

for Gases

(Highly compressible)

$$P = \rho \cdot RT$$

$$\rho \propto P$$

$$\text{Mach No. (Ma)} = \frac{V}{c}$$

$V$  = Velocity of fluid flow

$c$  = Velocity of Sound in the medium

"If  $Ma \leq 0.3$ , the flows are considered as Incompressible."

# For Ideal Gas

## Eq<sup>n</sup> of state

$$1) \quad PV = n \bar{R} T$$

$\uparrow$  universal Gas constant  
 $n$  No of moles

$$2) \quad PV = \frac{m}{M} \cdot \bar{R} \cdot T$$

$\uparrow$  molecular Mass

$$= m \cdot \left( \frac{\bar{R}}{M} \right) T$$

$$PV = m \cdot R \cdot T$$

$\uparrow$  characteristic Gas constant

$$3) \quad P = \rho \cdot R \cdot T$$

## Isothermal Compressibility of Gases

(T = constant)

$$PV = \text{const}$$

$$\frac{P}{\rho} = \text{const}$$

$$P \rho^{-1} = \text{const}$$

for ideal Gas

$$P = \rho R T$$

Diff<sup>n</sup> it

$$\rho^{-1} dP - \rho^{-2} P \cdot d\rho = 0$$

$$\rho^{-1} (dP - P \cdot \frac{d\rho}{\rho}) = 0$$

$$dP = P \frac{d\rho}{\rho}$$

$$K_{\text{iso}} \left( \frac{dP}{d\rho/\rho} \right) = P$$

$$K_{\text{iso}} = P$$

$$\beta_{\text{iso}} = 1/P$$

## Adiabatic Compressibility of Gases

$$PV^\gamma = \text{const}$$

$$m = \rho \cdot V$$

$\uparrow$  const.

$$P \cdot \left( \frac{m}{\rho} \right)^\gamma = \text{const}$$

$$P \cdot \rho^{-\gamma} = \text{const}$$

Diff<sup>n</sup> it

$$\rho^{-\gamma} \cdot dP - \gamma \cdot \rho^{-\gamma-1} \cdot P \cdot d\rho = 0$$

$$\rho^{-1} \left( dP - \gamma \cdot P \cdot \frac{d\rho}{\rho} \right) = 0$$

$$dP = \gamma \cdot P \cdot \frac{d\rho}{\rho}$$

$$K_{\text{adia}} \left( \frac{dP}{d\rho/\rho} \right) = \gamma \cdot P$$

$$K_{\text{adia}} = \gamma \cdot P$$

$$\beta_{\text{adia}} = (\gamma \cdot P)^{-1}$$

for monoatomic gas

$$\gamma = 1.67$$

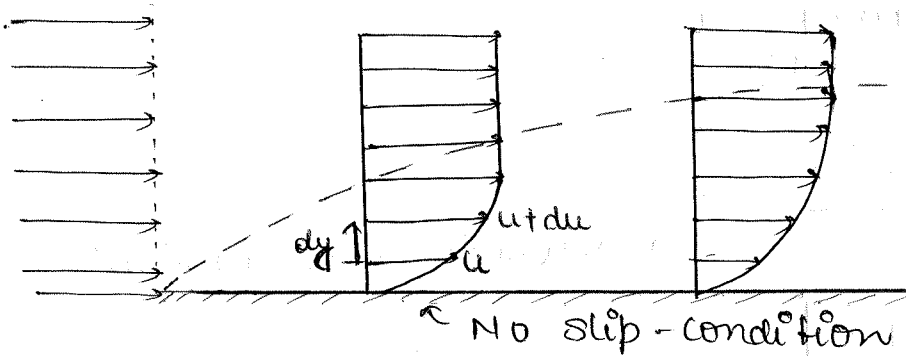
$$\left(\gamma = \frac{C_p}{C_v}\right)$$

for Diatomic gas

$$\gamma = 1.4$$

In General

## flow over a flat Plate

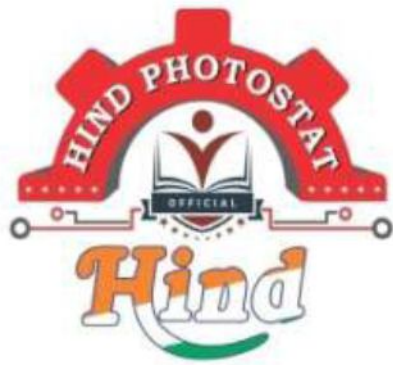


When a Real fluid flows over a Solid Body, the fluid particles at the surface of the Body flow with the same velocity as that of the surface to satisfy 'No slip-condition' so the Relative velocity of fluid particles at the surface of solid Body is 'zero'.

In the

Away from the solid Body, in transverse dir<sup>n</sup> the velocity of fluid particles increases gradually thus the velocity gradient exist in this region close to boundary.





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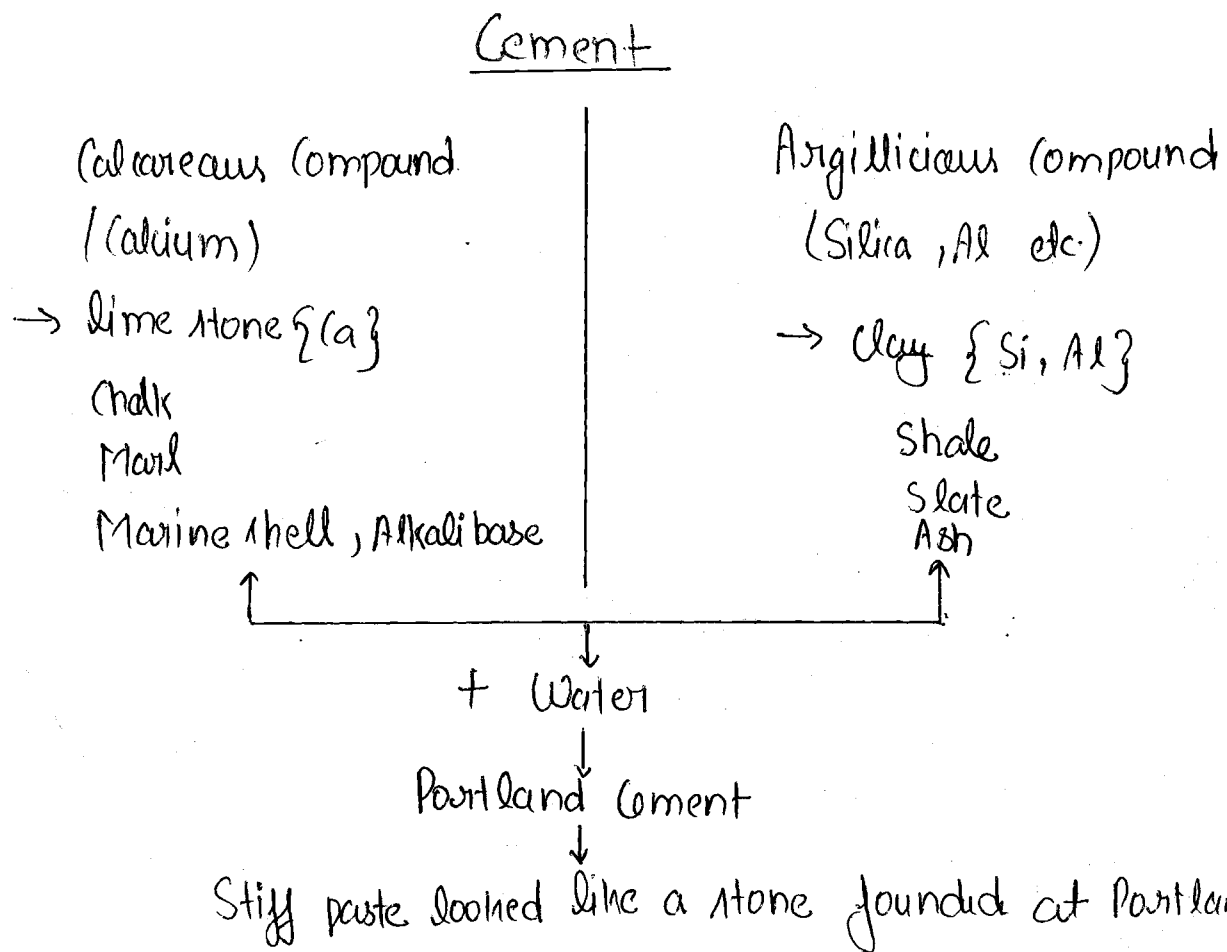
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CementChapter - 1

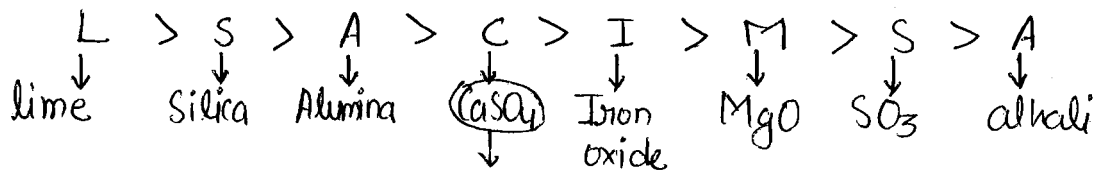
- It is a binding material imparts <sup>Eg- lime</sup> cohesive, <sup>Alumina</sup> cohesive property both, made up by Calcareous & Argillaceous compound.
- It is founded in 1824-25 by Joseph Aspdin.



- Both Calcareous & Argillaceous compound impart binding property.
- Cement is a artificial building material.

# # Constituents of Cement -

H2H GI 42211



gypsum

↳ It is not the constituent of cement, it is extra

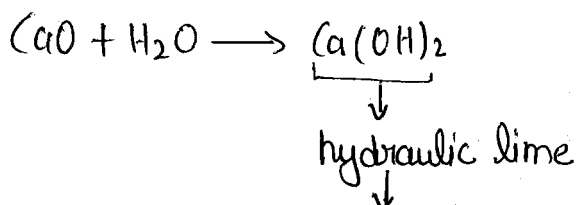
It is mandatory admixture i.e. why considered as the constituents

## 1) Lime (62% - 67%) - CaO

• Impart Strength to cement.

• If excess → Present in form of lime (CaO)

→ Unsoundness means increasing of volume.



→ Volume of hydraulic lime is more than CaO  
So, excess of lime impart Unsoundness

Means cracks develop → Area required for load transfer is lost  
↓  
Strength reduces.

→ If deficiency - Reduce the strength.

## 2) Silica (17-25%) - SiO<sub>2</sub>

→ Impart Strength

→ Setting means to reduce plasticity.

→ If in excess → Setting time increase  
Setting get delayed.

Plasticity ↑  
↓

→ Excess of silica depends on Requirement.

↓  
If transportation is quite long.

So plasticity loose  
hame me time

jada logiya i.e. why setting get delayed.

→ If in deficiency - Reduce the strength.

### 3) Alumina (3-8%) - $Al_2O_3$

→ Causes flash set  
(quick set)

↓ Means

High heat of hydration → Reaction with water.

Water evaporates.

↓  
Volume ↓  
(Total)

Plastic Shrinkage crack

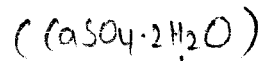
↓  
Deficiency in required water for complete hydration.

∴ Strength ↓

→ When calcium, alumina reacts with sulphate, it forms a compound known as calcium aluminosulphate, volume of which is 227% more than original volume. That means excess of Alumina reduces the sulphate resistance. So the large cracks will develop becz. sulphate will react in the presence of alumina.

→ Advantage of Alumina is, it acts as flux which reduces clinking temperature & makes the manufacturing economical.

### 4) Gypsum (3-4%) - $CaSO_4$



↳ get removed in high

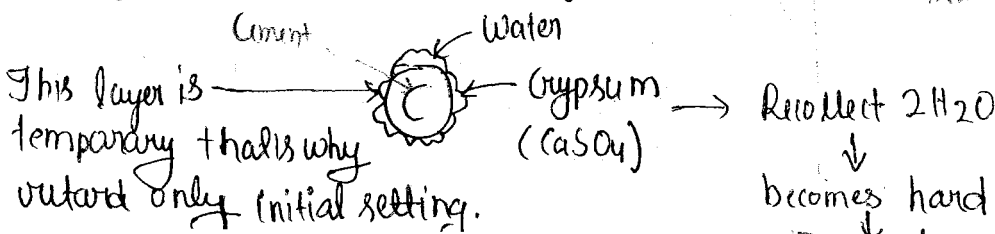
→ Presence of Gypsum increases initial setting time because it controls over the reactivity of alumina.

→ It is mixed in cement clinker during grinding in tube mill.

→ During mixing in tube mill, Gypsum lost its crystallization water<sup>due to very high temp</sup>, it will be collected when we mix the water in cement like when you

→ As a result little stiffness occurred in cement paste due to hardening of gypsum, known as false setting.

Means jabga ki cement hard ho rahi but actually ho na rahi



Jabtak cement plastic stage me hoga, plastic shrinkage hoga.

Aluminium oxide layer attract water but why flash set occurs

5) Iron oxide (3-4%) -  $Fe_2O_3$

→ It imparts strength, hardness & reddish brown colour tinge (greyish colour) to the cement.

6) Magnesium oxide (1-3%) -  $MgO$

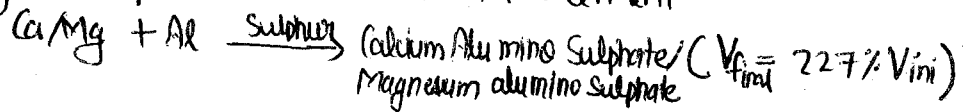
→ It also impart strength hardness & yellow-tinge to the cement.

7) Sulphur (1-3%) -  $SO_3$

→ It make the cement unsound due to sulphur attack.

Note-1) Iron oxide &  $MgO$  helps lime & silica to fuse with each other during burning.

Note-2) Excess of  $MgO$  imparts 'unsoundness' in cement.



8) Alkali - (base) - (0.2-1%)

→ Alkali in cement result in efflorescence which means white stains/white spot over the finished surface.

→ When alkali react with aggregate, it also impart the unsoundness (concern of concrete).   
 not with cement.

→ Alkali also accelerate setting time of cement.   
 Process

→ Alkali does not impart unsoundness to the cement; it impart unsoundness to the aggregate used

Note - Unsoundness → Lime,  $MgO$ , Sulphate, ~~Alkali~~.   
 (To cement)

→ All the above constituents of cement intergrind, burn & fuse with each other & forms the complex compound known as Bouguier's Compound.

# Bougué's Compound :- at 100 all Bougué's compound have same quantity, but their nature are diff.

1)  $C_3A$  (Tricalcium Aluminate) ( $3CaO \cdot Al_2O_3$ ) (4-14%) (White)  
(Early setting)

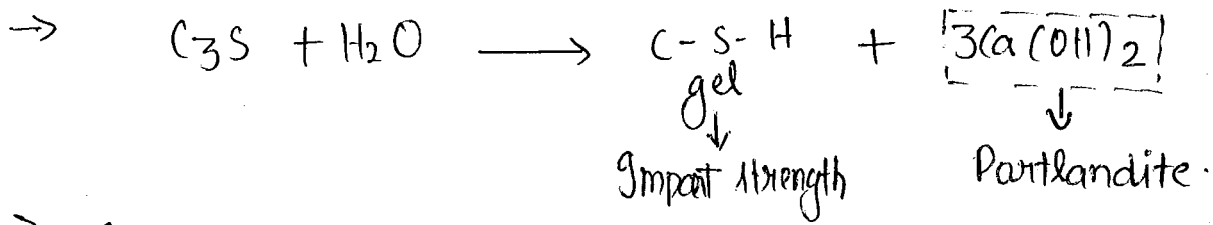
- Imparts flash set (due to Alumina)
- Release high heat of hydration →  $865 \text{ J/g}$  <sup>Per day</sup>,  $310 \text{ cal/gm}$  <sup>at 90 day</sup>
- High rate of hydration (80% hydrated within 24 hours)
- Causes plastic shrinkage crack (Water evaporates,  $V \downarrow$ )
- Weakens the cement (required water is not present)
- Reduce sulphate resistance (becz. form calcium alumina sulphate when vol. is more which crack/fail the concrete)
- 'Harmful ingredient'

2)  $C_4AF$  (Tetra calcium aluminoferrite) (10-18%) ( $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ )  
(Felite) (Final Setting)

- Rate of hydration is highest (90% hydrated within 1 hour)
- Release heat of hydration ( $419 \text{ J/g}$  at 90 days →  $100 \text{ cal/gm}$ )
- Sulphate resistance is less but better than  $C_3A$ .
- Also impart flash set (due to Alumina)
- No role in imparting strength or any further binding property.
- 'Worst compound'. becz. ye strength me hi saghad pada aurat ka chhina

3)  $C_3S$  (Tricalcium Silicate) ( $3CaO \cdot SiO_2$ ) (45-65%) (Alite)  
(Early strength)

- It is responsible for imparting early strength. becz. both lime & silica is in high amount.
- It get hydrated within 7 days
- heat of hydration ( $502 \text{ J/g}$   $90 \text{ days} \rightarrow 105 \text{ cal/gm}$ )
- Road construction, prefabricated structure, cold weather construction, construction related to less stripping time. means jaha bhi early strength ni requirement hai.



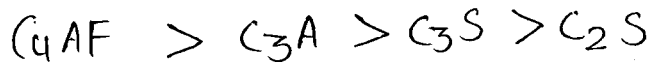
- $C_3S$  imparts high resistance against front action, because the size of molecule of  $C_3S$  <sup>( $C_3S$  ka size kum hot hai)</sup> reduces its permeability.
- When  $C_3S$  react with water, it forms  $C-S-H$  gel known as calcium silicate hydrated gel or Tobermite gel or Thumboh hydrated gel which actually responsible for imparting strength.
- When  $C_3S$  react with water it also liberates hydrated lime known as portlandite.
- Leaching out of portlandite makes the finished surface porous which finally reduces the durability of finished surface, but presence of portlandite makes the surrounding alkaline. (due to presence of  $OH^-$  ion,  $\therefore pH > 13$ ) as the result corrosion of reinforcement can be prevented.
- Presence of portlandite also participate for sulphur attack when it is used for foundation work.

4)  $C_2S$  (Di-calcium Silicate) (15-35%) ( $2CaO \cdot SiO_2$ ) (Belite)

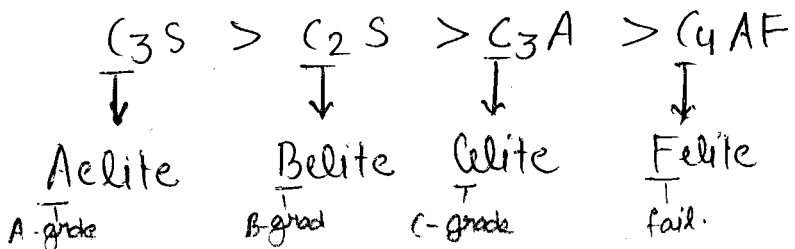
- It <sup>(Final strength)</sup> imparts later or ultimate strength  $\rightarrow$  (bezz. % lime is less)
- It gets hydrated after a long time (Yearly)
- heat of hydration. (260 J/g, 90 days  $\rightarrow$  40 cal/gm)
- $C_2S + H_2O \rightarrow \underset{\text{gel}}{C-S-H} + Ca(OH)_2$
- Used for dam construction, Bridge construction or all type of mass concreting because of low amount of liberating of portlandite. No surface finishing is good.
- An reaction of  $C_2S$  &  $H_2O$  releases comparatively less amount of portlandite, so it founds more durable.
- It also increases the resistance against chemical attack (bezz reactivity is slow)



Note-1 - Rate of hydration -

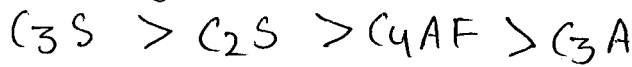


Note-2 - Binding property - Binding occurs when cement starts to gain strength no when starts setting.



kuki ye barha hi rehti means gut fail in impending strength. 1 hr me hi 90% hydrate ho jata hai.

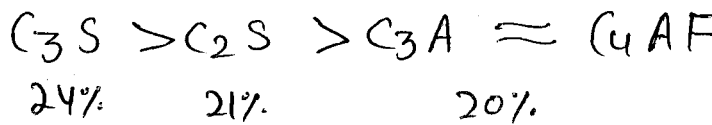
Note-3 - Amount of bouquet compound -



Note-4 - Amount of heat of hydration -  
 (fasted generally -)



Note-5 - Water requirement -



Ex-Fair Note-6

Sample = 500gm

$C_3A \rightarrow 10\% \rightarrow 50gm \rightarrow 310 \times 50 = 15500$

$C_4AF \rightarrow 15\% \rightarrow 75gm \rightarrow 100 \times 75 = 7500$

$C_3S \rightarrow 50\% \rightarrow 250gm \rightarrow 105 \times 250 = 26250$

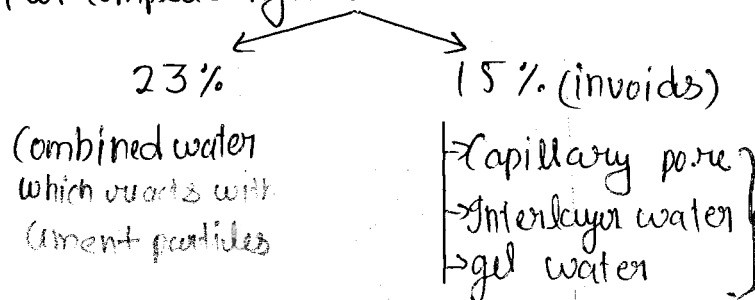
$C_2S \rightarrow 25\% \rightarrow 125gm \rightarrow 40 \times 125 = 5000$

So in absolute term as in mass considering amount of heat of hydration of  $C_3S$  is more than  $C_3A$ .

Note-6 - Because amount of  $C_3S$  is higher than amount of  $C_3A$  i.e why in absolute term <sup>or in mass conc</sup> high amount of heat is released by  $C_3S$ .

Note-7 - For complete the hydration process 23% of water (by weight of cement is required) but 15% water gets interrupted in voids/pores of cement so we must add 38% of water is added to complete the hydration process.

→ For complete hydration 38% water to be added.



To water free hole, red means except 23% will be responsible for shrinkage & drying of hydration. Free form → Cause for shrinkage.

Yahi vo reason hai jo shrinkage ko cause krta hai.

⇒ Water cement ratio (w/c)  $> 0.38$  → Strength ↓ → Excess water evaporates.

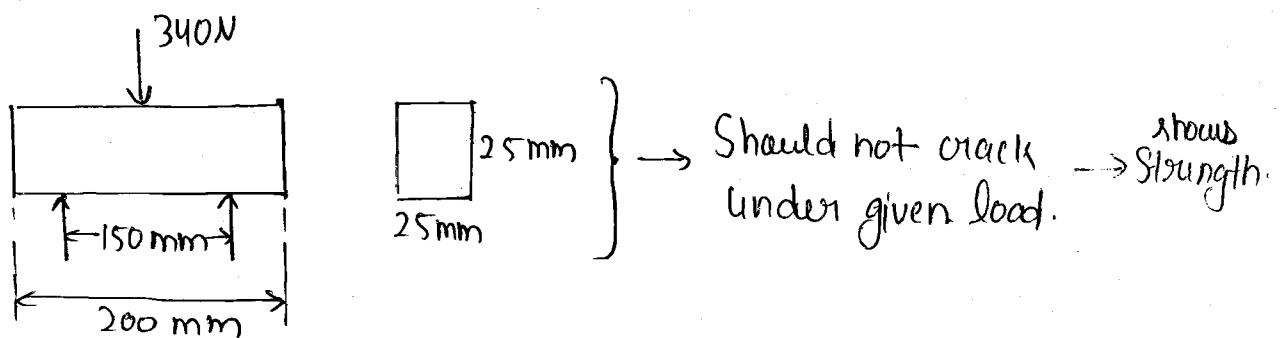
⇒ Water cement ratio (w/c)  $< 0.38$  → Strength ↓ → Required amount of water is not present.

## # Testing of Cement :-

### 1) Field Test -

- i) It should be uniform grey colour { shows fusion of all ingredients }
- ii) It should feel smooth, when rubbed b/w fingers { Shows fineness }
- iii) When we insert hand in cement bag it should feel cool & no lumps should be found (otherwise it signifies prehydration of cement)
- iv) A thin paste of cement should feel sticky { shows binding }
- v) When cement particles thrown into the water, it should sink { shows specific gravity }
- vi) A thick cement paste (paste) should plane in water for 24 hrs over a glass plate, it should not show any sign of crack. { Shows soundness / presence of free lime }

vii)

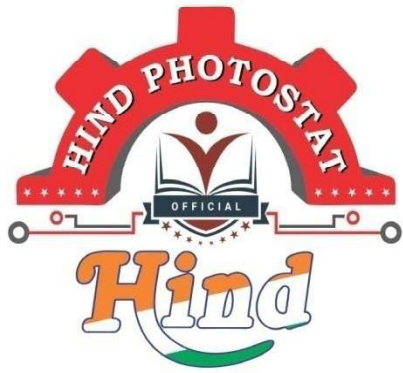


### 2) Lab Test -

#### 1) Fineness Test :-

→ Fineness of cement increases the rate of gain in strength, rate of evolution of heat, rate of setting, rate of prehydration, rate of alkali aggregate reaction etc.

→ More fine cement has more specific surface area. so everything will increase.



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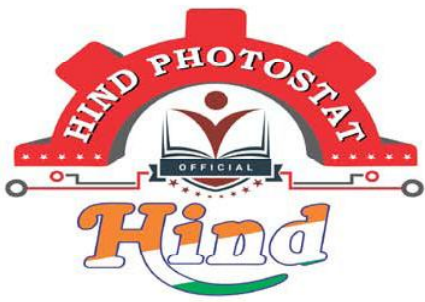
C.P.M

By-MANISH SIR

- Theory
- Explanation
- Derivation
- Example
- Shortcuts
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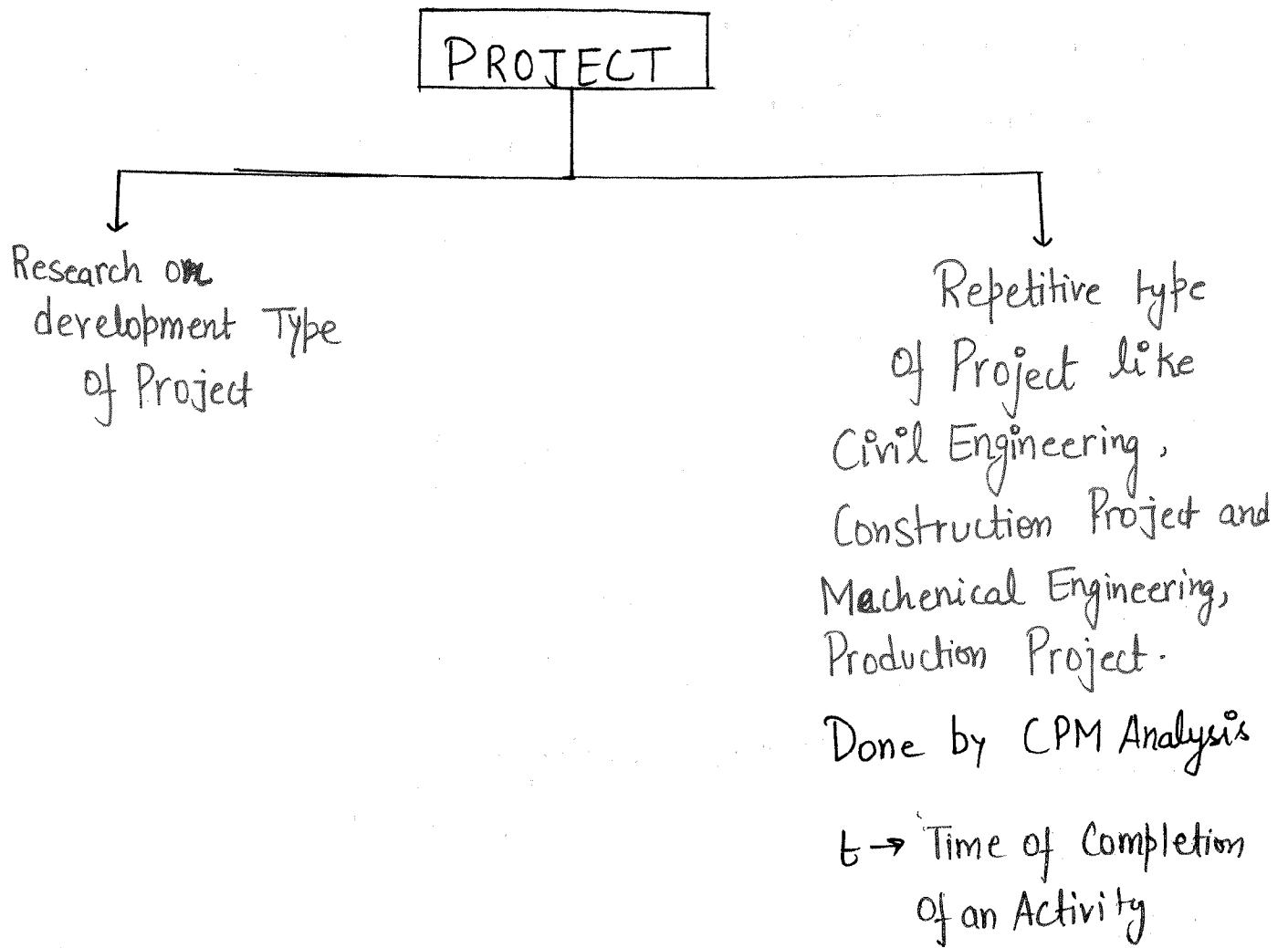
# CONSTRUCTION PLANNING & MANAGEMENT

## \*\*SYLLABUS:\*\*

- CH. 01: Basics of Project Management and Network Rule.
- CH. 02: PERT Analysis
- CH. 03: CPM Analysis
- CH. 04: CPM Cost Model Analysis (crashing and updating of a CPM network).  
Resource Allocation, Resource levelling, A-O-N Network, and Ladder Network.
- CH. 05: Engineering Economy [IMP.]
- CH. 06: Construction Equipment ESE only
- CH. 07: Contracts and Tenders. ESE
- CH. 08: Quality Control, Safety and Welfare. ESE only
- CH. 09: Estimating Costing. ESE only
- CH. 10: Site investigation and Management and, Productivity and operations. ESE only
-



# INTRODUCTION:-



## Proposed Plan:

### Construction of Village Roads.

- Desk Study via Map
- Field Survey and Transmit Work for verification of Alignment
- Formations of DRR (detailed Project Report).
- TA (technical Approval) by Head quarters engineers Signalled by PIU. [JE, AEE, AEE].
- AA (administrative Approval)
- TS (Technically Sanctioned by -  
STA: State Technical Authority  
CTA: Central Technical Authority.
- NT: (Notice inviting Tender)  
Published in leading newspaper.
- Formation of BOQ (Bill of quantity).
- Uploading of BOQ on Website of department.
- Tender
- Submission of Tender by bidder including 2% Earnest Money (EM) With Paper Cutting of NIT. → To avoid unnecessary Competition.
- CS Comparative Statement
- Tender Awarded
- Contractor and Engineers will visit site to stand the work.
- Work started by Contractor
- Payment Made to Contractor after deduction of 10% of SD inclusive of E.M from each running bill.  
↓  
Security deposit



1 cr Running Bill  
↓  
2% EM = 2 Lac. → Already deposited at the time of tender.

Now 8% SD has deducted i.e. 8 Lac Rupees from Running Bill.

EM → To avoid unnecessary competitions.

S.D → As a Security when Contractor will not complete the work or any defect in work

S.D will Refund after six Month (or) one Monsoon Season v of completion of work ~~of~~ after.

# 1. BASICS OF PROJECT MANAGEMENT AND NETWORK RULE.

Project Management :- It deals with Material and human resources both to increase productivity and efficiency.

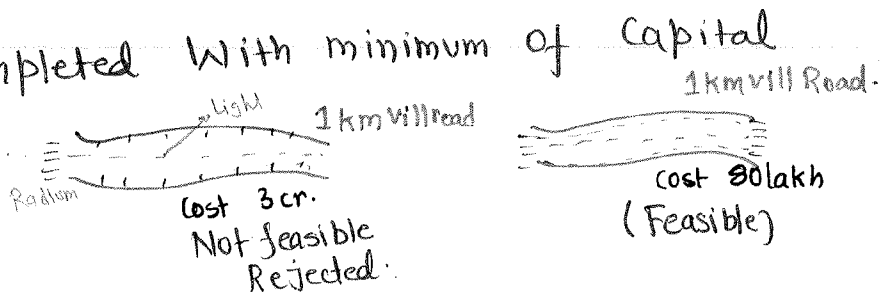
The Project should be completed in Minimum time by using optimum resources.

For completion of a Project, two basic things are required:

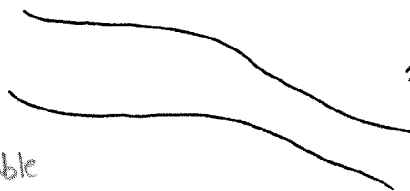
- (1) Material Resources
  - (2) Manpower Resources.
- } Active Resources  $\Rightarrow$  Money is passive Resources.

Every Project whether it is big(or) small has three objectives:

- (1). It should be completed in Minimum time. (optimum time).
- (2). It should use available Man Power and material resources as far as possible without delaying in completion of a Project.
- (3). It should be completed with minimum of Capital investment.



If Man Power is available locally when contractor labour is not available then use Man Power available locally even little price higher. These price is later adjusted.



1 km State Highway

time of completion: 9 Month.

↓  
Min<sup>m</sup> duration for completion of a project.

There are 3 important Phases of Project Management :-

(1). Planning (or) Project Planning :

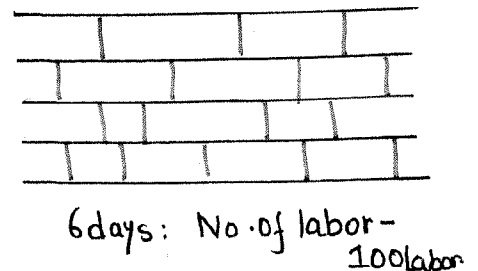
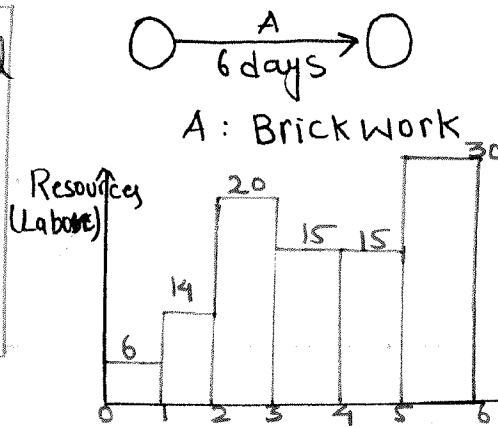
This is most important ~~Phase~~ of Phase of Project Management. Planning involves defining the objective of a project, listing of job or arrangement of jobs that must be performed, determining gross requirement for material, equipment, man power and preparing estimate of Cost and durations for completion of Project.

(2). Scheduling (or) Project Scheduling :

Scheduling is the allocation of resources such as material resources equipments, man power resources in appropriate manner such that it results in efficient working.

Scheduling also involves sequencing of activities.

Note:- In traditional technique of design, Planning and scheduling are performed as single step.

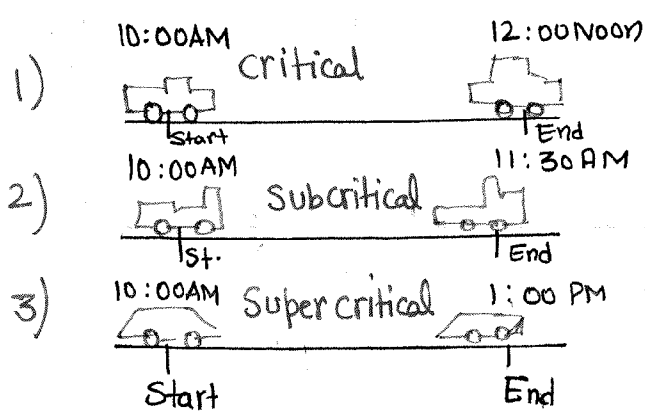


→ Resource allocation. (This Allocation is not good. Not uniform)

(3) Controlling (or) Project Controlling :

It is the process to identify critical Activity (running on schedule time), Sub-critical Activity (non-critical activity i.e. already completed before the schedule duration) and Super critical Activity (delayed activity i.e. completed after scheduled duration of projects).

Travel duration = 2hr allowed.

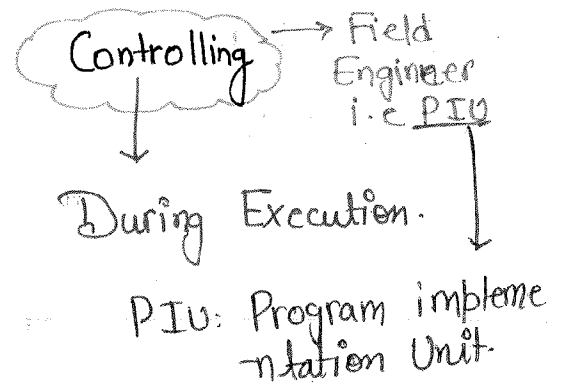
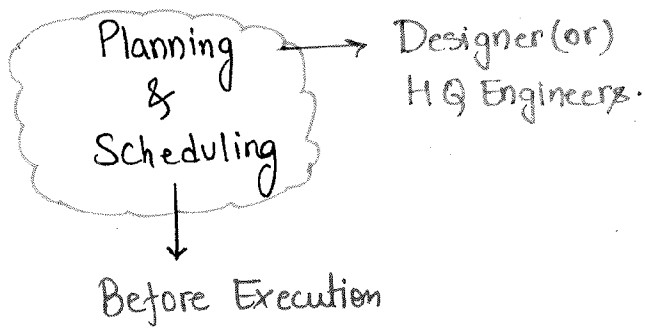


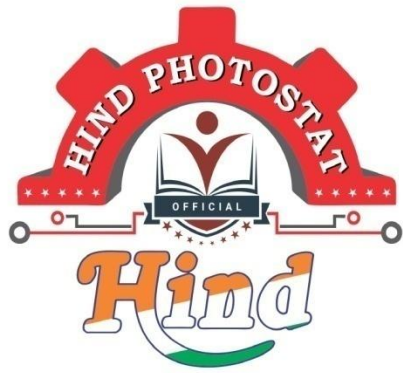
Critical and Supercritical activities are given extra attention in a Project.

Therefore, of regular interval of times Network is updated and Project Progress is reviewed.

Frequency of updating Will increase towards completion of a Project.

Note:- Planning and Scheduling are performed before execution of Project. Whereas Scheduling Controlling is carried on during execution of the project.





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# TRANSPORTATION ENGINEERING

(1)

## Syllabus

- 1) Introduction
- 2) Geometric design
- 3) Traffic Engineering
- 4) Pavement design
- 5) Highway material & Construction.

## 1) INTRODUCTION

Highways :- Highways are special type of road which are designed to permit high speed of vehicles. It is generally constructed over an embankment due to following advantages -

- a) Better drainage facility
- b) Safety in flood time
- c) No lateral entry of traffic / animal / Public. eg. Nation Highway, State highway.

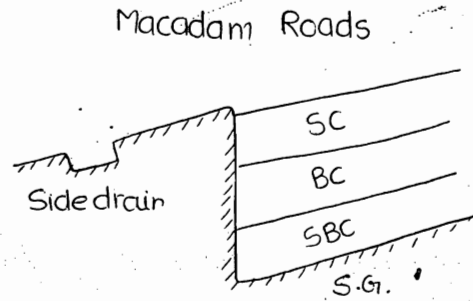
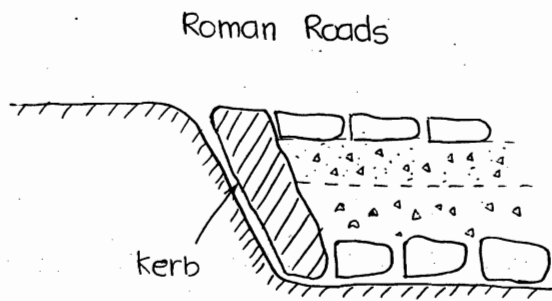
Express Highway :- Express highways are superior type of highway, designed as a direct connectivity b/w two places. Express highway organise the traffic in channelised way.

e.g. Yamuna express highway, Mumbai - Pune express highway.

Development of Roads :-

- i) Roman Roads
- ii) Tresaguet Roads
- iii) Telford Construction
- iv) Macadam Construction

Modern Construction → Macadam + CBR



drawback -

- i) No camber
- ii) No drainage System
- iii) Large Foundation Stone.

Highway Planning in India :- In Nov. 1927 Govt. appointed a road development committee headed by Mr. M.R. Jayakar.

- Recommendations of Jayakar Committee :-

- i) Road development should be considered as National interest.
- ii) An extra tax should be charged on Petrol & diesel for road development & maintenance.

Result - Central Road Fund (CRF) established in 1929

Note :- Current rate of CRF is ₹6 / lit.

- iii) A semi-technical body should be established for road design & specification.

Result - Indian Road Congress (IRC) established in 1934.

- iv) A research & development organisation should be established for road development.

Result :- Central Road Research Institute (CRR I) established in 1950.

- v) Jayakar committee gave more stress for long term planning.

Result - Various 20 years road plan.

• Comparison b/w various 20 years road plan.

(2)

	1 <sup>st</sup> 20 year Plan	2 <sup>nd</sup> 20yr Plan	3 <sup>rd</sup> 20 yr Plan
Name	Nagpur	Bombay	Lucknow
Duration	1943-1963 (completed in 1961)	1961-1981	1981-2001
Road density	16km/100 km <sup>2</sup>	32km/100 km <sup>2</sup>	82 km/100 km <sup>2</sup>
Pattern	Star & grid	-	-
Express-highway	-	1600 km Added	2000 km
Classification	- NH - SH - MDR - ODR - VR	Same	- Primary Roads (EH+NH) - Secondary Roads (SH+MDR) - Rural roads (ODR+VR)

• Length of road as per 3<sup>rd</sup> 20yr Plan:-

$$i) \text{ Total length of road} = \begin{cases} 4.74 \times \text{No. of towns \& villages} \\ \text{Max.} \left\{ \text{Road density} \times \text{Area} \right. \end{cases}$$

$$ii) \text{ Length of NH} = \left( \frac{\text{Area (km}^2\text{)}}{50} \right)$$

$$iii) \text{ Length of SH} = \begin{cases} \left( \frac{\text{Area (km}^2\text{)}}{25} \right) \\ \text{Max.} \left\{ 62.5 \times \text{No. of towns} - \text{Length of NH} \right. \end{cases}$$

$$iv) \text{ Length of MDR} = \begin{cases} \left( \frac{\text{Area (km}^2\text{)}}{12.5} \right) \\ \text{Max.} \left\{ 90 \times \text{No. of towns} \right. \end{cases}$$

Q-41)

$$\text{Area} = 13400 \text{ km}^2$$

Pg- 9)

$$\text{NO. OF TOWNS} = 12$$

$$\text{Length of NH} = \frac{13400}{50} = 268 \text{ km}$$



$$\text{Length of SH} = \frac{13400}{25} \quad \text{or} \quad 62.5 \times 12 - 268 \quad (\text{Max})$$

$$= 536 \quad \text{or} \quad 482$$

$$= 536 \text{ km}$$

$$\text{Length of MDR} = \frac{13400}{12.5} \quad \text{or} \quad 90 \times 12$$

$$= 1072 \quad \text{or} \quad 1080$$

$$= 1080 \text{ km}$$

$$\text{Total length of Road} = 4.74 \times 12 \quad \text{or} \quad \frac{82}{100} \times 13400$$

$$= 56.88 \quad \text{or} \quad 10988$$

$$= 10988 \text{ km}$$

Primary Roads (EH + NH)

$$= 268 \text{ km}$$

Secondary Roads (SH + MDR)

$$= 536 + 1080$$

$$= 1616 \text{ km}$$

Rural roads (ODR + VR)

$$= \text{Total length} - (\text{Primary} + \text{Secondary})$$

$$= 10988 - 268 - 1616$$

$$= 9104 \text{ km}$$

Engineering Survey for highway alignment :- Before a highway alignment is finalised, engineering survey are to be carried out in following stages -



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# Hydraulic Machines

(1)

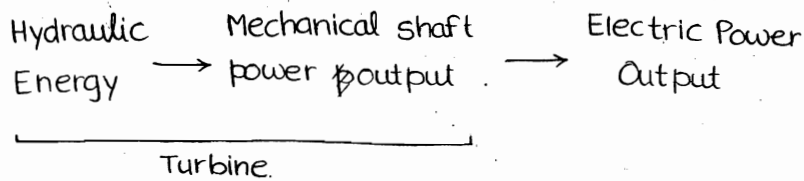
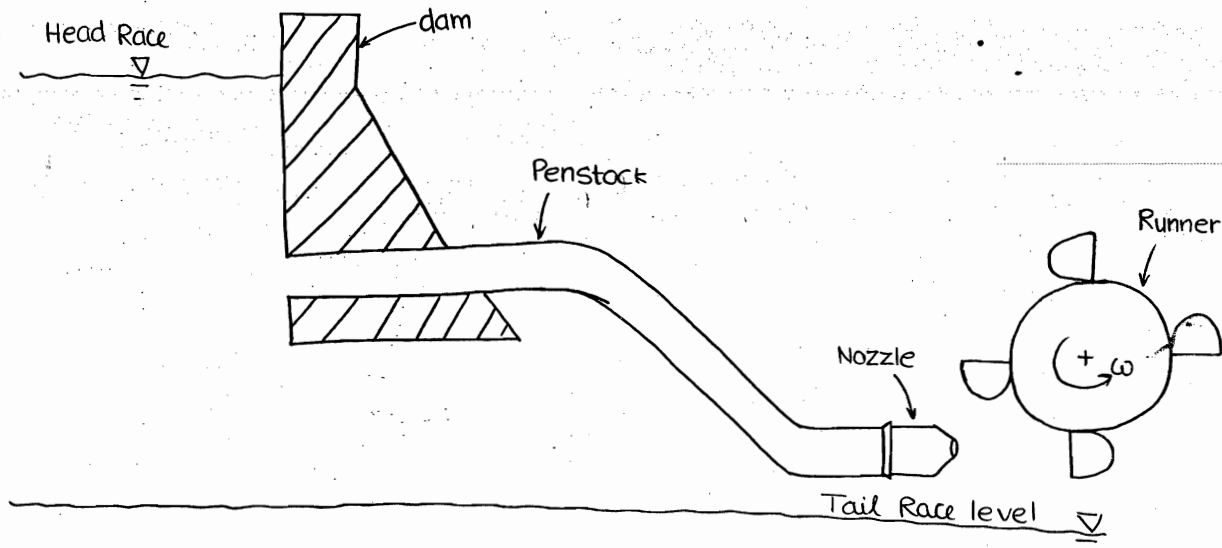
Flow in motion  $\longrightarrow$  Fluid dynamics

## Classification of hydraulic Machines -

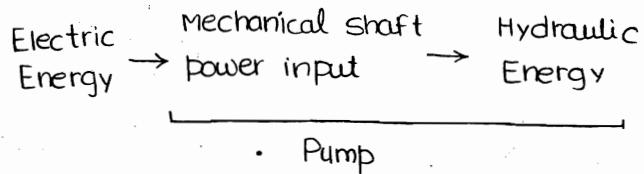
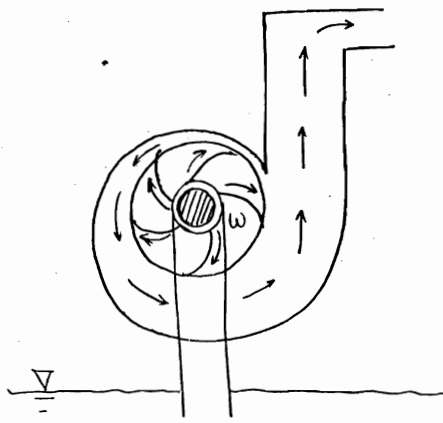
Work is done by the water (Ex- turbine)

Work is done on the water (Ex- Pump)

## Layout of hydro electric Power plant -



Pump:-



In General -

Energy (Joule)

$$= mgH$$

$$= \frac{1}{2} mV^2$$

$$= F \times X \quad \text{(workdone)}$$

Power (Joule/sec)

$$= mgH$$

$$= \frac{1}{2} \dot{m}V^2$$

$$= F \times u \quad \left( \frac{\text{Workdone}}{\text{Sec}} \right)$$

$$= T \times \omega$$

Work done per sec per unit weight of water striking per Sec

$$= \frac{\text{Work done per sec}}{\dot{m}g} = H \text{ (m)}$$

In General -

Water

(System)

A/c to Newton's 2<sup>nd</sup> law of motion

$$\vec{F} = \dot{m} \vec{V}_2 - \dot{m} \vec{V}_1$$

Momentum of water leaving per sec.      Momentum of water entering per sec.

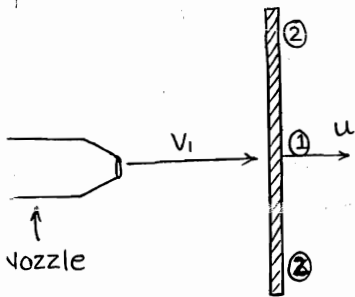
$\dot{m}$  = mass flow rate actually striking over vane.

$\vec{F}$  = Force applied on the water by the vane.

$$\text{Force applied by the water on the vane} = -\vec{F} \\ = \dot{m} \vec{V}_1 - \dot{m} \vec{V}_2$$

In General -

Notations :-



inlet of vane  $\Rightarrow$  1

exit of vane  $\Rightarrow$  2

$\vec{V}_1$  = absolute velocity of water at the inlet of vane

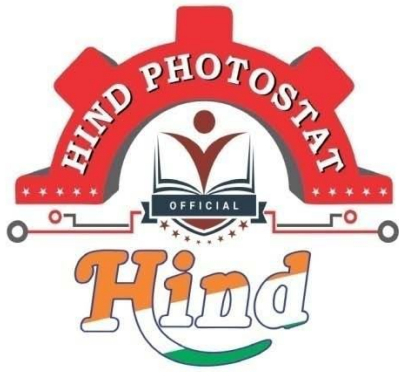
$\vec{u}_1$  = absolute " " vane " " " " "

$\vec{V}_{r1}$  = Relative " " water " " " " "

$\vec{V}_2$  = Absolute velocity of water at the exit of vane

$\vec{u}_2$  = Absolute " " vane " " " " "

$\vec{V}_{r2}$  = Relative " " water " " " " "



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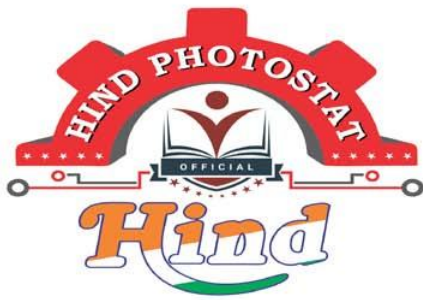
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2. E /E /
- D, E /E /
4. / E /E /
- /E D E /KE E /E /
6. KD /

**,GATE, TEST @**

❖ -W / & D /

❖ GATE

➤ E - ALL E /E / E

➤ ALL sW / YEAR Y /KE W @

W / /K K -

**EASY, ,ACE, ,KREATRYX, GATE /, ,GK**

**, YADAV, KD D, &K E /KE, -GRAW, D, W KE...K s**

**/ K @**

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# ENGINEERING HYDROLOGY.

## \*\* SYLLABUS :- \*\*

CH: 01 Basic Concepts :

- (i) Precipitation and its Measurements.
- (ii) Evaporation and its Measurements
- (iii) Infiltration and its Measurements. \*
- (iv) Transpiration and Evapotranspiration.

CH: 02 Stream flow Measurements

CH: 03 Hydrograph Analysis \*

CH: 04 Floods and Flood Routing

\* \* ESE - Prelims 6 to 7 questions \* \*

- Mains 30 - 35 Marks \*

\* \* GATE - 3 to 4 Marks. \* \*

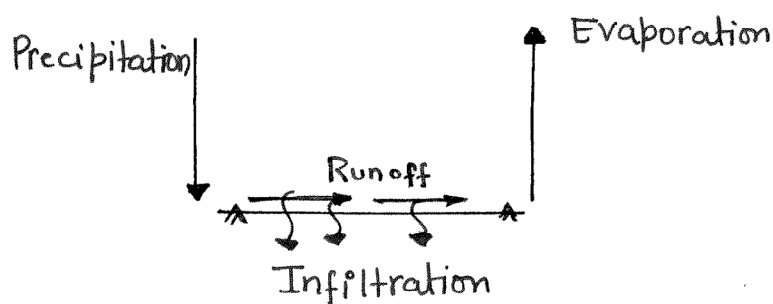




# 1. BASIC CONCEPTS.

## ⇒ Hydrology

It is the science which deals with the occurrence of water, its flow on ground and movement of the moisture into the atmosphere.



Q: What is difference between hydrology and engineering hydrology??

The study which is mainly concerned with academic aspects (back year record) is known as academic hydrology.

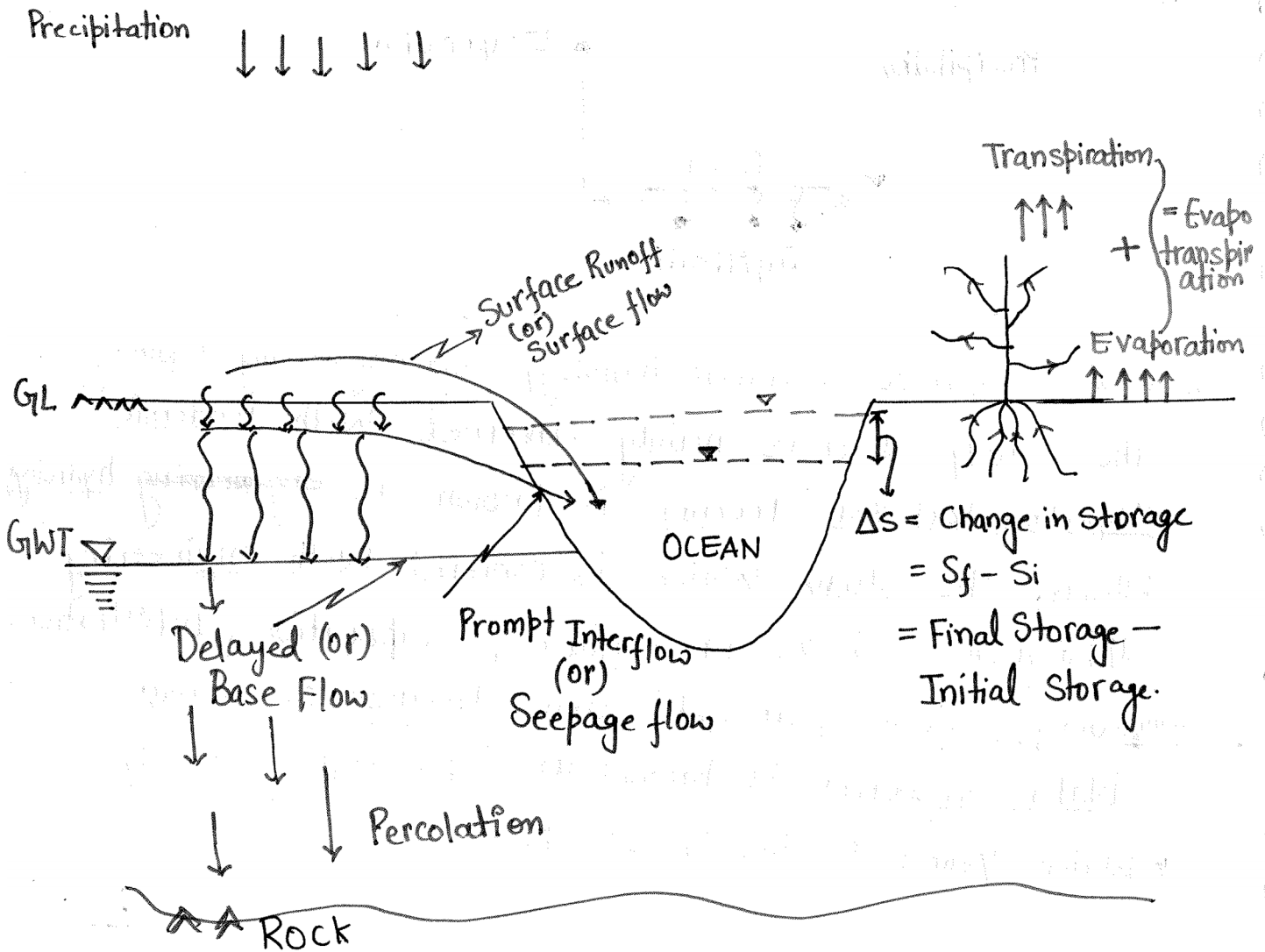
Whereas, the study which is concerned with engineering application such as precipitation, evaporation, Infiltration, evapotranspiration, Runoff, floods, droughts and estimation of various water resources is known as Engineering hydrology.

→ Water year: 1<sup>st</sup> June to 31<sup>st</sup> May.

→ Hydrological Cycle:

Precipitation and Evaporation Continues forever therefore a balance is maintained between the Two.

This process is known as hydrological cycle  
[ (or) Water cycle ]



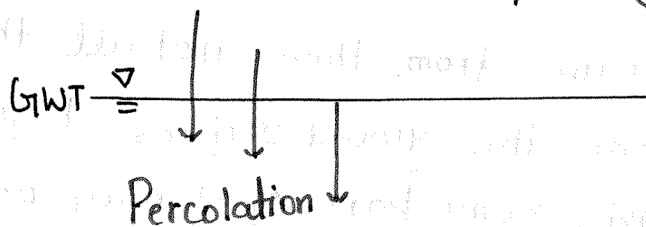
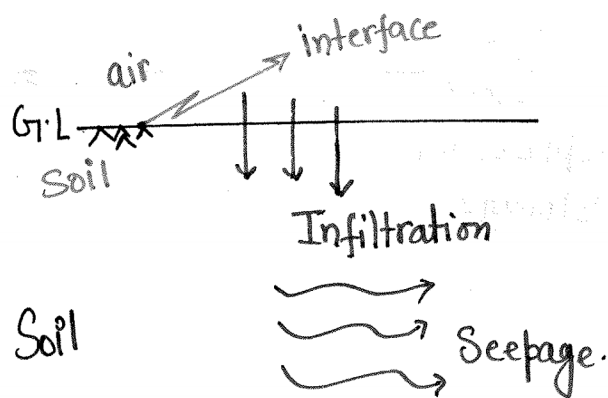
Note:

### 1) Infiltration, Percolation and Seepage:

Infiltration and Percolation are both process in which water moves in the pores of the soil.

The main difference between these two process is that infiltration occurs closer to the the surface of the soil and interface is essential in infiltration process.

In percolation, water moves from unsaturated zone to <sup>Saturated</sup> surface zone.



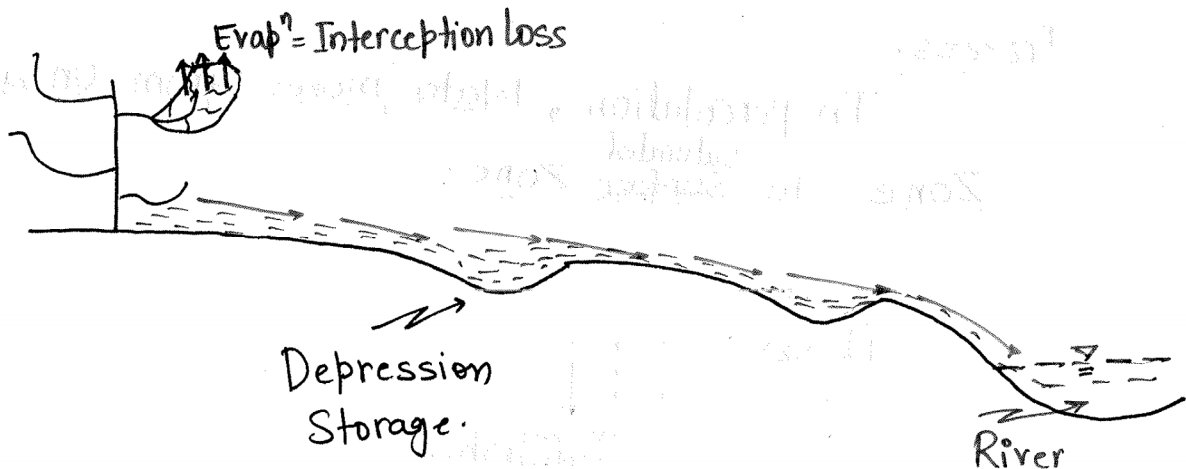
(22) Seepage:- Flow of water in any arbitrary direction other than downward movement.

Max. Capacity of Seepage is permeability.

Note:

Initial losses ———→ (I) Interception loss  
—————→ (II) Depression Storage.

Precipitation ↓ ↓ ↓ ↓



### Interception loss:

When there is a rain from then not all the precipitation falls directly onto the ground surfaces. Before it reaches on the ground, some part of it may be received by vegetations and consequently evaporated back to the atmosphere. The volume of water loss is called Interception loss.

### Depression Storage:

When there is a rain then before it flows on the ground, it must fill all depressions.

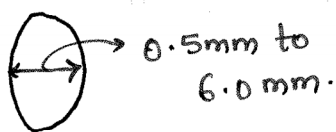
The volume of water trapped in these depressions are called depression storage.

# 1. PRECIPITATION AND ITS MEASUREMENTS:

Precipitation: The term precipitation denotes all forms of water that reaches on the earth from atmosphere.

## Various forms of Precipitation:

(i) Rain: This term is mainly used when water droplets are of size 0.5 mm to 6.0 mm.



## Classification of Rain:

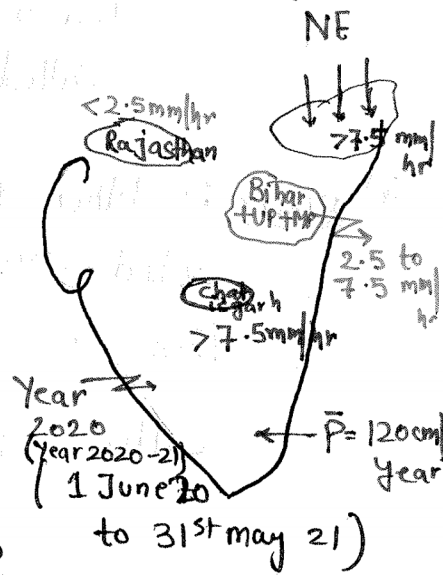
Intensity (mm/hr)	Rain
$< 2.5$ mm/hr	Light Rain
2.5 mm/hr to 7.5 mm/hr	Moderate Rain
$> 7.5$ mm/hr	Heavy Rain

\* If Total rain in a day is more than 2.5 mm then that day is called Rainy day.

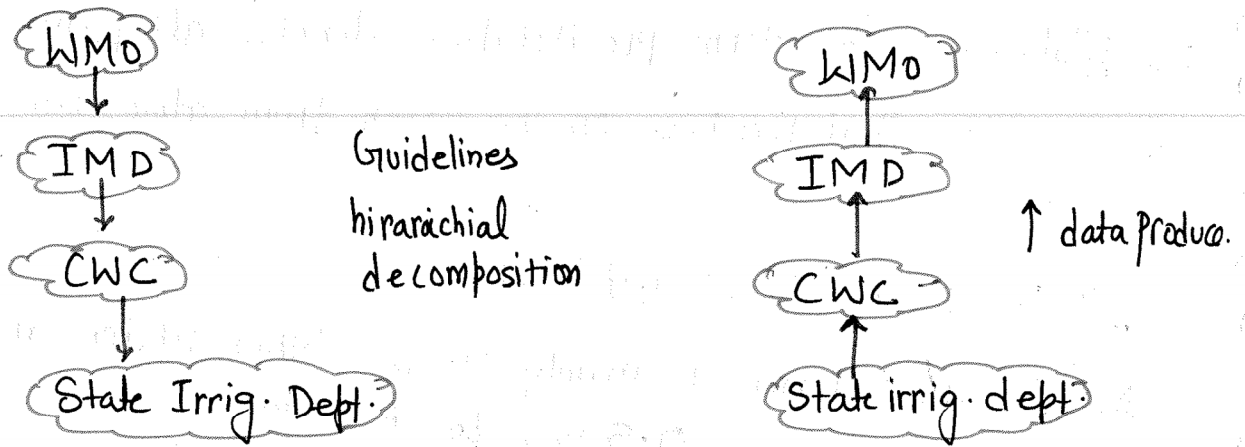
\* In India, avg annual ppt<sup>n</sup> is about 120 cm which is greater than world avg. ppt<sup>n</sup> of 100 cm/year.

→ In order to find avg. annual rainfall of a place, a minimum of 30 years data has been taken as per W.M.O (Water Meteorological Organisation)

$$\text{eg: } \bar{P}_{2020} = \frac{P_{1991} + P_{92} + \dots + P_{2020}}{30}$$

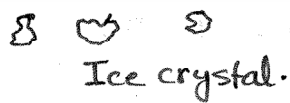


Note:



(ii) Snow: Snow consists of ice crystal having average density of  $0.1 \text{ gm/cc}$ .

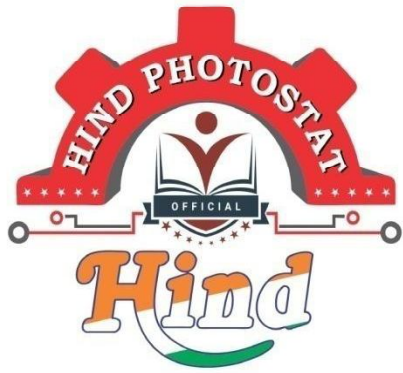
In India, Generally occurs in Himalayan Zones.  
The accumulation of snow may result into formation of glaciers.



(iii) Drizzle :- When rain drops are of size less than 0.5mm and intensity is less than 1mm/hr then it is called Drizzle.

(iv) Glaze :- When rain(or) drizzle comes in contact with solid body (or) ground at freezing temperature then it forms ice coating and this coating is called Glaze.





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~ Session : 2022-23 ~

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# CHAPTER 1

## INTRODUCTION TO IRRIGATION & METHODS OF IRRIGATION

### CONTENTS

Students should write this after chapter completion. This provides with overall view & acts as a tool for active recalling.



## Course Structure

1. Introduction to Irrigation, Methods of Irrigation.
2. Water Logging, Quality of Irrigation Waters (CWCG, IARI) <sup>AS PER</sup>
3. Water Requirement for Croops. \*\*
4. Canal design.
5. Analysis of Gravity Dams.
6. Conveyance and Regulating Structures for Canals.
7. Theories of seepage.
8. River Training and Diversion Headworks.
9. Dams, Spillways and Energy Dissipators.

## Weightage

YEAR	ESE (PRE)	GATE
2014	14 Q	1.5 M (AVG)
2015	15 Q	1.5 M (AVG)
2016	11 Q	1.5 (AVG)
2017	10 Q	2 (AVG)
2018	11 Q	1 (AVG)
2019	11 Q	1 (AVG)
2020	12 Q	3 (AVG)
2021	14 Q	3 (AVG)

## Official GATE Syllabus

Irrigation: Types of irrigation systems and methods; Crop water requirements - Duty, delta, evapotranspiration; Gravity Dams and Spillways; Lined and unlined canals, Design of weirs on permeable foundation; cross drainage structures.

## Official ESE Syllabus

### **2. Hydrology and Water Resources Engineering:**

Hydrological cycle, Ground water hydrology, Well hydrology and related data analysis; Streams and their gauging; River morphology; Flood, drought and their management; Capacity of Reservoirs. Water Resources Engineering : Multipurpose uses of Water, River basins and their potential; Irrigation systems, water demand assessment; Resources - storages and their yields; Water logging, canal and drainage design, Gravity dams, falls, weirs, Energy dissipaters, barrage Distribution works, Cross drainage works and head-works and their design; Concepts in canal design, construction & maintenance; River training, measurement and analysis of rainfall.

27/12/2021

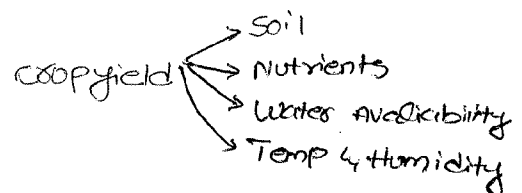
usage of water: →  
 32% → Agriculture  
 6% → domestic & municipal need.  
 12% → industries.

## WHAT IS IRRIGATION?

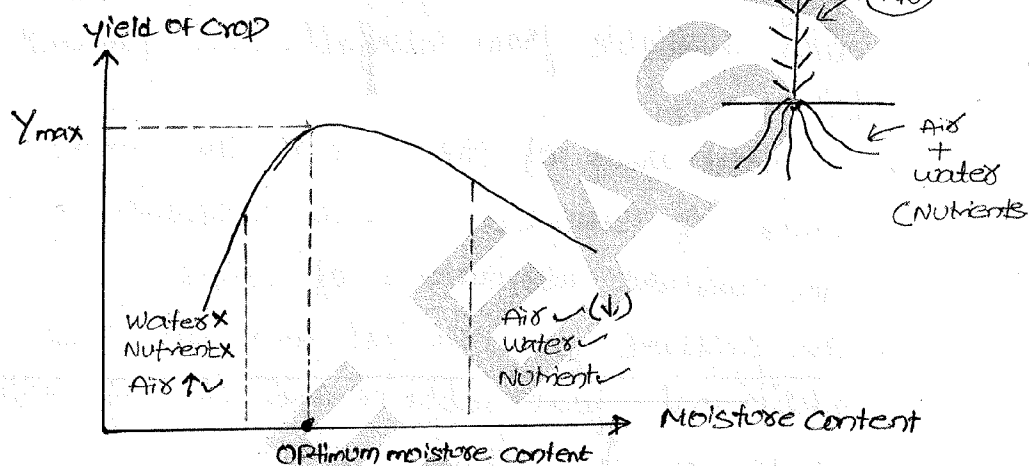
- Irrigation is the artificial application of water to soil throughout the crop period to assist in the production of crops.
- Irrigation water is supplied to supplement the water available from rainfall and ground or soil.
- In many areas of the world, the amount and timing of rainfall are not adequate to meet the moisture requirements of crops.
- The pressure for survival and the need for additional food supplies are causing rapid expansion of irrigation throughout the world.

## Advantages of Irrigation

1. Increase in food production - Exact quantity required can be supplied as different crops have different water requirements and the same crop may have different water requirements at different places, depending upon the variation in climate, type of soil, method of cultivation, useful rainfall etc.



2. Ensuring Optimum Growth in Field - Maximum yield is obtained when just sufficient quantity is supplied and the corresponding moisture content is called as optimum moisture content.



3. Elimination of Mixed Cropping - Farmers have a tendency to cultivate more than one type of crop in the same field such that even if one dies without the required water, atleast he would get the yield of the other.
- However, this reduces the overall yield from the field.
  - With assured water from irrigation, farmer would cultivate only one type of crop at any time, which would increase the yield.

Prepare Interview for  
as State multiple Projects  
(Dams) like Nagarjuna Sagar  
dam, Srisaam dam.

Note - Mixed Farming & Mixed Cropping are being used interchangeably in irrigation engineering. (Refer class for clarity in both definitions).

Mixed farming is a method in which multiple crops are grown in the field to utilize the space (or) land more effectively. In addition to that, it helps to prevent (or) control soil erosion.

#### 4. Domestic & Industrial Water Supply -

The canal system can be utilized for domestic and industrial water supply for nearby areas.

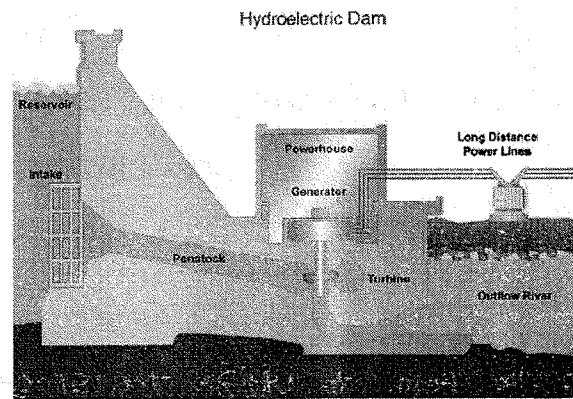
#### 5. Flood Control - Provision of various techniques such as building of canals, flood cushioning, embankments and dykes, flood plain zoning, flood proofing etc.

#### 6. Generation of Hydroelectric Power -

Various multipurpose projects generate hydroelectric power. It is a clean, reliable and renewable energy source. Eg → Bhakra-Nangal project, Hirakud project, Nagarjuna Sagar project, Damodar Valley Project to name a few.

Potential head → K.E → Mechanical head → Electrical energy.

## Introduction to Irrigation &amp; Methods of Irrigation

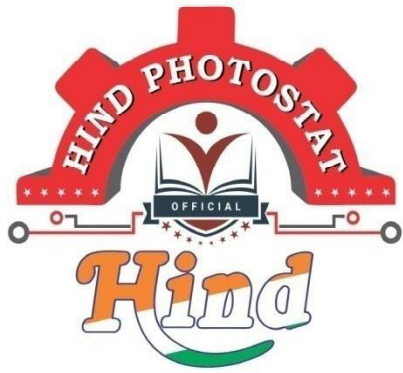


7. Drought Control - Good irrigation practices promote soil conservation, water harvesting and development of ground water which in turn reduces draughts.

## DEMERITS OF IMPROPER IRRIGATION

1. Over irrigation may cause water logging which reduces the crop yield. The roots of most crops require oxygen for respiration and hence, full saturation leads to restricted growth. However, exceptions such as rice, jute etc. which demand standing water for their growth. Rice → close growing crop.
2. Excessive irrigation may cause leaching of pesticides, insecticides, nitrates etc. to ground water.
3. Water logging due to over irrigation leads to creation of favourable conditions for the spread of diseases like dengue and malaria.
4. Over irrigation may increase the salinity of soil (CH-2)
5. Excessive pumping out of groundwater for irrigation decreases the ground water level which increases the risk of land subsidence.
6. Needless to say, it leads to wastage of our valuable water.





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Gate: 2-4 marks.

ESE: OBJ → 5-6 Q

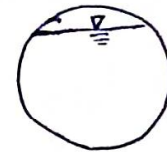
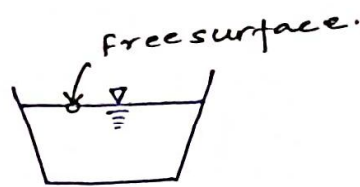
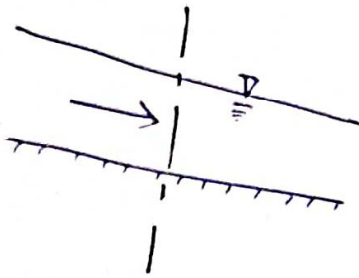
CONV → 50-60 marks

1. Introduction:
2. Uniform Flow
3. Energy Depth Relationship.
4. Gradually varied flow.
5. Rapidly varied flow → Hydraulic Jump
6. Surges

### Introduction:

→ Open channel flow refers to the flow of liquid in channel open to atmosphere or in a partially filled conduit.

→ It is characterized by the presence of liquid-gas interface called free surface.



partially filled conduit.

NOTE: • The driving force in an open channel flow is gravity.  
• Shear stress on the free surface is zero.

### Types of channels:

(i) Prismatic and Non-prismatic channel:

If cross-section, shape, size, bed slope remains constant in the direction of flow then the channel is called prismatic otherwise non-prismatic.

(ii) Rigid and Mobile Boundary channel:

A. Rigid Boundary channel: Only depth varies with space and time.

Boundaries not deformable.

→ Shape and roughness parameter are not function of flow.

eg: lined canal and sewer.

### b. Mobile Boundary channel:

→ In this case the depth, width, bed slope as well as layout are functions of space and time.

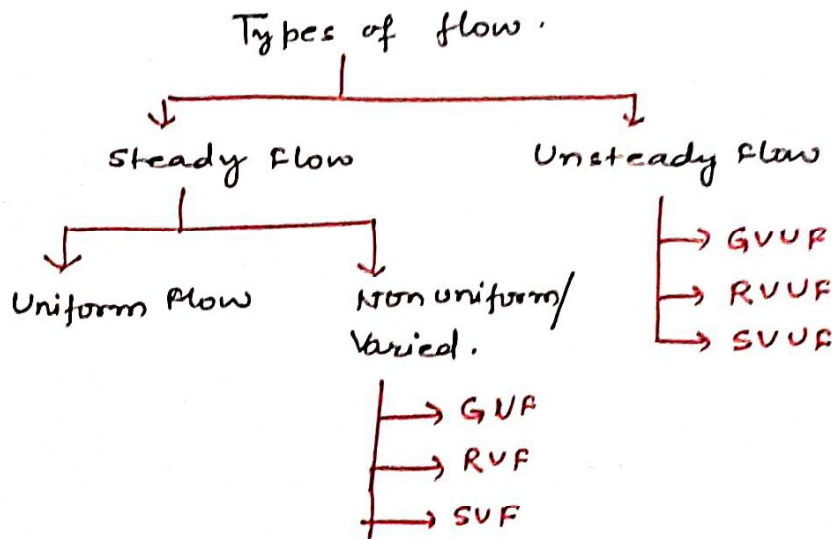
eg: Unlined canals.

NOTE: The rigid boundary channel has one degree of freedom while mobile boundary has four degrees of freedom.

We will study only rigid boundary channels.

Rigid Boundary ~~→~~ Prismatic  
Prismatic → Rigid Boundary.

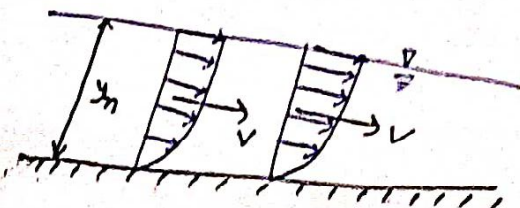
### Types of flow:



### Uniform flow:

→ Flow is called steady uniform if the depth of flow does not vary in space.

→ The underlying assumption that is that the velocity also does not vary which means that the cross-section parameter, roughness parameter, slope parameter are not varying.

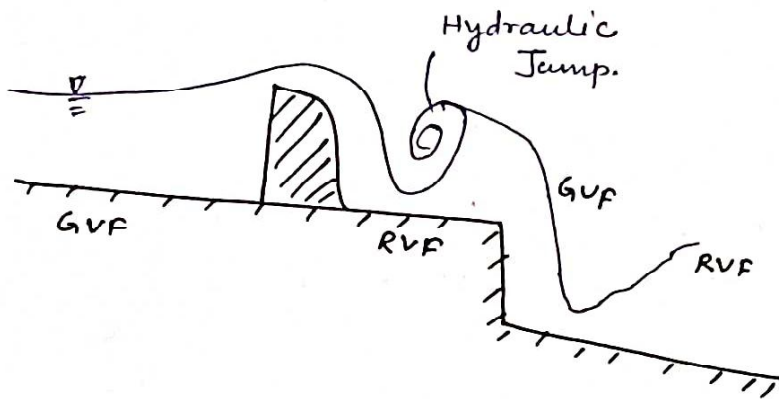


$y_n$  = depth of flow.

$V$  = Avg. velocity of flow.

- In uniform flow the energy gained due to elevation fall is lost due to flow i.e. frictional losses.
- In prismatic channel, constant depth flow means uniform flow and the depth of flow is called normal depth of flow. ( $y_n$ )

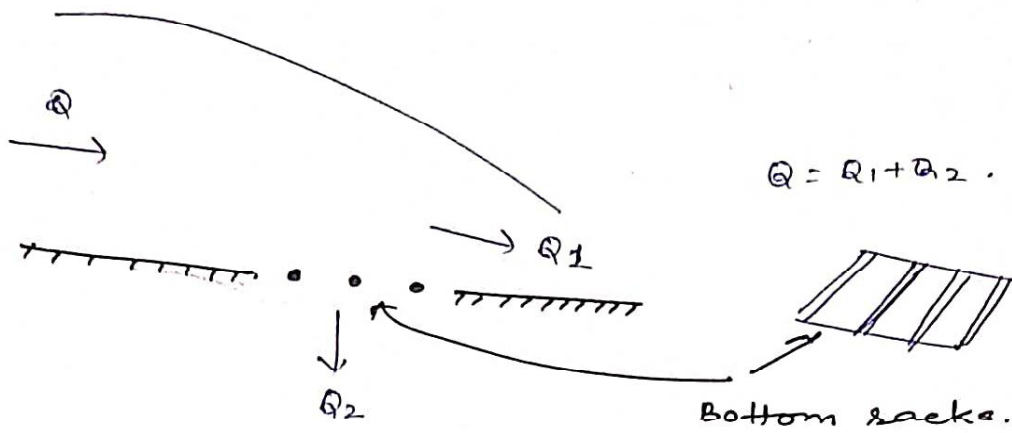
## 2. Non-uniform / Varied flow:



- Presence of obstruction in channel such as weir, dropping bed, change in slope or cross-section causes the flow to vary, this flow is called non-uniform flow or varied flow.
- Flow is called gradually varied if the depth changes gradually over a long distance of channel.
- Curvature of streamline is gentle in this case.
- If the depth of flow changes significantly over a short distance such that the curvature changes rapidly, the flow is called rapidly varied flow.  
eg: Hydraulic Jump.

NOTE: Friction plays an important role but in GVF but not important case of RVF.

If some flow is added or extracted from the system, the flow is called spatially varied flow.  
eg: flow over bottom rack.



### Unsteady flow:

a. Gradually varied Unsteady flow:

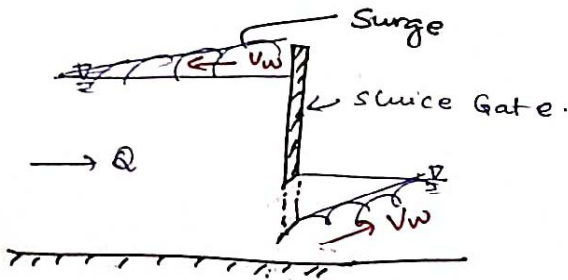
eg: Passage of flood wave in river.

b. Rapidly varied unsteady flow:

eg: surges, tidal bores, breaking of waves on shore.

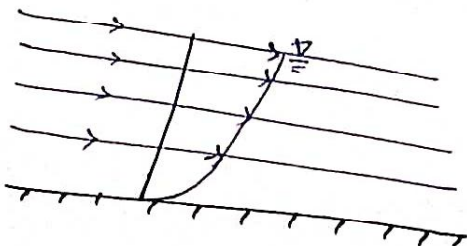
c. Spatially varied Unsteady flow:

eg: surface runoff due to rain fall.



### Laminar Flow and Turbulent Flow:

→ when the flow occurs such that one layer of the liquid slides past the other as if one lamina is sliding over the other, the flow is called laminar flow, where there would be no momentum transfer between different layers.



→ However if water from one layer goes into the other and vice-versa, there could be momentum transfer between different layers such a flow is called turbulent flow.

$$Re = \frac{VR}{\nu}$$

Re = Reynold's number. (dimensionless)

V = Avg. velocity.

R = Hydraulic Radius.

$$= \frac{A}{P}$$

A = Area of x-section.

P = Wetted Perimeter.

$\nu$  = Kinematic viscosity. ( $m^2/s$ )

$\nu = \frac{\mu}{\rho}$        $\mu$  = Dynamic viscosity. (Pa-s)

if  $Re < 500$  Laminar flow.

$500 < Re < 2000$  Transition flow.

$Re > 2000$  Turbulent flow.

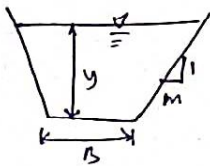
Critical / Subcritical / Super-critical flow:

$$Fr = \frac{V}{\sqrt{gA/T}}$$

Fr = Froude's no. (Dimensionless)

A = Area of x-section.

T = Top width.



$$T = B + 2my$$

$$A = By + my^2$$

Critical

$$Fr = 1$$

$$V = V_c$$

$$y = y_c$$

Subcritical

$$Fr < 1$$

$$V < V_c$$

$$y > y_c$$

Super-critical

$$Fr > 1$$

$$V > V_c$$

$$y < y_c$$

$$V_c = \text{critical velocity} = \sqrt{gA/T}$$

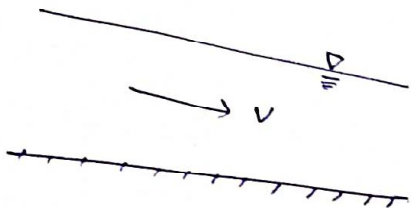
$y_c$  = critical depth.

Celerity ( $C_0$ ):

Denominator of Froude's no. represents a speed with which disturbance created to flow travels in still water, is called Celerity ( $C_0$ ).

$$C_0 = \sqrt{gA/T} = \sqrt{gL_c}$$

$L_c$  = characteristic length.



$$\left( V_{\text{wave/ground}} \right)_{\text{u/s}} = \left( V_{\text{wave/water}} \right)_{\text{u/s}} + \left( V_{\text{water/ground}} \right)_{\text{u/s}}$$

$$\left( V_{\text{wave/ground}} \right)_{\text{u/s}} = C_0 - V$$

For subcritical flow.

~~For super-critical:~~

$$Fr < 1$$

$$\frac{V}{C_0} < 1$$

$$C_0 - V > 0$$

d/s control.

→ At low flow velocity ( $Fr < 1$ ) a small disturbance to the flow will cause disturbance wave which travels ~~to~~ u/s with the velocity ~~base~~  $C_0 - V$  wrt a stationary observer.

→ Due to upstream movement of water, upstream cond<sup>n</sup> gets affected. Thus in case sub-critical flow condition upstream is affected by the cond<sup>n</sup> at downstream, and the down stream section is taken as control section.



For super-critical flow:

$$Fr > 1$$

$$\frac{V}{C_0} > 1$$

$$C_0 - V < 0$$

ups control.

At high flow velocity  $Fr > 1$ , the upstream flow velocity of wave ( $C_0 - V$ ) will become negative i.e. the disturbance wave will not travel upstream, it will travel downstream with a velocity of  $(V - C_0)$

Hence, flow cond<sup>n</sup> downstream will be affected and super-critical flow has upstream control.

NOTE: Sub-critical flow has downstream control while super-critical flow has upstream control.

When  $Fr = 1$ , flow is critical and the disturbance velocity  $C_0 - V = 0$  i.e. disturbance wave will not travel at all.

Q: A wide sect. channel is 1m deep and has a velocity of flow  $V = 2.13$  m/s. If the disturbance is caused and elementary wave can travel upstream with a velocity of

a) 1 m/s

b) 3.13 m/s

c) 2.13 m/s

d) 5.26 m/s.

$$C_0 = \sqrt{gA/T} = \sqrt{g \times \frac{By}{B}}$$

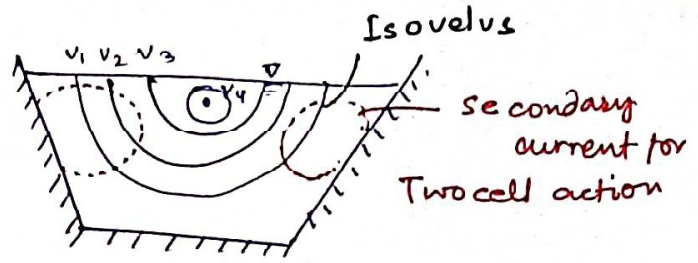
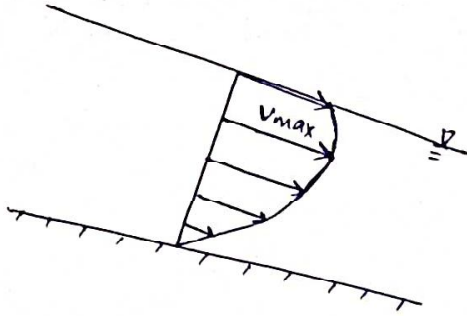
$$= \sqrt{g \cdot y}$$

$$C_0 = \sqrt{9.81}$$

$$3.13 \text{ m/s.}$$

$$(V_{\text{wave/ground}}) = C_0 - V = 3.13 - 2.13 = 1 \text{ m/s}$$

# Velocity Distribution:



$$v_4 > v_3 > v_2 > v_1$$

Isovels: contours of equal velocity

$$\text{Aspect Ratio} = \frac{\text{Depth}}{\text{width}}$$

Reduction or dip in the velocity is because of secondary current which is a function of aspect ratio.

If aspect ratio is large, depth at which max velocity occurs is deeper.

10/04/21

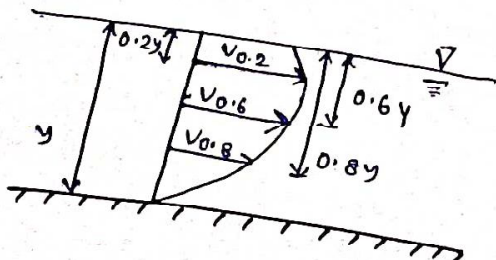
## Average Velocity

$$1. \quad V_{avg} = \frac{\int v \, dA}{A}$$

$V$  = Average velocity.

$v$  = Actual velocity.

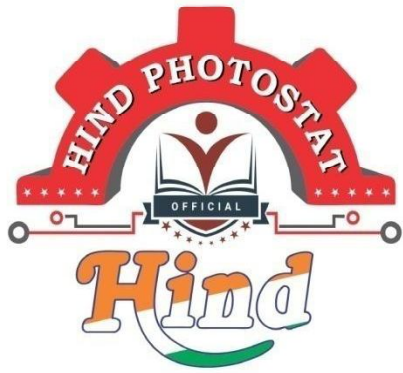
2.



$$V_{avg} = \frac{v_{0.2} + v_{0.8}}{2}$$

OR

$$V_{avg} = v_{0.6} \quad (\text{less reliable})$$



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## # CONTENTS :

- (1) Analysis of statically determinate trusses  
(Methods of Joints and Method of sections).
- (2) Deflection in statically determinate trusses (using strain energy method  $\odot$  unit load Method).
- (3) Analysis of statically indeterminate trusses (using strain energy  $\odot$  unit load method).
- (4) Influence line diagram for statically determinate trusses.
- (5) Influence line diagram for Indeterminate structures.
- (6) Deflection in statically Determinate Frames (using strain energy  $\odot$  unit load method)
- (7) Analysis of indeterminate structure - Moment Distribution method.
- (8) Slope deflection method
- (9) Analysis of cables (only tension)
- (10) Analysis of 3-hinged Arches.
- (11) Analysis of 2-hinged Arches.
- (12) Approximate methods in structural analysis (Portal and cantilever method).
- (13) Static Indeterminacy, kinematic indeterminacy, stability of structures.
- (14) stiffness Matrix Method (15) Flexibility Matrix Method
- (16) structural Dynamics

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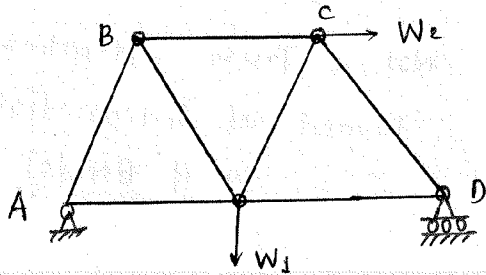
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# ch: 01 Analysis of Statically Determinate Trusses

# Truss - It is a structure in which all members are subjected to axial forces only. (Tension and compression).  
Bending Moment is zero everywhere in this structure.

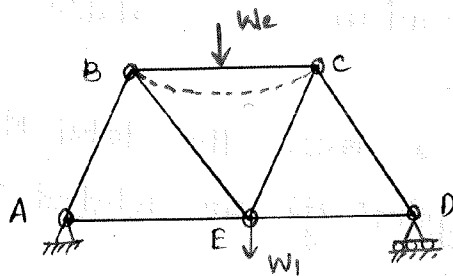


: Truss (In a truss, all members are called links).

**NOTE** - (1) Link :- If any structural member connected by pin at the ends and not loaded at intermediate location, is called a link.

(2) Frame :- It is a structure in which members are subjected to bending moment also. (In addition to tension and compression.)

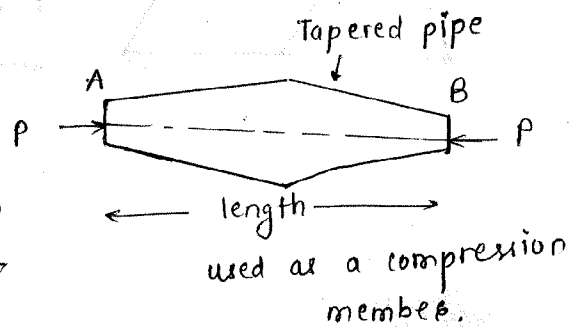
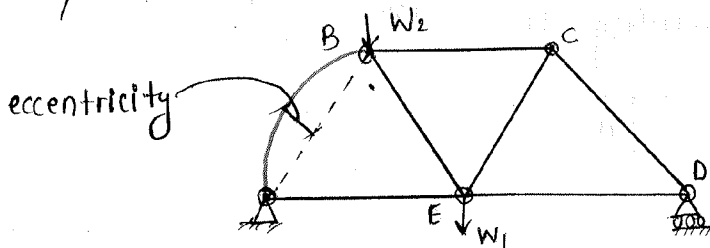
(To called a truss members must behave like a link)



: Frame (as member BC bends).

## (3) Assumptions in the Analysis of Trusses.

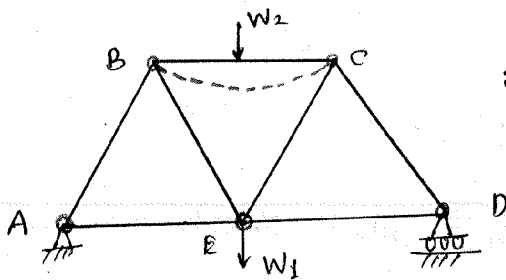
(a) All members must be straight and connected by smooth pins at the ends (otherwise, if the members are curved, then they will bend and the structure cannot be called as a Truss.)



2M Members must be straight but need NOT to be Prismatic.

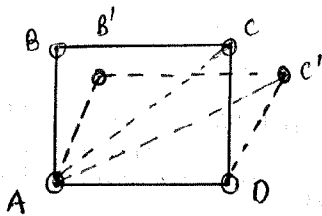
Prismatic - Having same c/s throughout its length.

(b) Loads must be applied only at the joints (otherwise, if the loads are applied at intermediate locations of the members, then they will bend and the structure cannot be called as a Truss.

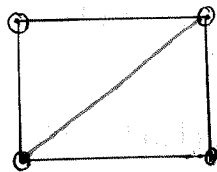


Not a Truss (Member BC is loaded at intermediate location, so it Bends).

(4) Mechanism - unstable structure. (without increasing stress strain coming).



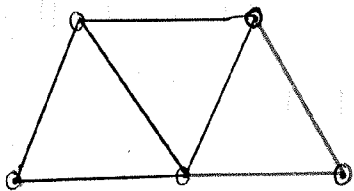
4 link Mechanism



stable structure

Conclusion :- In a truss, the total No. of members (m) and total no. of joints (j) are related by :

$$(m) = (2j - 3) **$$



For the first 3 joints, 3 members are required. For each additional joint, 2 members are required. combining these two statements,

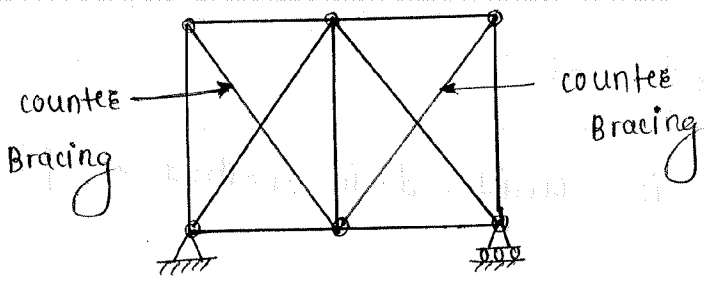
$$m = 2J - 3$$



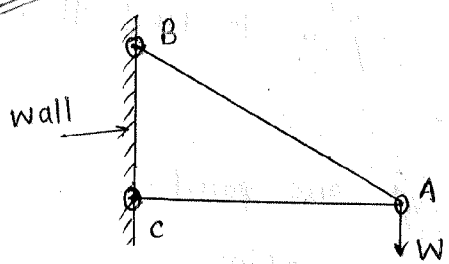
NOTE :- If the above condition is satisfied, then we get a 2M stable, triangulated and determinate truss.

- (5) (a) IF  $m = (2J-3)$  - perfect, stable Truss  
 (b) IF  $m < (2J-3)$  - Deficient or unstable Truss  
 (c) IF  $m > (2J-3)$  - Redundant Truss [We provide more members than  $(2J-3)$  to make the structure more stable.]

This additional members are called counter Bracing.

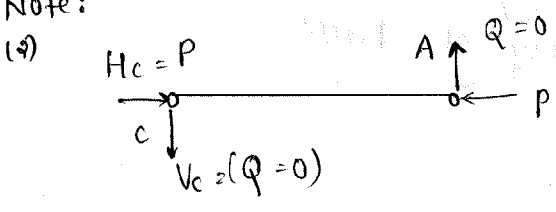


Que: (1) For the structure shown in fig., Bending moment exists in the member. (a) AC (b) AB (c) Both AB, AC (d) No member



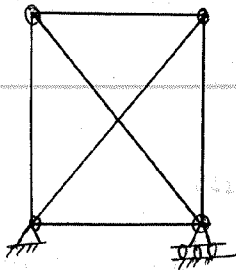
Note: (1) since all members are straight connected by pins and loaded at intermediate locations, they behave like links so No member bends.

Note:



Link } IF  $Q \neq 0$ , anticlockwise couple cannot be balanced and it will not be in equilibrium.

Que: (2) The truss shown in fig. (a) Perfect (b) Deficient  
~~(c) Redundant~~ (d) None



$$m = 6$$

$$J = 4$$

$$m \quad (2J - 3)$$

$$6 \quad (2 \times 4 - 3)$$

$$6 > 5$$

conclusion : Redundant Truss (1 counter Bracing member).

# Analysis of Trusses [ (a) Method of joints (particular case of method of section only)  
 (b) Method of sections ]

# (a) Method of Joints :-

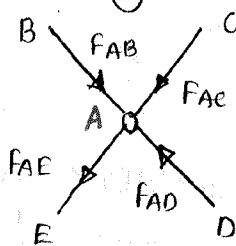
(1) Equilibrium of a joint is considered in method of joints.

(2) Procedure :-

(I-step) - Find the support reactions by considering equilibrium of entire truss.

Step-II] - consider equilibrium of a joint where only 2 unknown forces are available and use  $\sum X = 0$   $\sum Y = 0$  to find them.

similarly, proceed to the other joint.



concurrent - Meeting at one point.

coplanar - lying in one plane.

system - Group of forces.

: Coplanar, concurrent force system.

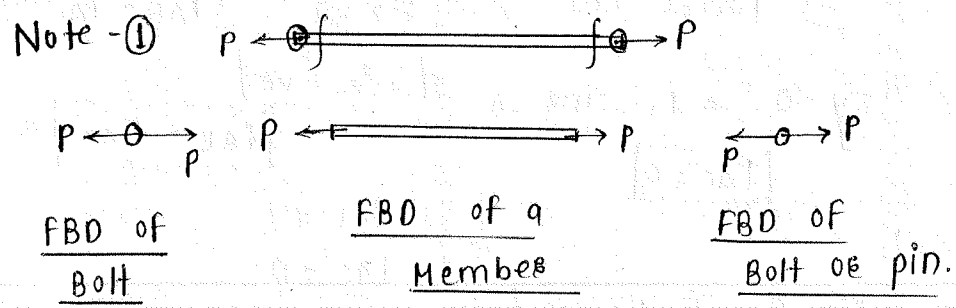
$$\sum X = 0$$

$$\sum Y = 0$$

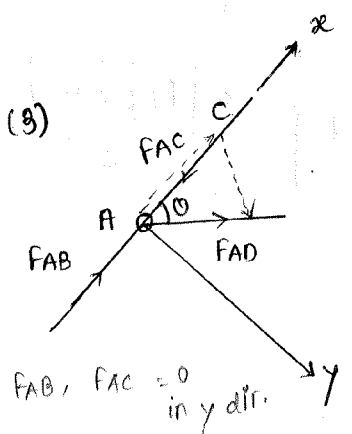
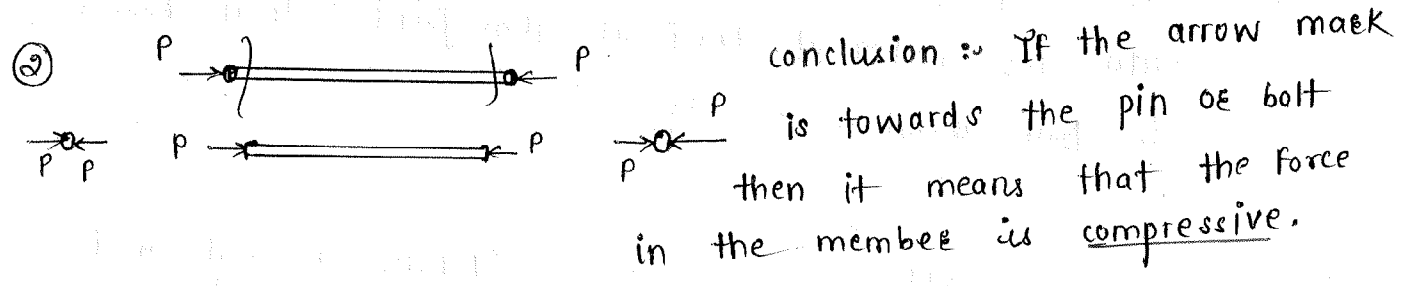
$$\sum M_A = 0 \Rightarrow 0 = 0$$

conclusion - In a coplanar, concurrent force system the NO. of equations of equilibrium available are only two.  
 $(\sum x = 0 \quad \sum y = 0)$

With two eqns. we can only find two unknown forces. so, we must select a joint where only two unknown forces are available.



conclusion :- If arrow mark is away from joint or bolt it means that force in the member is Tensile.



tail to head  $\dots \rightarrow$   
collinear - same line of action.

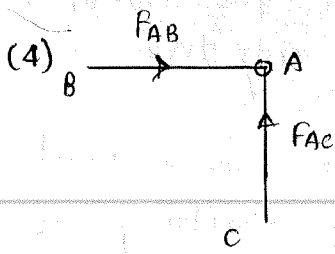
$$\sum y = 0$$

$$+ F_{AD} \cdot \sin \theta = 0 \quad (\text{only})$$

$$\sin \theta \neq 0$$

$F_{AD} = 0$

conclusion - At a joint, if three members or 3 forces are meeting, 2 members are collinear, then force in the third member is Always zero.



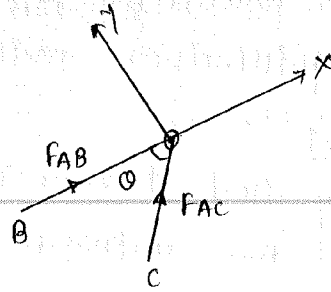
Two Non-collinear forces  
(at  $\theta = 90^\circ$ )

$$\sum X = 0 \Rightarrow \boxed{F_{AB} = 0}$$

→ ←  
+ve -ve

$$\sum Y = 0 \Rightarrow \boxed{+F_{AC} = 0}$$

↑ ↓  
+ve -ve

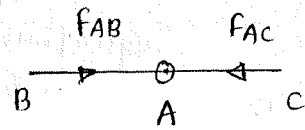


Two Non-collinear forces ( $\theta$ )

$$\sum Y = 0 \Rightarrow F_{AC} \cdot \sin \theta = 0$$

$$\boxed{F_{AC} = 0}$$

$$\sum X = 0 \Rightarrow \boxed{+F_{AB} = 0}$$



Two collinear forces

$$\sum X = 0 \Rightarrow +F_{AB} - F_{AC} = 0$$

$$\left[ \begin{array}{cc} \rightarrow & \leftarrow \\ +ve & -ve \end{array} \right]$$

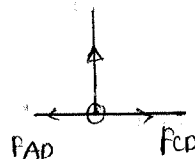
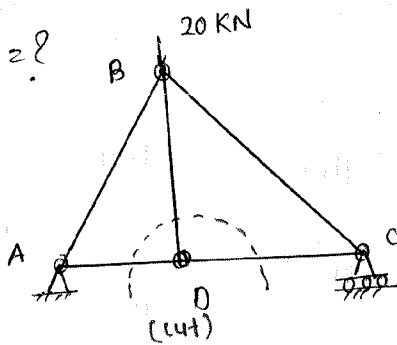
$$\boxed{F_{AB} = F_{AC}}^*$$

$$F_{AB} \neq 0$$

$$F_{AC} \neq 0$$

Conclusion - At a joint, if two non-collinear members are meeting with no external load at that joint then forces in both members will be zero.

Que: (3) FBD = ?



F.B.D. of Bolt at D

$$\sum Y = 0$$

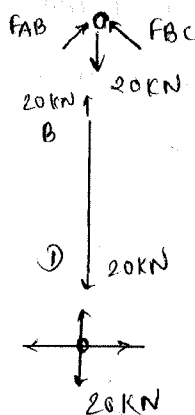
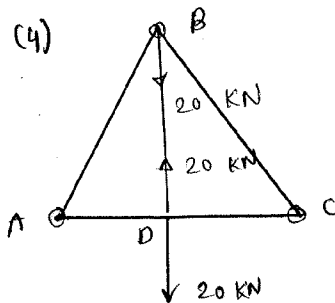
$$\left[ \begin{array}{cc} \uparrow & \downarrow \\ +ve & -ve \end{array} \right]$$

$$\therefore \boxed{F_{BD} = 0}$$

: Ans.

two collinear  
At third FBD = 0. (Ans)

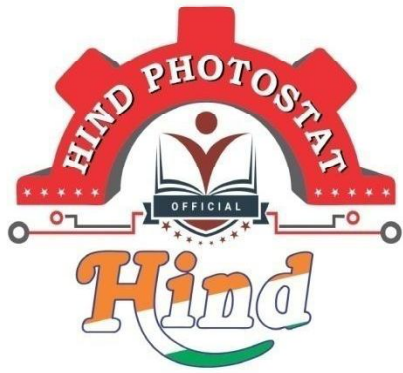
Que: (4)



FBD of Bolt at B

FBD of member BD

FBD of Bolt at D.



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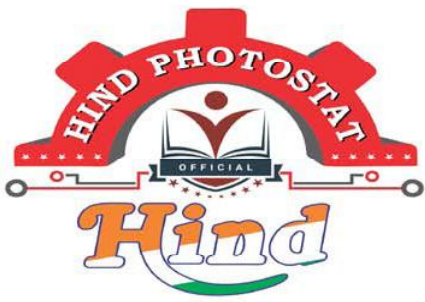
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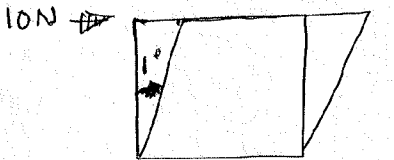
1-Q

Engg. Science

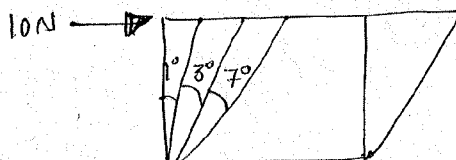
Solid Mechanics

Fluid Mechanics

Properties of Material



$t = 2 \text{ sec} \rightarrow 1^\circ$   
 $t = 5 \text{ sec} \rightarrow 1^\circ$   
 $t = 10 \text{ sec} \rightarrow 1^\circ$

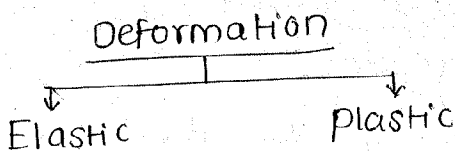


$t = 2 \text{ sec} = 1^\circ$   
 $t = 5 \text{ sec} = 8^\circ$   
 $t = 10 \text{ sec} = 7^\circ$

Engg. Mechanics

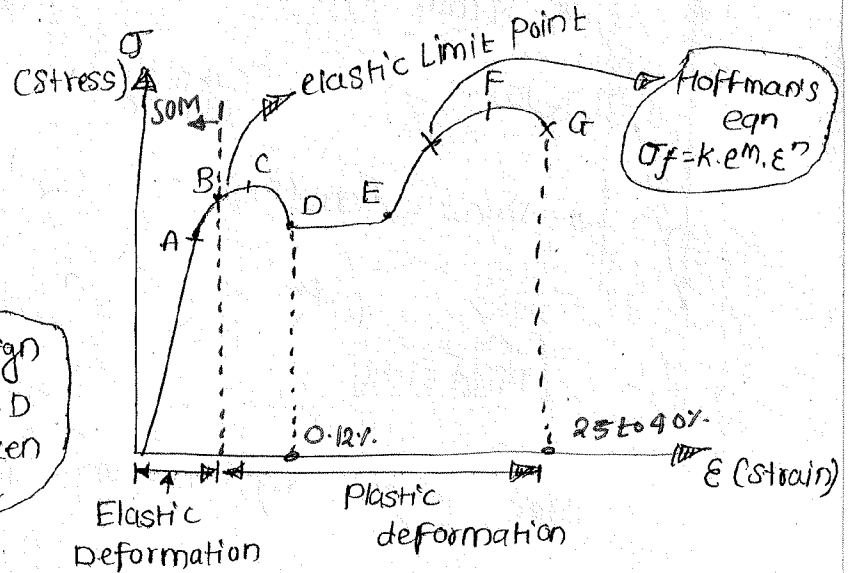
SOM/MOS/MOHDB

Mechanics of Highly Deformed Body.

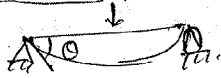


upto A,  $\sigma \propto \epsilon$

for design A, B, C, D is taken same



Steel



$$\delta = \frac{PL^3}{48EI}$$

$\delta$  is very small

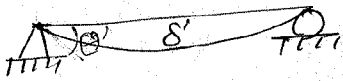
$$\frac{1}{R} = \frac{d^2y/dx^2}{\left[1 + \left(\frac{dy}{dx}\right)^2\right]^{3/2}}$$

$$\Rightarrow \frac{1}{R} = \frac{d^2y}{dx^2} \Rightarrow \frac{M}{EI} = \frac{d^2y}{dx^2}$$

$$M = EI \cdot \frac{d^2y}{dx^2}$$

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

Hard Rubber



$$\delta' \neq \frac{PL^3}{48EI}$$

$$\frac{1}{R} \neq \frac{d^2y}{dx^2}$$

$\delta', \theta'$  is Large

$$\frac{1}{R} = \frac{d^2y/dx^2}{\left[1 + \left(\frac{dy}{dx}\right)^2\right]^{3/2}}$$

$\neq 0$

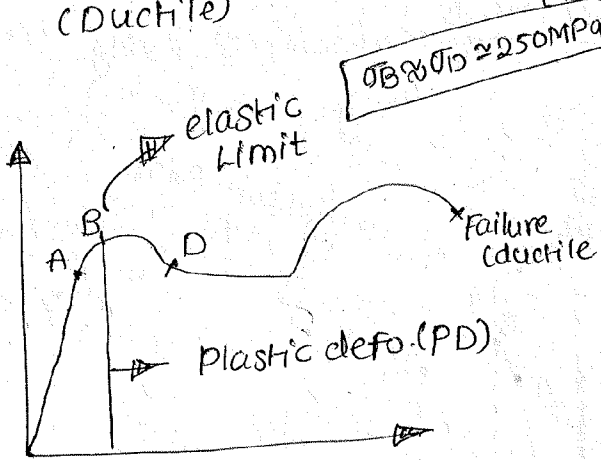
Plastic Deformation is greater than Elastic Deformation

1-B

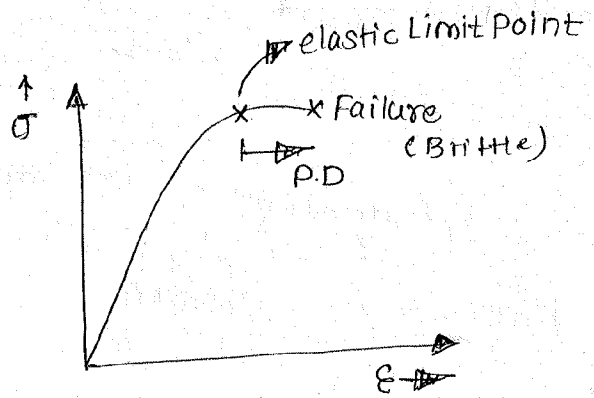
Failure of Material:-

Plastic Deformation (Ductile)

Fracture (Brittle)



Mild steel

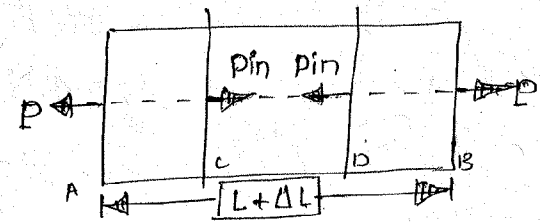
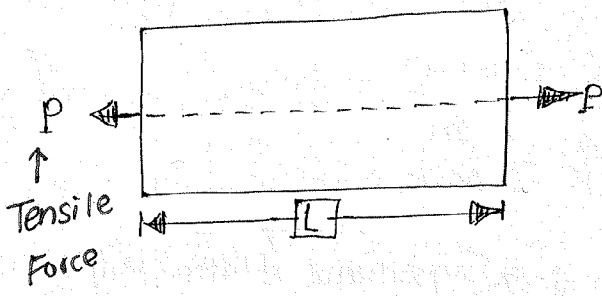


Cast Iron

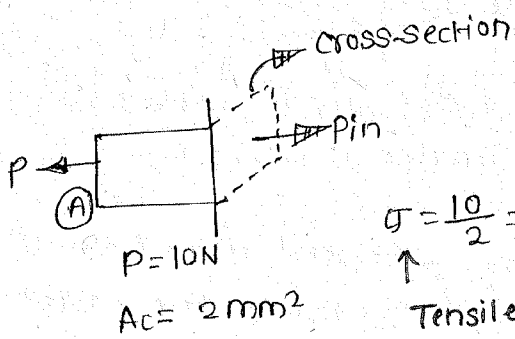
More plastic deformation More ductility



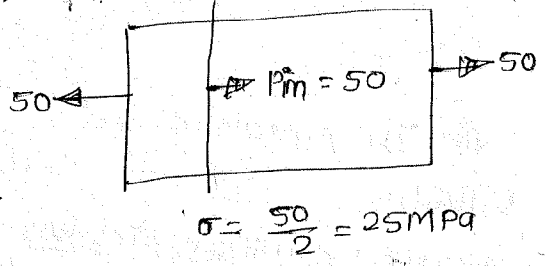
\* Difference B/w Strength and Stress :



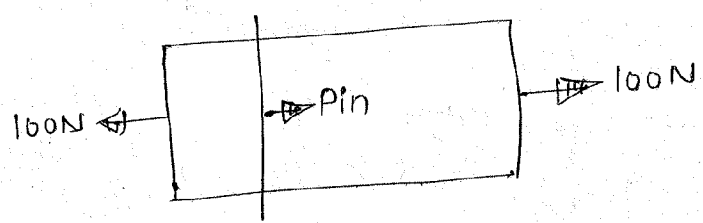
Tensile strain,  $\epsilon = \frac{\Delta L}{L}$



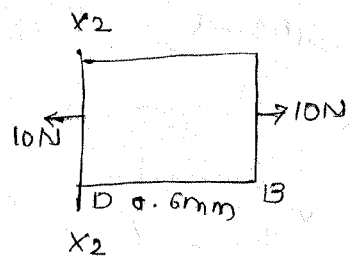
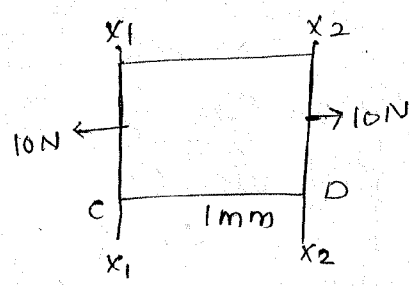
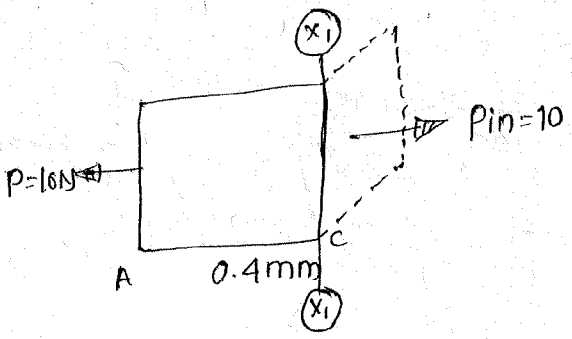
Tensile Stress  $\sigma = \frac{10}{2} = 5 \text{ N/mm}^2$



$\sigma = \frac{50}{2} = 25 \text{ MPa}$



$\sigma = \frac{100}{2} = 50 \text{ MPa} \Rightarrow \text{Strength}$



→ \* Strain is a cause of Stress.

Stress is a internal resisting force offered by material against deformation.

\* Hook's Law: (Axial Deformation)

$$\epsilon = \frac{\Delta L}{L}$$

Hook's Law

$$\sigma \propto \epsilon$$

$$\sigma = \frac{P \cdot l_0}{A_c} = \frac{P}{A}$$

$$\sigma = E \epsilon$$

$$\epsilon = \frac{\sigma}{E} = \frac{P/A}{\Delta L/L}$$

$$\Delta L = \frac{PL}{AE}$$

Constitutive relationship.

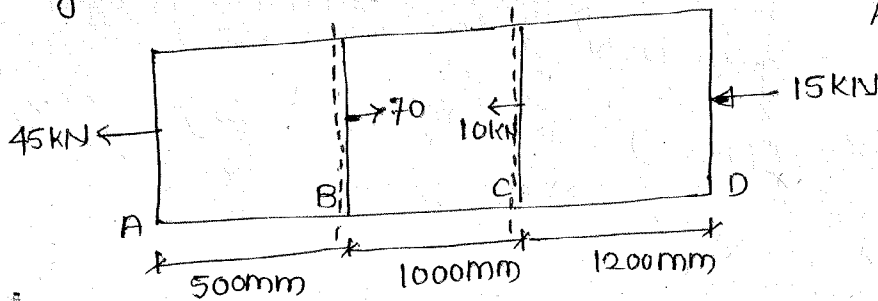
The equation relating stress and strain is called Constitutive Equation because, it depends on material behaviour.

Statically determinate problem.

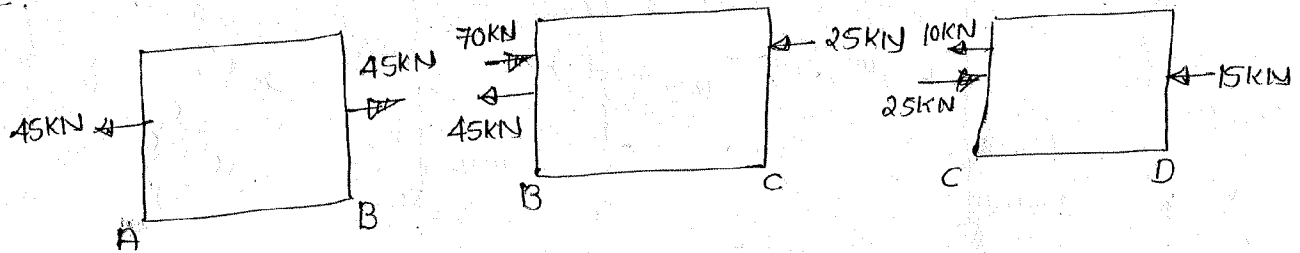
Que: A rectangular cis Bar having cross-sectional area  $800 \text{ mm}^2$  is subjected to axial loading as shown. Determine the total change in length of Bar.

$$E = 100 \text{ GPa}$$

$$A_c = 800 \text{ mm}^2$$



Soln:-



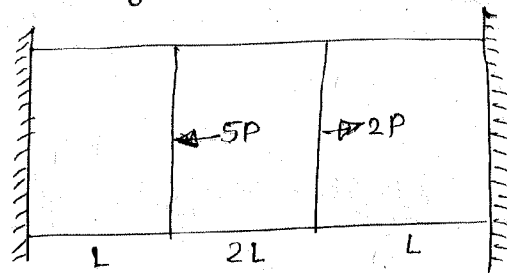
$$\Delta_{\text{Total}} = \Delta_1 + \Delta_2 + \Delta_3$$

$$= \frac{1}{(800 \text{ mm}^2) (100 \times 10^3) \frac{\text{N}}{\text{mm}^2}} \left[ (45 \times 10^3)(500) + (-25 \times 10^3)(1000) + (-15 \times 10^3)(1200) \right]$$

$$= -0.25625 \text{ mm}$$

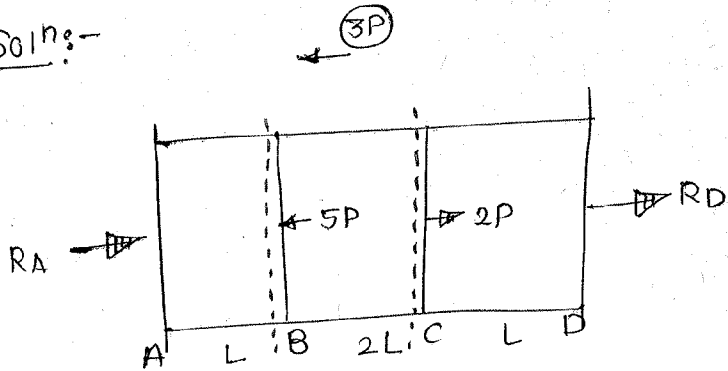
Que:  $E = 100 \text{ GPa}$   
 $A_c = 800 \text{ mm}^2$

Statically Indeterminate Problem

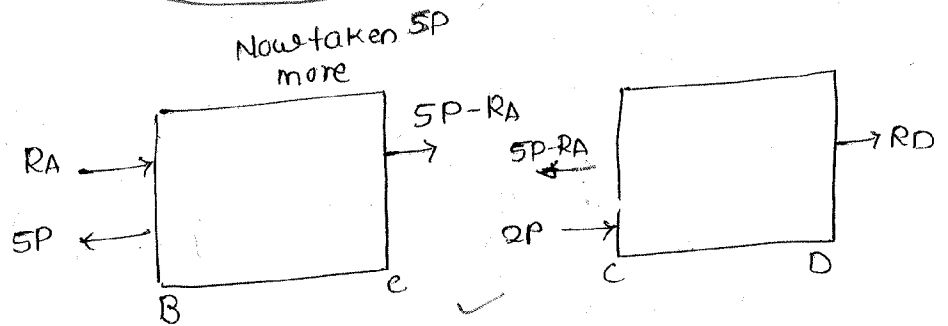
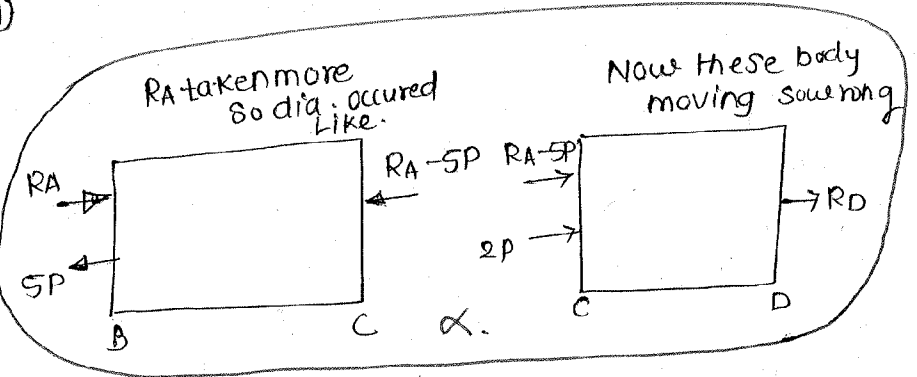
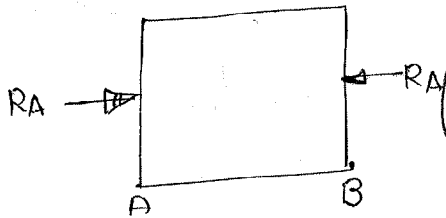


A bar arrangement as shown. Determine Support Reaction and draw axial force diagram

Soln:-



$$R_A + R_D = 3P \quad \text{--- (1)}$$



$$5P - R_A - R_D - 2P = 0$$

$\Delta_{\text{Total}} = 0$  (bca both ends are fixed)

$\Delta_1 + \Delta_2 + \Delta_3 = 0$  (compatibility eqn)

$R_A + R_D = 3P$

checked.

$$\frac{1}{AE} \left[ \{(-R_A \cdot L)\} + \{(5P - R_A)2L\} + \{(+R_D \cdot L)\} \right] = 0 \quad \text{--- (2)}$$

$$-RA \cdot L + 10PL - 2RA \cdot L + RD \cdot L = 0$$

$$-RA + 10P - 2RA + RD = 0$$

$$-3RA + 10P + RD = 0$$

$$3RA - RD = 10P \quad \text{--- (2)}$$

$$RA + RD = 3P \quad \text{--- (1)}$$

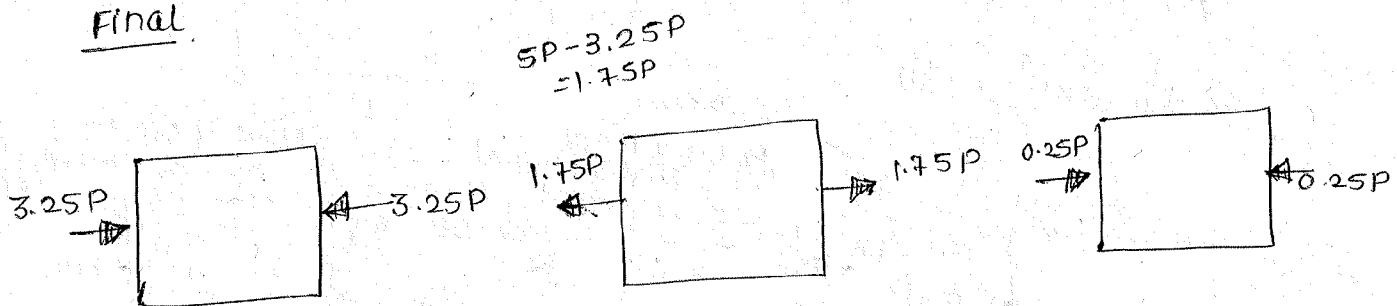
$$\underline{\hspace{10em}}$$

$$4RA = 13P$$

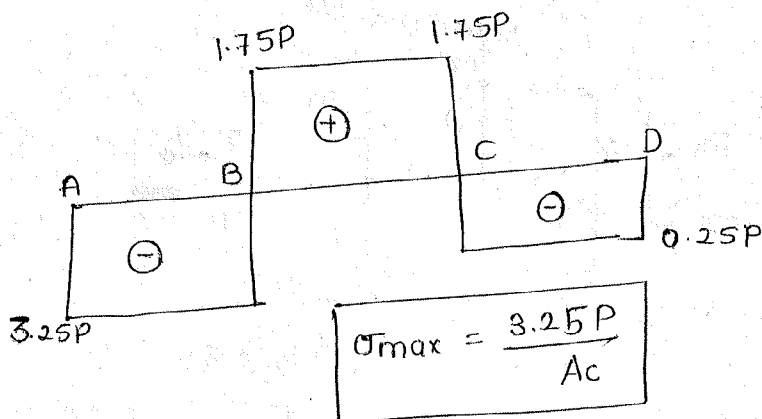
$$RA = \frac{13P}{4} = 3.25P$$

$$\therefore RD = -0.25P$$

Final

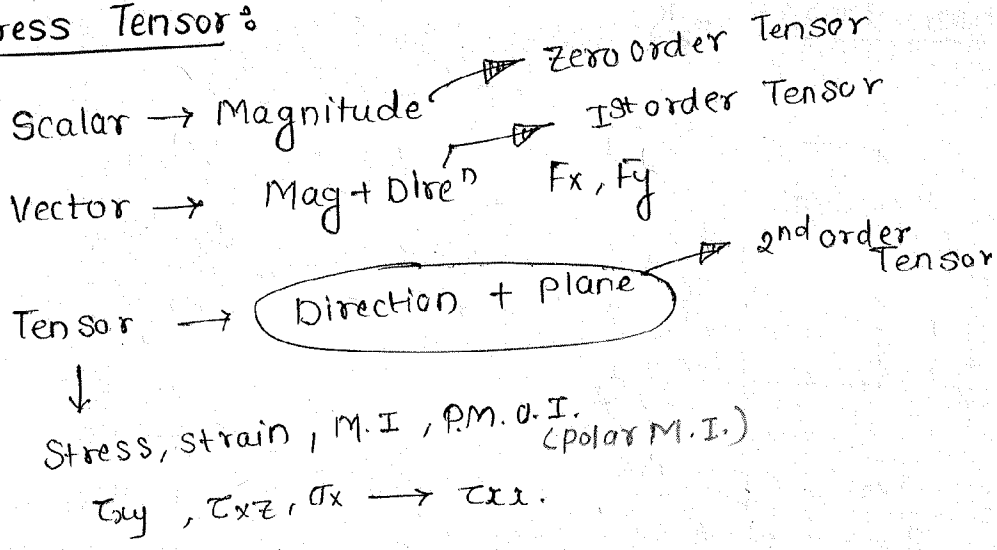


Axial Force Diagram : (equilibrium Diagram)



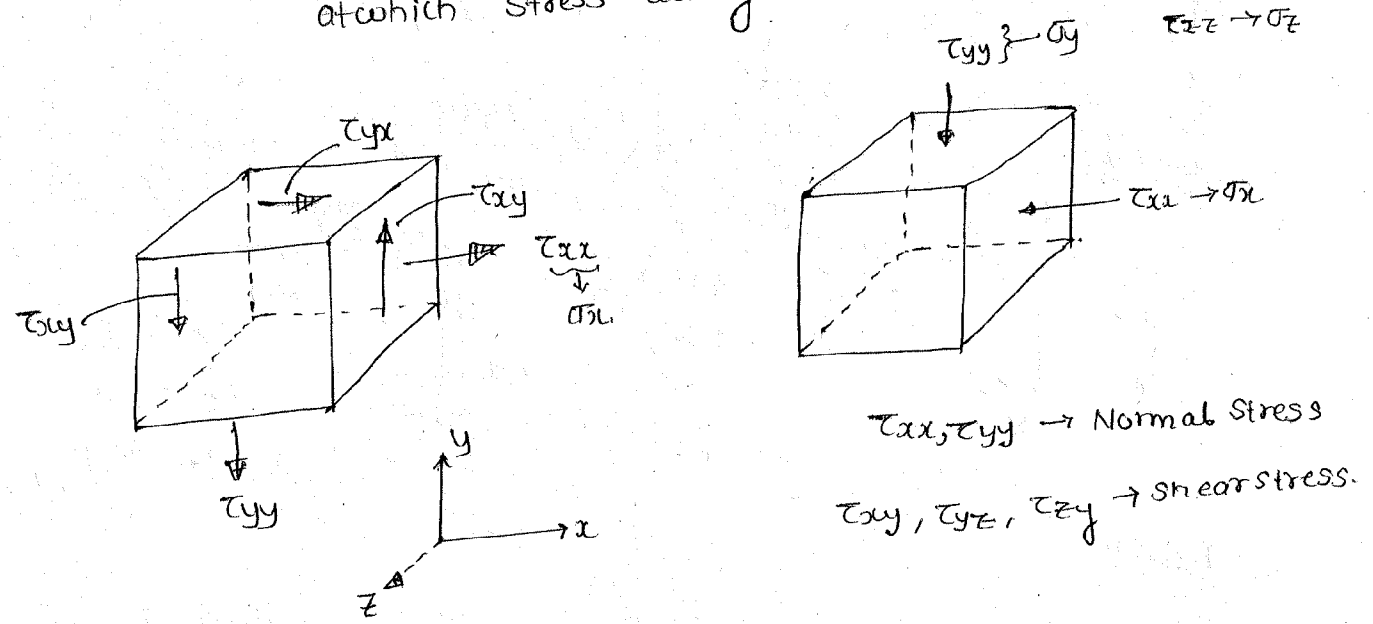
Compatibility Equation is the relationship b/w unknown forces and known deformation.

\* Stress Tensor:

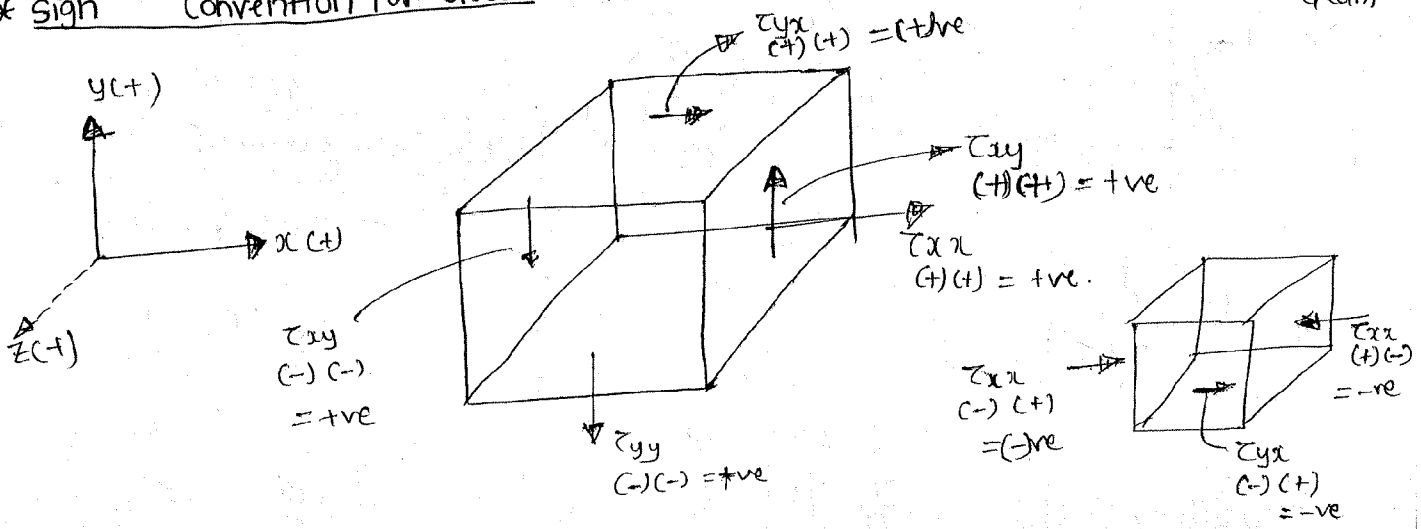


Stress Representation:

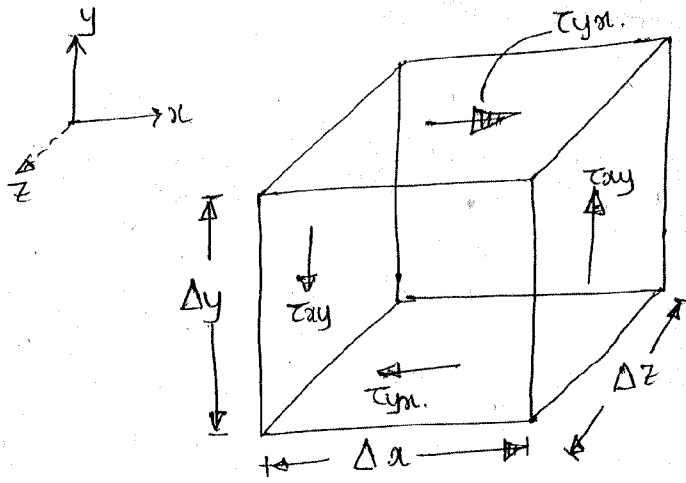
$\tau_{ij}$   $\rightarrow$  represent the stress direction  
 $\downarrow$   
 represent the plane (outward Normal)  
 at which stress acting.



\* Sign Convention for stress: पहले subscript में plane को देखना then arrow को देखना.

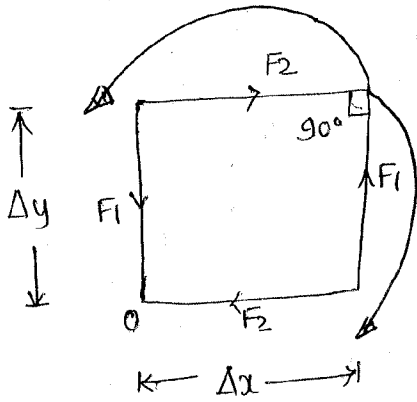


# Equality Of Shear Stress: (2.10)



$$F_1 = \tau_{xy} (\Delta z \cdot \Delta y)$$

$$F_2 = \tau_{yx} (\Delta x \cdot \Delta z)$$



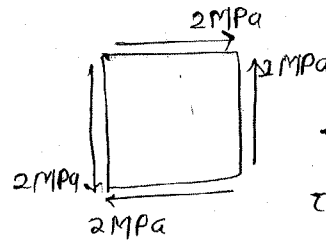
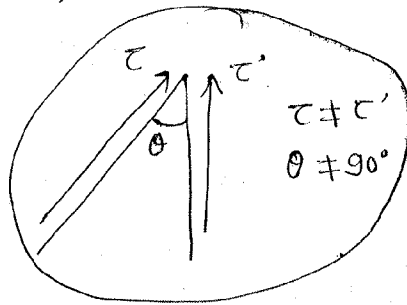
By moment Equilibrium Condition

$$\sum M_0 = 0$$

$$F_1 \cdot \Delta x = F_2 \cdot \Delta y$$

$$\tau_{xy} \cdot (\Delta z \cdot \Delta y) \Delta x = \tau_{yx} \cdot (\Delta x \cdot \Delta z) \cdot \Delta y$$

$$\tau_{xy} = \tau_{yx}$$

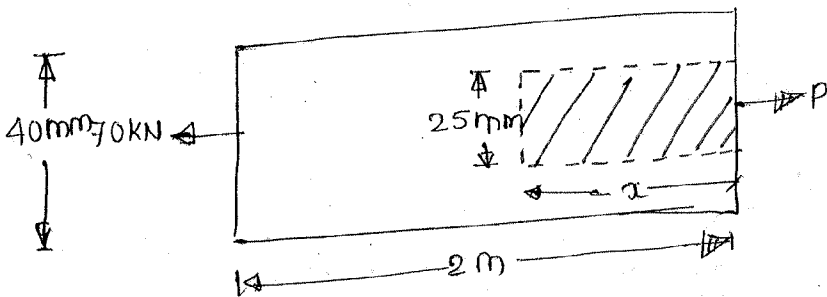


$$\tau_{xy} = \tau_{yx}$$

$$\tau_{xz} = \tau_{zx}$$

$$\tau_{yz} = \tau_{zy}$$

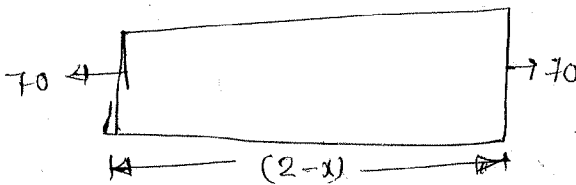
Que: 6: WB: CH-02



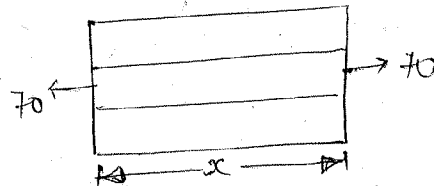
When No Boring

$$\delta_1 = \frac{(70 \times 10^3) (2 \times 10^3)}{\frac{\pi}{4} (40)^2 E}$$

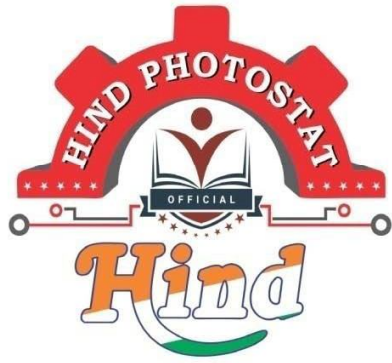
When Boring Complete



$$\delta_1 = \frac{(70 \times 10^3) (2-x) \times 10^3}{\frac{\pi}{4} (40)^2 \times E}$$



$$\delta_2 = \frac{(70 \times 10^3) (x \times 10^3)}{\frac{\pi}{4} (40^2 - 25^2) E}$$



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# Design of Steel Structure

GATE :- 2M - 1Q = 2M  
2Q - 1M = 2M → 4M

ESE: (Pre) :- 10 - 15Q (20-30M)

(Mains) :- 60M

BARC }  
ISRO } 100% Q  
DRDO } Steel

[S.K Duggal]

IS 800:2007 [L.S.M]

800:1984 (WSM)

Steel Table

## Syllabus

### 2] Design Philosophy (ESE)

- WSM
- Plastic Method of design
- Limit State method of Design

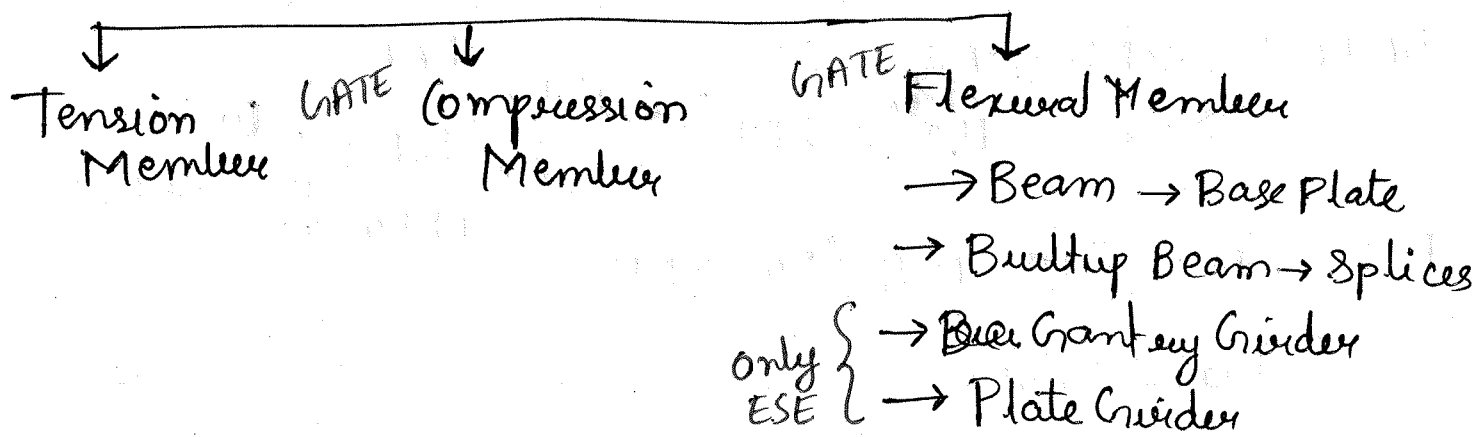
### 3] Connection Design

Simple Connection      (GATE) ↓ Eccentric

- Rivets
- Bolts
- Welding
- Type I
- Type II

GATE/ESE

#### 4] Member Design (ESE)



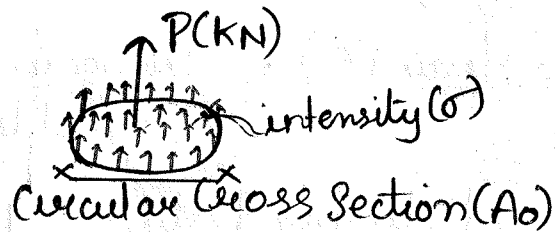
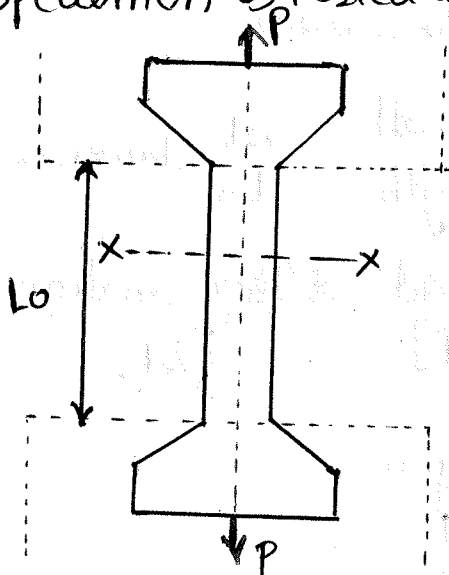
#### 6] Industrial Roof (ESE)

- Roof truss
- Purlin

# Chapter 1: Plastic Analysis of Beams & Frame

## # Stress Strain Curve for Mild Steel

- A tensile test is conducted on a Mild steel specimen (ie coupon)
- Specimen is tested in universal testing machine (U.T.M)

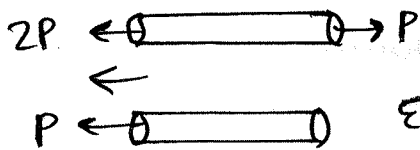


$A_0$  → Original cross sectional area ( $\text{mm}^2$ )

$P$  → Applied load (KN)

$\sigma$  → Nominal Tensile Stress

$$\sigma = P/A_0$$



$\epsilon_F = 0$  { Rigid body Translation }

- As material is assumed to be homogenous & Isotropic, the intensity distribution of load on the cross section can be assumed to be equal

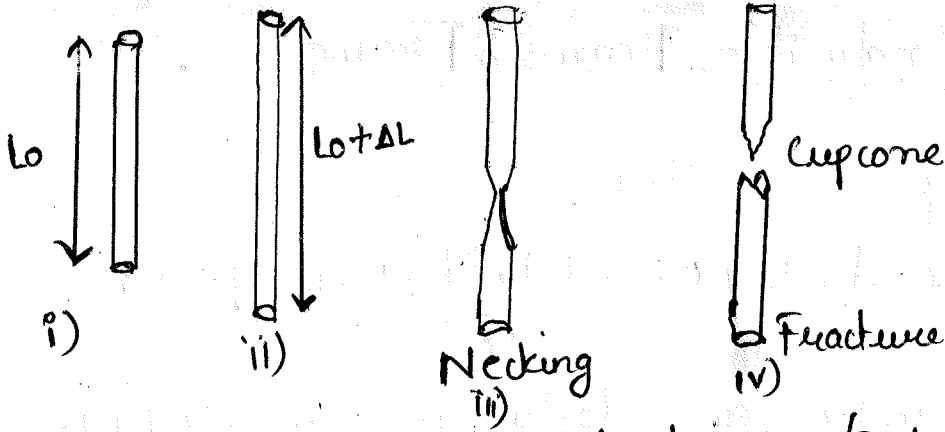
- The intensity of load over cross-sectional is termed as stress

$$\left[ \sigma = \frac{P}{A_0} \frac{(N)}{(\text{mm}^2)} \rightarrow \text{Unit } N/\text{mm}^2 \text{ or MPa} \right]$$

- The length over which specimen is tested is called as gauge length & it is given by

$$L_0 = 5.65 \sqrt{A_0}$$

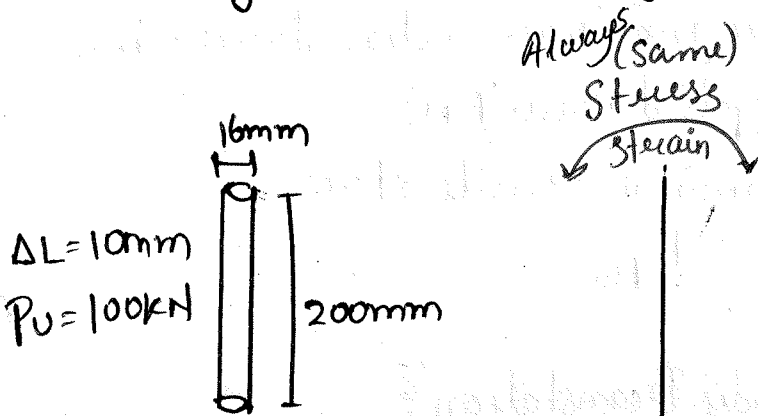
- Specimen is subjected to gradually increasing tensile loading



$\Delta L$  = Change in length (mm) / Extension / Deformation

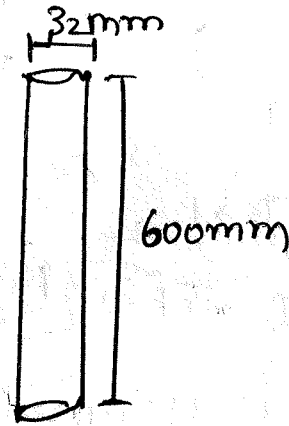
→ Normal tensile strain ( $\epsilon$ )  $\Rightarrow \frac{\text{Change in length}}{\text{Original length}} = \frac{\Delta L}{L_0}$  (Dimensionless)

→ Reading observed during testing → Load [P] & Deformation [ $\Delta L$ ]



$$\sigma_u = \frac{P_u}{A_0} = \frac{100 \times 10^3}{\frac{\pi}{4} \times 16^2} = 497.36 \text{ N/m}^2$$

$$\epsilon = \frac{\Delta L}{L} = \frac{10}{200} = 5 \times 10^{-2}$$



$$\sigma_u = \frac{P_u}{A_0} \therefore 497.36 = \frac{P_u}{\frac{\pi}{4} \times 32^2}$$

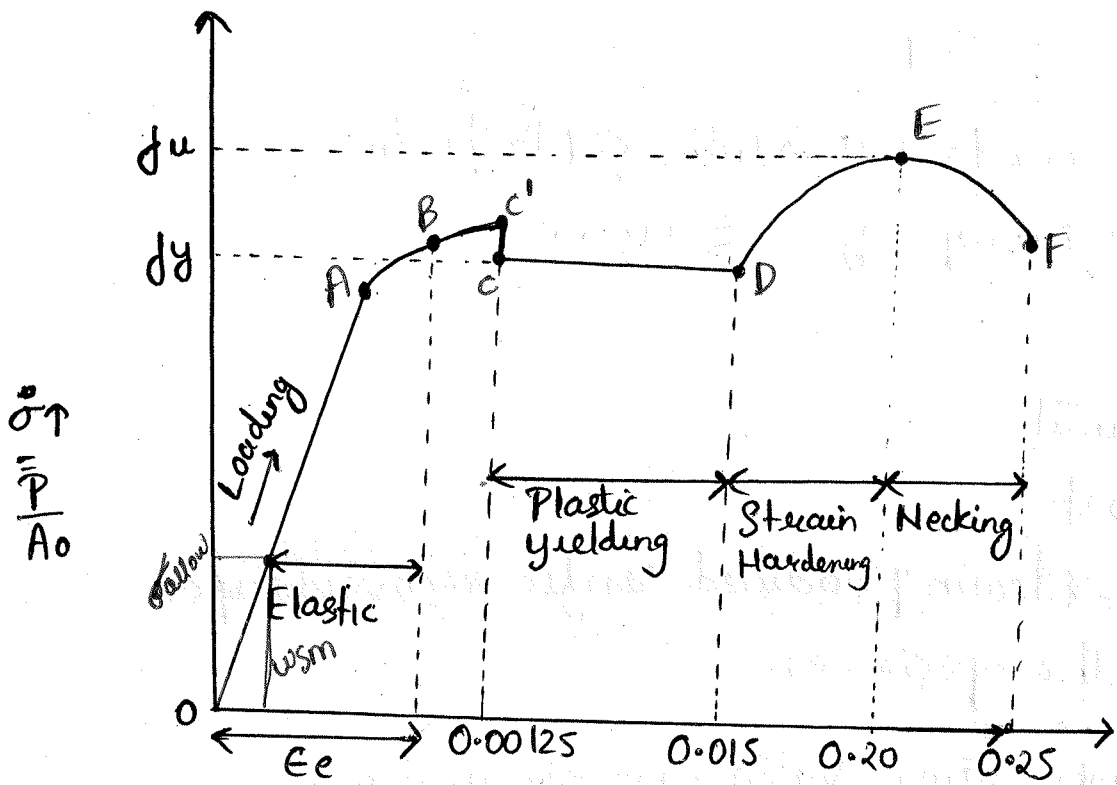
$$P_u = \underline{400 \text{ kN}}$$

$$\epsilon = 5 \times 10^{-2} = \frac{\Delta L}{600}$$

$$\Delta L = 30 \text{ mm}$$

→ P- $\Delta$  graph will be different for different size of specimen

→ Hence  $\sigma$ - $\epsilon$  curve is plotted for specimen { It will be same for a given material }



$$\frac{\Delta L}{L_0} = \epsilon \rightarrow$$

$\sigma_y$  = yield strength (N/mm<sup>2</sup>)

$\sigma_u$  = Ultimate tensile strength (N/mm<sup>2</sup>)

(y)	(x)
P	$\Delta L$
0	0
i) 10kN	1mm
ii) 20kN	2mm
iii) 30kN	3mm
iv) 38kN	4mm

$$\text{slope} = \frac{dy}{dx} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$\frac{20-10}{2-1} = 10 \text{ kN/mm}$$

$$\frac{30-20}{3-2} = 10 \text{ kN/mm}$$

$$\frac{38-30}{4-3} = 8 \text{ kN/m}$$

ex. for graph

$$y = m \cdot x$$

$$\boxed{y \propto x}$$

⇒ Imp Points :-

i] Region OA

→ A is a proportional limit

→ Graph is linear (ie slope is constant)

→  $\sigma \propto E$  (Hook's law)

→  $\sigma = E \cdot \epsilon$ ,  $\frac{\sigma}{E} = \epsilon$

→  $E =$  Elastic constant / Modulus of Elasticity

$E = \tan \theta \rightarrow$  Slope of  $\sigma, \epsilon$  Curve

2] Region AB

→ B → Elastic limit

→ Linearity is lost

→ upto point B, strain produced can be recovered upon unloading of the specimen

→ Assume: Hook's law is valid upto elastic limit

3] Region B-C-C

→ C' = upper yield point { transient → short interval }

→ C = Lower yield point { stable, designates yield strength of material }

→ If is a point below which material behaves elastically

Above which material behaves plastically

4] C-D Region

→ Plastic yielding or yield Plateau

→ Material / specimen deforms to very large extent without resisting any stress

→ If is a limiting slope

→ Fielding Failure

### 5] Region D-E

- Strain Hardening
- Specimen re-crystallizes due to which it resists stresses along with its further extension
- It occurs upto point E
- E ⇒ Point of Ultimate strength
- Till Date this part is not used<sup>in</sup> design

### 6] E-F Region

⇒ ~~Necking~~ ⇒

- Necking: Reduction in cross sectional area
- F ⇒ Breaking point / Fracture point
- Fracture is also termed as Rupture
- Shape: Cup & Cone failure

### ⇒ Mechanical property from $\sigma$ & $\epsilon$ curve

1)  $\sigma_y$

3) E

2)  $\sigma_u$

4) Ductility

⇒ Ductility: Ability of material to undergo large deformation without breaking. It is measured in terms of % Elongation

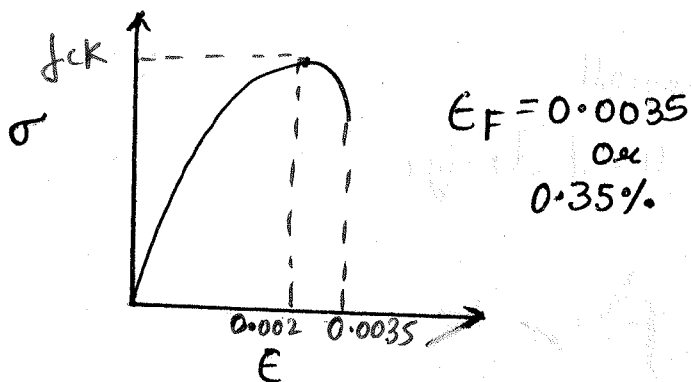
$$\% \text{ elongation} = \frac{\text{Final length} - \text{gauge length}}{\text{gauge length}} \times 100$$

% Elongation	Material
> 15%	Ductile (steel, Al)
15 - 5%	Interm. Ductile (mn)
< 5%	Brittle (concrete, cast iron)

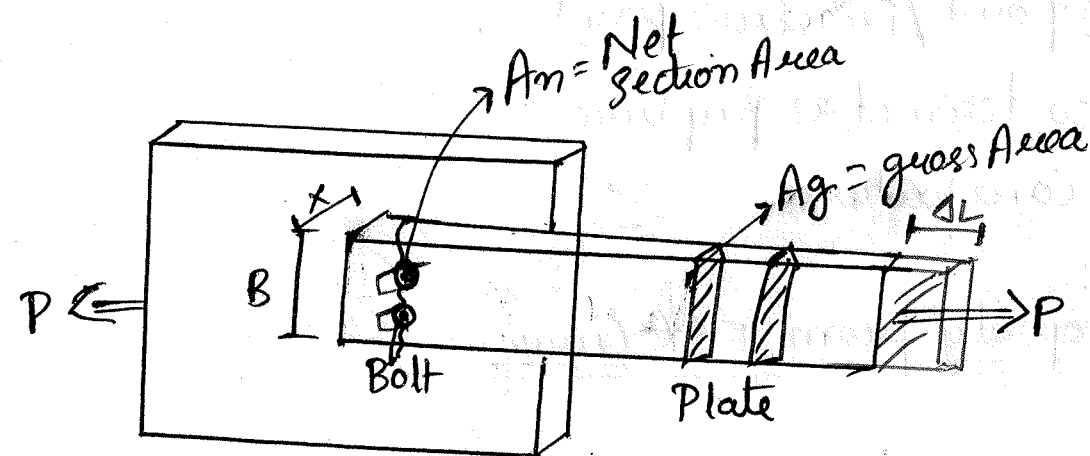
→ Hardness :- Resistance to Wear & Tear (ie Abrasion)

→ Toughness :- Resistance to impact loading

### Concrete Compression test

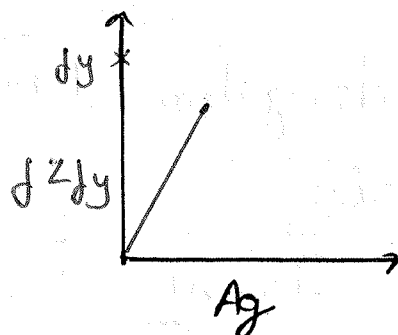
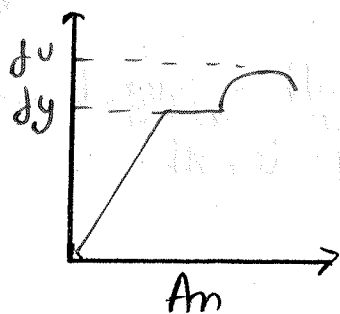


### ⇒ Practical Case of Tension member



There are two type of limiting stage

- 1) Gross section yielding
- 2) Net-section Rupture



Note:

→ For design of tension member connected with Rivet/Bolts there are two types of limit state

- 1) Gross section yielding
- 2) Net section Rupture





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# INTRODUCTION

Surveying -

It is the art of determining relative positions of points through direct or indirect measurements of distance, dirn and elevation. It also includes establishment of points on ground which are predetermined ~~in nature~~ on paper.

Types of Surveying -

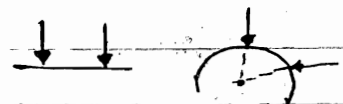
① Plane Survey.

Survey in which curvature of earth is not considered. Suitable for a small area.

② Geodatic Survey -

Survey in which curvature of earth is considered. Suitable for a large area.

Note ① - Two plumb lines at two different places will be parallel to each other in plane survey. However in geodatic survey they will intersect at centre of earth.



② - Generally geodatic survey considered for an area more than  $250 \text{ km}^2$

③ Observations -

(a) - For a line of length 12 km in plane survey geodatic length will be only one centimeter extra

(b) For a triangle with area  $195.5 \text{ km}^2$  sum of internal angle will be just one second extra in geodatic survey.

## Classification of Survey-

Ⓐ Land Survey - Survey on surface of earth

① Topographical Survey - To know about general topography of area.

② Cadastral Survey - To know about property lines

③ City Survey - To provide different services in city eg. Road network, water supply & sewer pipelines etc.

Ⓑ Hydrographic Survey - To know about underwater features =

Ⓒ Astronomical Survey - To know about positions of stars, planets moon, sun etc.

## Principle of Survey

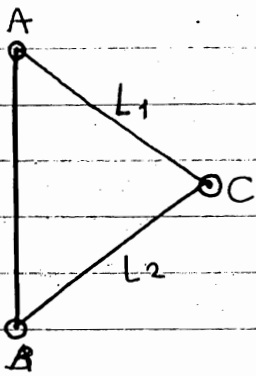
Principle ① - To do work from whole to part

(Refers to a common datum)

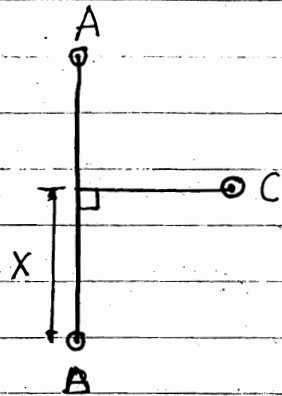
Larger measurements are taken by high degree of precision then smaller measurements are taken even with low degree precision. In this way errors of smaller measurement will not be reflected in larger measurements.

Principle ② - Location of point w.r.t. two reference points

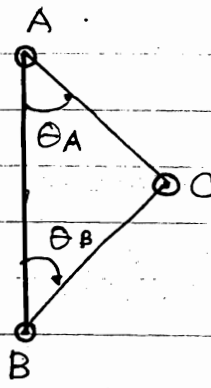
Any point can be established on the ground using two reference points.



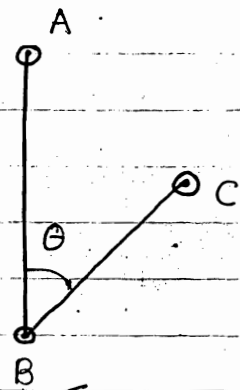
Chain Method



Offset Method



Compass method



Traversing Method

## ② Linear Measurement & Chain Surveying

Linear Measurement -

Linear measurement on horizontal plane is called distance & linear measurement on vertical plane is called elevation.

Scale -

It is a technique to measure & represent ground distance on the sheet of paper.

$$\text{Scale} = \frac{\text{Map Distance}}{\text{Ground Distance}}$$

Representation of scale

①  $1\text{cm} = 10\text{m}$

②  $\text{Scale} = \left(\frac{1\text{cm}}{10\text{m}}\right)$

③  $1\text{cm} : 10\text{m}$

Representative Factor (RF)

$$\text{RF} = \frac{1\text{cm}}{(10 \times 100)\text{cm}} = \frac{1}{1000}$$

$$\text{scale} = 1:1000$$

Area scale

$$(1\text{cm})^2 = (100\text{m})^2$$

$$1\text{cm}^2 = 100\text{m}^2$$

Vernier Scale -

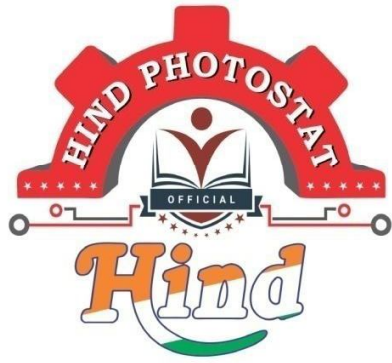
It is secondary unit of main scale used for exact reading. Through vernier scale we can measure the distance/angle which is even lesser than least count of main scale.

Types of Vernier -

Ⓐ Direct Vernier.

This vernier is calibrated in same dir<sup>n</sup> of main scale. This vernier has division slightly smaller than division on main scale.

→  $(n-1)$  division of main scale are distributed into  $n$  division of vernier scale.



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# Soil Mechanics and Foundation Engineering

## Syllabus

Gate → 15-18 MARKS

ESE → Pre → 16-21 Q  
Main → 100-110M

- \*\*\* 1. Properties of Soil. Obj + conv + int
- 2. Classification of Soil. Obj
- \*\* 3. Effective Stress. Obj + conv
- \*\*\* 4. Permeability & Seepage. Obj + conv + int
- 5. Stress Distribution. Obj
- 6. Compaction. Obj
- \*\*\* 7. Consolidation. Obj + conv + int
- \*\*\* 8. Shear Strength. Obj + conv + int
- \*\* 9. Earth Pressure. Obj + conv
- 10. Stability of Slope. Obj

## FOUNDATION ENGINEERING

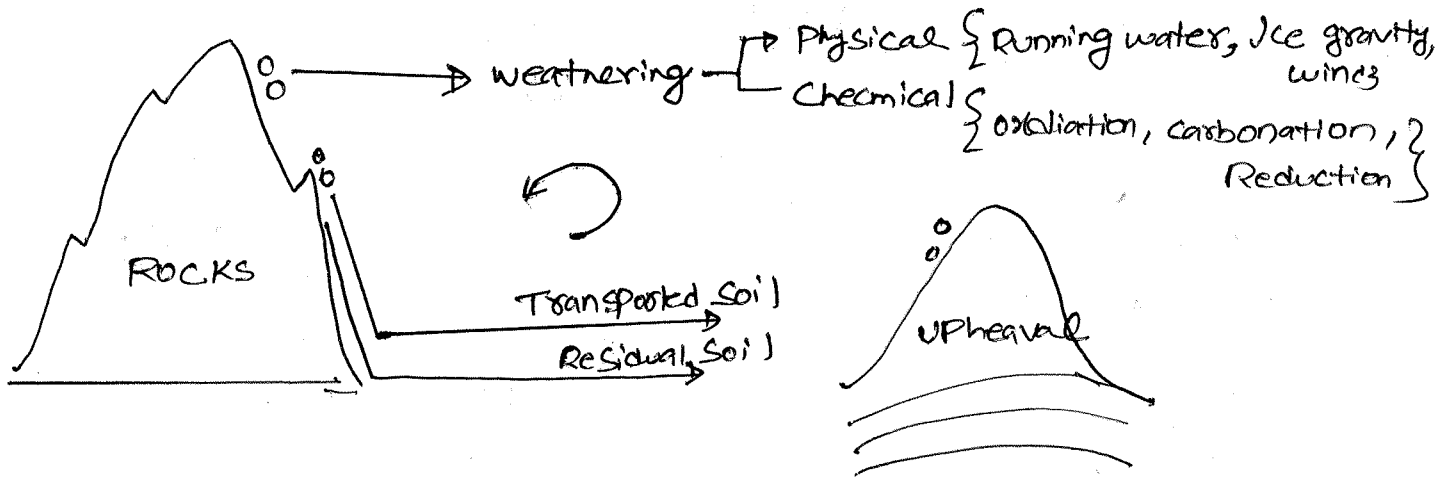
- \*\*\* 11. Shallow foundation. Obj + conv + int
- \*\* 12. Pile foundation. Obj + conv

## MISCELLANEOUS

- 13. Soil Exploration.

12/10/2021

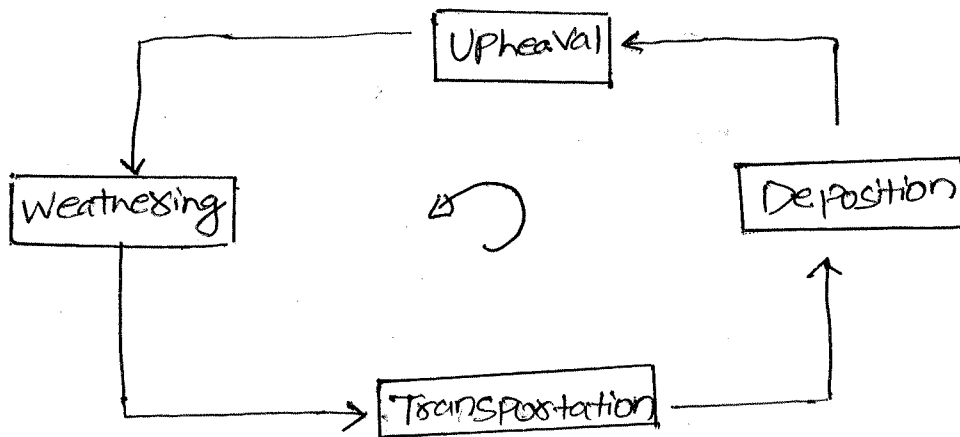
# 1. Properties of Soil



→ Soil is the disintegrated parts of rocks.

→ Pedogenesis ⇒ Process of formation of soil.

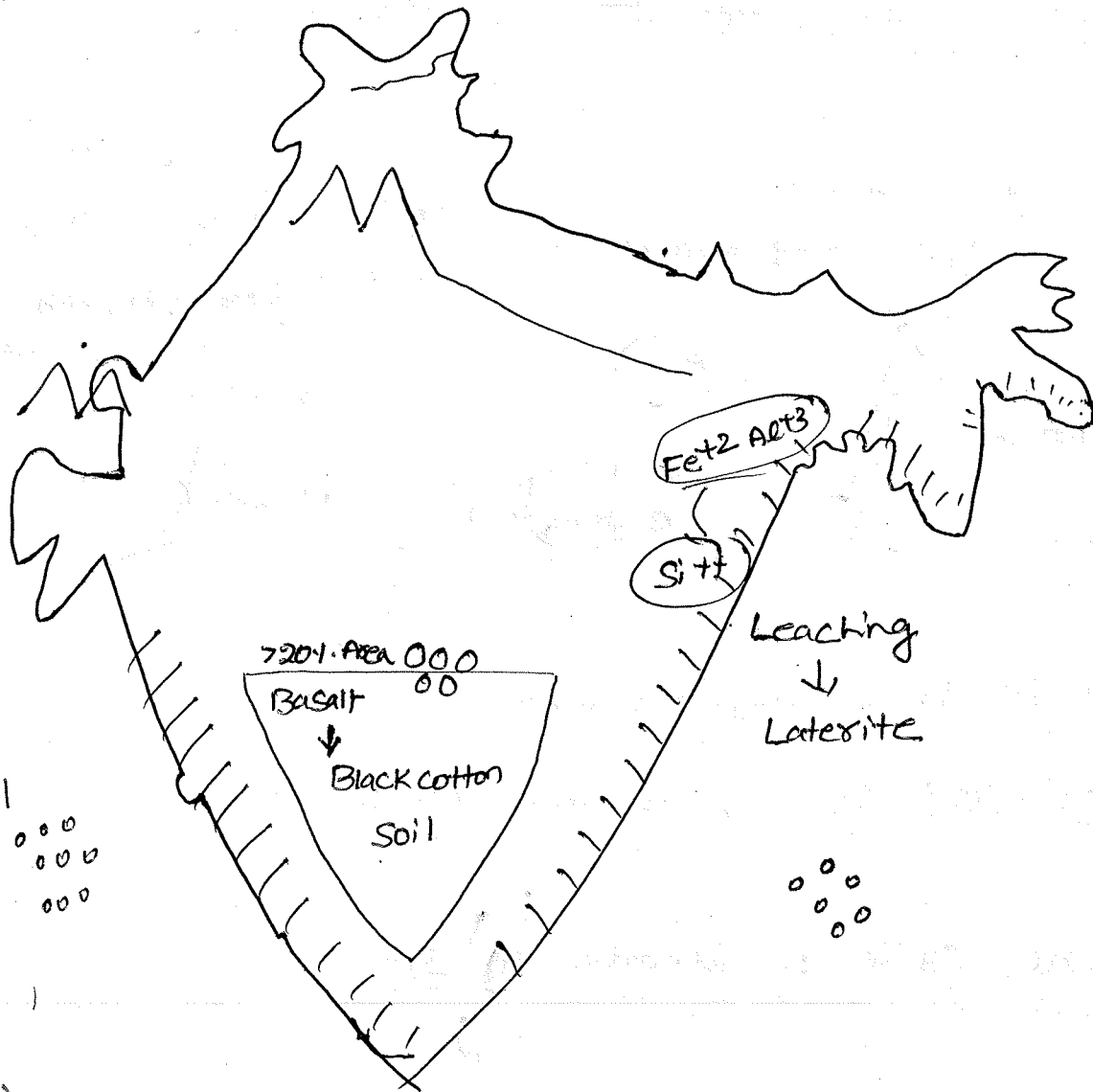
## Geological Cycle of formation of Soil



• Karl Terzaghi ⇒ father of Soil mechanics.



# Types of Soil



Transported

Type of Soil	Agents	Region
1. Alluvial Soil	Running water	Near River banks
2. Lacustrine	Fresh & Still water	Lakes & Ponds
3. Marine Soil	Sea water	Sea shores
4. Glacial (Till)	Ice	Glaciers
5. Colluvial (Talus)	Gravity	Mountain valleys
6. Aeolian (Sand dunes)	wind	Desert
7. Loess when it becomes whe wet it is collapse.	wind blown slit	Desert

# Chemical weathered Soils

## 1. Marl Soil

- It is fine grained Calcium Carbonated Soil of Marine origin.
- It is formed by Chemical decomposition of aquatic plants and animal bones

## 2. Black Cotton Soil

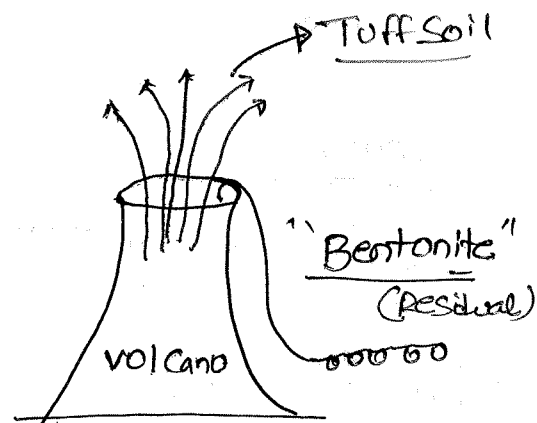
- It is residual soil formed from basalt by chemical weathering.
- It contains high amount of clay mineral "Montmorillonite"
- It shows high Compressibility, high plasticity, high Swelling and Shrinkage and low Shear strength.

## 3. Tuff Soil

- It is transported volcanic ashes
- Transported wind (or) water.

## 4. Bentonite Soil

- It is Chemically weathered volcanic ashes.
- Generally used as lubrication in drilling operation.
- It is Clay containing high amount of Montmorillonite hence it shows high Swelling and Shrinkage and low Shear strength



## 5. Laterite Soil

- Formed due to leaching (washing out of silicious compound and accumulation of iron oxide and aluminum oxide).
- Found in humid areas like Eastern ghat, western ghat and great north east.

## 6. Organic Soils

### (a) MUCK SOILS

- It is the mixture of organic matters and in-organic soil.

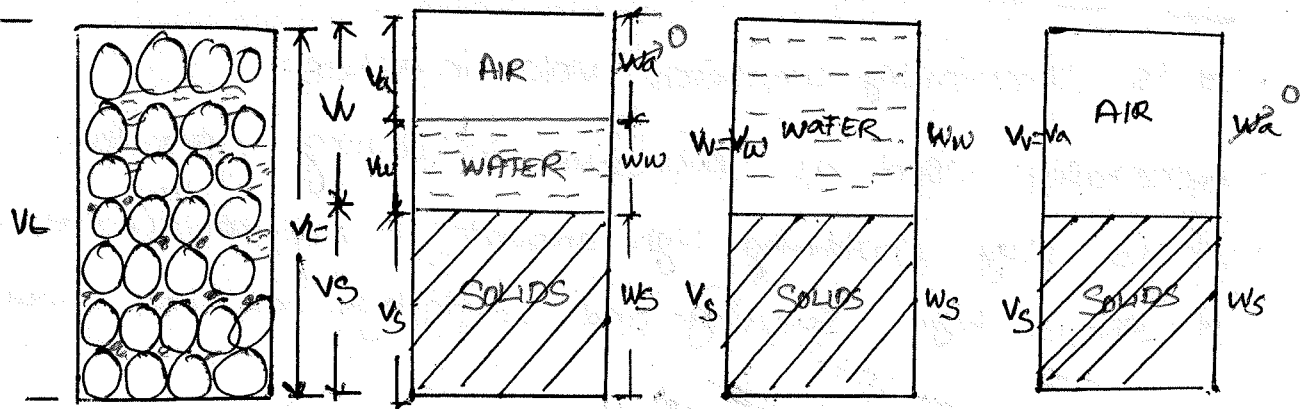
### (b) Peat Soils (Pt)

- In almost entirely consist of vegetative matters @ different stages of decomposition.
- It possess organic odour and black to dark brown colour.

## 7. Loam

- It is the mixture of sand, silt and clay.

## Phase Diagram



$V_S$  → volume of soil solids

$V_C$  → Total vol. of soil

3 phase diagram

Saturated stage

Dry Stage

2 phase diagram

# Important Definitions

## 1. Water content (w)

$$w = \frac{\text{wt. of water}}{\text{wt. of Solids}} \times 100$$
$$w = \frac{W_w}{W_s} \times 100 = \frac{M_w}{M_s} \times 100$$

Note 1: Range of w

$$w \geq 0\%$$

Note 2: Relation b/w w, W<sub>s</sub> & W<sub>total</sub>

$$w = \frac{W_w}{W_s} \quad \text{adding 1 both side}$$

$$1+w = 1 + \frac{W_w}{W_s}$$

$$1+w = \frac{W_s + W_w}{W_s} = \frac{W_{\text{total}}}{W_s}$$

$$W_s = \frac{W_{\text{total}}}{1+w}$$

Note 3: Water content can also represent total wt of soil mass

$$w' = \frac{\text{wt. of water}}{\text{Total wt of soil}} \times 100$$

$$w' = \frac{W_w}{W_t} \times 100 = \frac{M_w}{M_t} \times 100$$

$$\text{Range of } w' \Rightarrow 0 \leq w' \leq 100\%$$

$$w' \neq 100\% \text{ because}$$

$w' = 100\%$  then i.e.  $w_w = w_t$   
which is not possible in  
Soil mass

Relation b/w  $w$  &  $w'$

$$w' = \frac{w_w}{w_s} = \frac{w_w}{w_w + w_s} = \frac{w_w}{w_w \left(1 + \frac{w_s}{w_w}\right)} = \frac{1}{\frac{1}{w} + 1}$$

$$w' = \frac{w}{1+w}$$

$w$  in terms of  $w'$

$$w = \frac{w'}{1-w'}$$

- Total wt. of Soil mass changes with change in wt. of water hence significance of ' $w$ ' is more than ' $w'$ ' because Solids are still on quantity.

2) Void Ratio ( $e$ )

$$e = \frac{\text{Volume of voids}}{\text{Volume of solids}} = \frac{V_v}{V_s} \quad **$$

Note-1 Range of  $e$   $e > 0$

$$e \neq 0$$

- Generally represented as decimal fraction

(3) Porosity ( $n$ )

$$n = \frac{\text{Volume of voids}}{\text{Volume of Solids Total}} \times 100 = \frac{V_v}{V_t} \times 100 \quad **$$

Note-1 Range of  $n$   $0 < n < 100\%$

$$n \neq 0 \quad \& \quad n \neq 100\%$$

- $\therefore$  If  $n = 100\%$ , then  $V_v = V_t$  which is not possible in Soil mechanics mass.

Note-2:  $\rightarrow$  Though size of void is more in Coarse grain Soil but the total no. of voids is more in fine grain soil hence fine-grain soils are more porous it means void ratio and porosity is more.

Note 3:  $\rightarrow$  Relation in b/w  $v_s, v_e$  &  $e$

$$e = \frac{v_w}{v_s}$$

adding '1' on both sides

$$1+e = 1 + \frac{v_w}{v_s}$$

$$1+e = \frac{v_s + v_w}{v_s}$$

$$1+e = \frac{v_e}{v_s}$$

$$\boxed{v_s = \frac{v_e}{1+e}}$$

\*\*

Note 4:  $\rightarrow$  Relation in b/w  $e$  &  $n$

$$n = \frac{v_w}{v_e} = \frac{v_w}{v_s + v_w} = \frac{v_w}{v_w \left( \frac{v_s}{v_w} + 1 \right)} = \frac{1}{\frac{1}{e} + 1}$$

$$\boxed{n = \frac{e}{1+e}}$$

\*\*

$e$  in terms of  $n$

$$n = \frac{1}{\frac{1}{e} + 1} \Rightarrow \frac{1}{e} + 1 = \frac{1}{n}$$

$$\frac{1}{e} = \frac{1}{n} - 1$$

$$\boxed{e = \frac{n}{1-n}}$$

\*\*

#### 4. Degree of Saturation (S)

\*\*

$$S = \frac{\text{Volume of water}}{\text{Volume of voids}} \times 100$$
$$S = \frac{V_w}{V_v} \times 100$$

In dry condition  $\rightarrow S = 0 \rightarrow ac = 100\%$

In saturation condition  $\rightarrow S = 100\% \rightarrow ac = 0$

In partially saturated  $\rightarrow 0 < S < 100\% \rightarrow 0 < ac < 100\%$

#### 5. Air content (ac)

\*\*

$$ac = \frac{\text{Volume of air}}{\text{Volume of voids}} \times 100$$
$$ac = \frac{V_a}{V_v} \times 100$$

#### Relation in b/w S & ac

$$S = \frac{V_w}{V_v} = \frac{V_v - V_a}{V_v} = 1 - \left( \frac{V_a}{V_v} \right) \rightarrow ac$$

\*\*

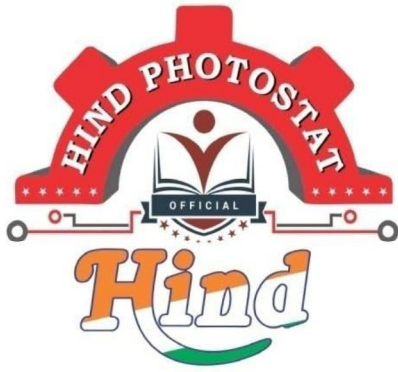
$$\therefore S + ac = 1$$

#### 6. Percentage of Air voids ( $n_a$ )

$$n_a = \frac{\text{Volume of air}}{\text{Total volume}} \times 100$$
$$n_a = \frac{V_a}{V_t} \times 100$$

$$0 \leq n_a < 100\%$$

$$n_a \neq 100\%$$



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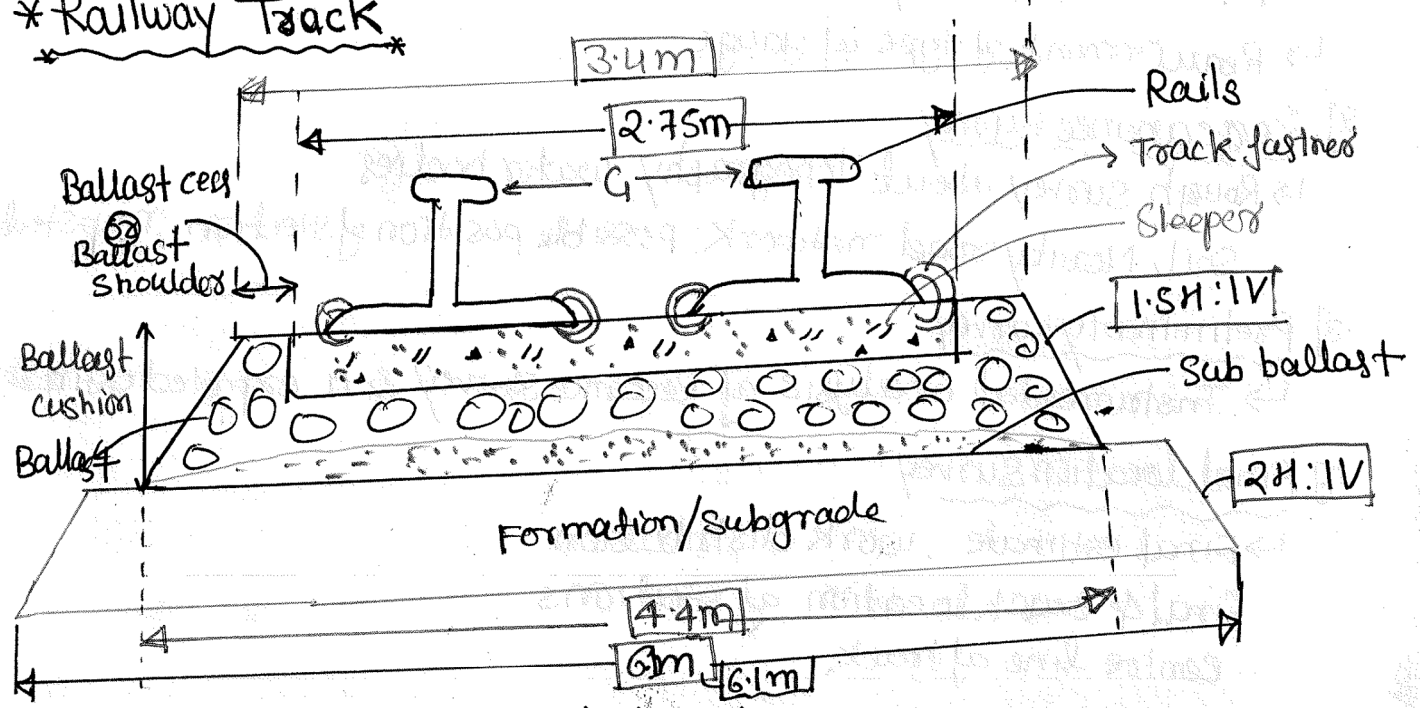
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↳ Railway is very huge, rapid and reliable transportation system all over the world.

\* Railway Track



Rails ⇒ Allows movement of train

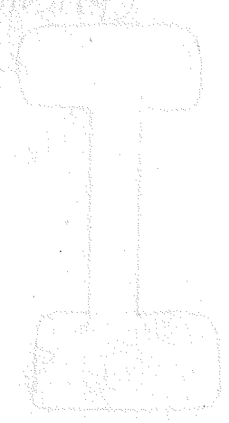
Sleepers ⇒ hold rail in position & take load from rails

Ballast ⇒ hold sleepers & rail in position & distribute load coming from sleepers.

Track fasteners ⇒ Attach rail & sleepers together

Formation/subgrade ⇒ working as a formation of track.

Sub ballast ⇒ made from murrum soil (Fine grained soil)  
↳ less permeable soil      ↳ decomposition of laterite



# # Survey Required Before Railway track construction \*

## 1] Traffic Survey

- ↳ Numbers & type of train
- ↳ population & Industry to be served
- ↳ Requirement of type of gauge

## 2] Reconnaissance Survey

- ↳ Rough survey about topography, water bodies, soil, nearby road network, possible position of station, map study

## 3] Preliminary survey

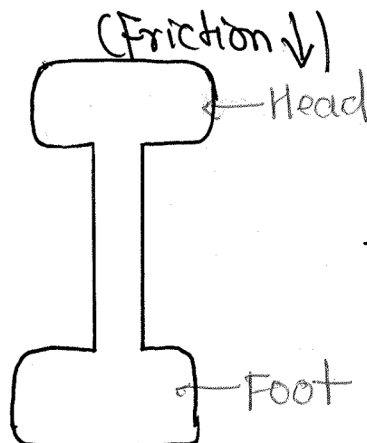
- ↳ Instrumental analysis of Reconnaissance survey & a expected estimate

## 4] Final location survey

- ↳ Final estimate, work distribution
- Final & exact location of stations
- centre line of track

## ★ Chapter 1 ★ Rails ★

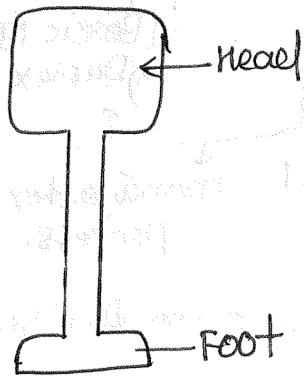
- Strong, smooth, Frictionless
- parallel, levelled, & continuous
- It is a continuous girder as it allows movement of train i.e. moving load.
- ∴ Contact Area of wheel is very less with compare to perimeter, so moving load considered as point load



- equal thickness of Head & Foot
- Purpose to use from both side but found lot of wear & Indentation mark at bottom due to movement of train.

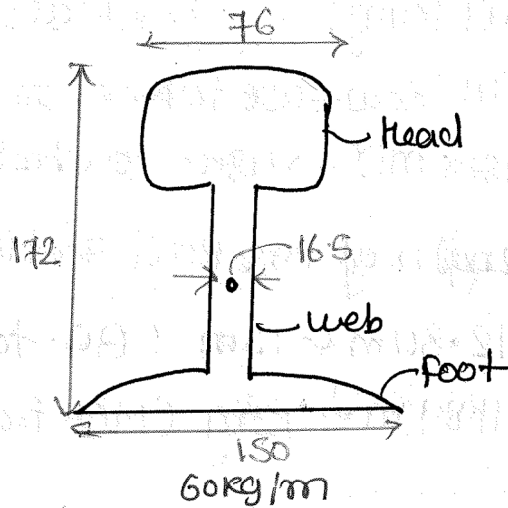
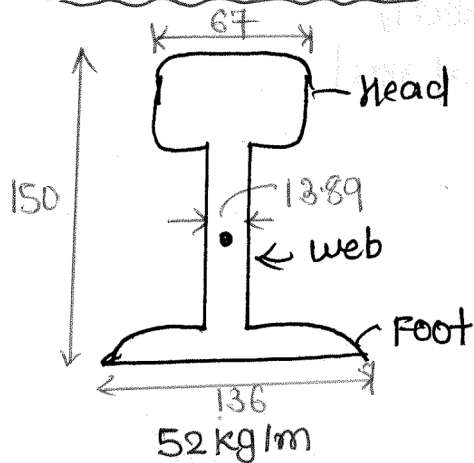
## 1] Double Headed

## 2] Bull headed Rail



→ Top head thickness increased

## 3] Flat Footed Rail



→ Carbon > Magnese > Silica > Phosphorous > Sulphur.

→ Equal distributed of material

→ CG must be in centre to reduce chances of development of bending stress

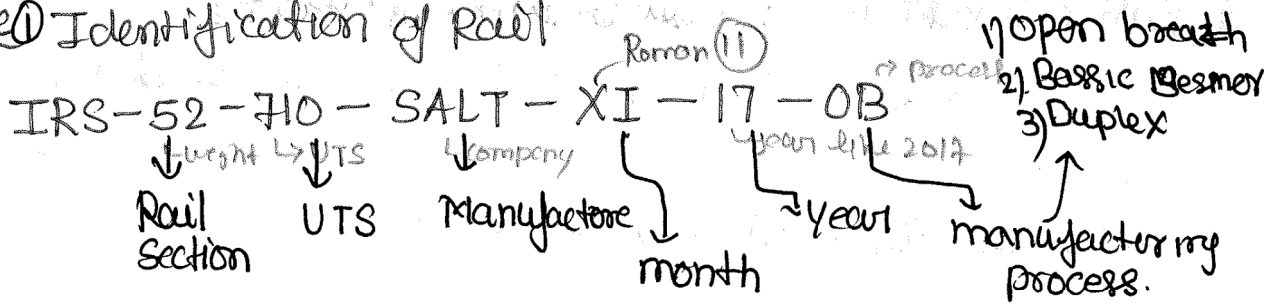
→ head ⇒ should be enough thick to provide vertical stiffness

→ web ⇒ should be enough thick to provide flexural Rigidity in horizontal plane

→ foot → should be flat, to resist overturn & start distribution of load.

	Speed	UTS (Mpa)	A (mm <sup>2</sup> )	GMT (Gross million Tonn Per year per km)
52 kg/m	130 kmph	710	6615	20-25
60 kg/m	160 kmph	880	7686	35

Note 1 Identification of Rail



Note 2 Falling weight test & Top test to be done on Rail section.

Note 3 Rail tongs - to hold rail

Jim (row - use to bend or break Rail)

Vises mid → used to check level of rail

Note 4 Length of one Rail section

= 12.80 m ≈ 13m (BG-track)

= 11.89 m ≈ 12m (MG-track)

Important

# Defects in Rail

1] Corrugation in Rail / Roaring Rails

{Rail pe dhul nikali sunnat}

↳ Minute depression over top of rail surface (spreading in nature)

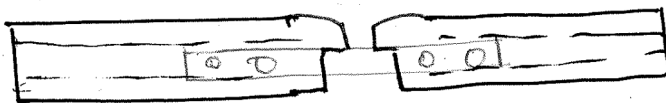
↳ when train moves through it makes roaring sound (Train becomes dhool)

↳ it can also occur due to accumulation of dust over rail surface

↳ generally cause behind depression is break application, acceleration etc.

2] Hoggin In Rail (⊕)

↳ due to loose fish plate & bolt



③ Kinking in Rail (Ye bolt loose hone ke wajah se)

↳ placing of ballast becomes loose along with fish plate and Fish bolt.

↳ Rails misalignment (out of track)



\* 4] Buckling of Rail (Ye bolt tight hone ke wajah se)

→ Due to tight bolts & close packing of rails, if further temperature increase rail buckles in lateral direction

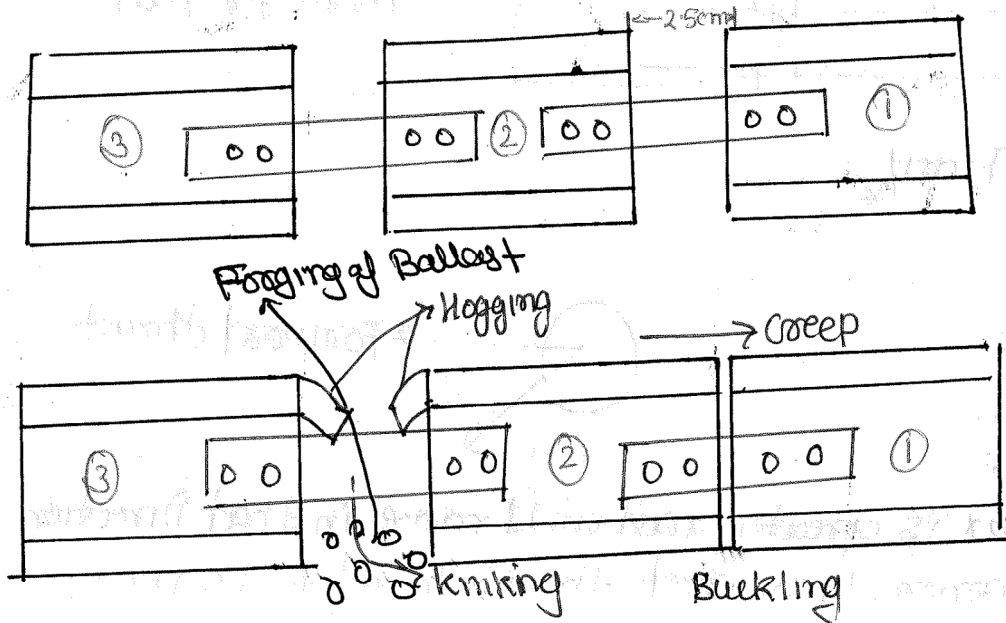
→ Misalignment → widening of gauge.

→ downward deflection will not occur due to continuous support.



\* VI Imp

\* 5] Creep in Rail (घाटा)



⇒ The movement of rail w.r.t sleepers in the direction of traffic known as creep of track

⇒  $\geq 150\text{mm}$  or 6 continuous rail should not be subjected to creep.

⇒ At least within 3 months

⇒ Creep indicators.

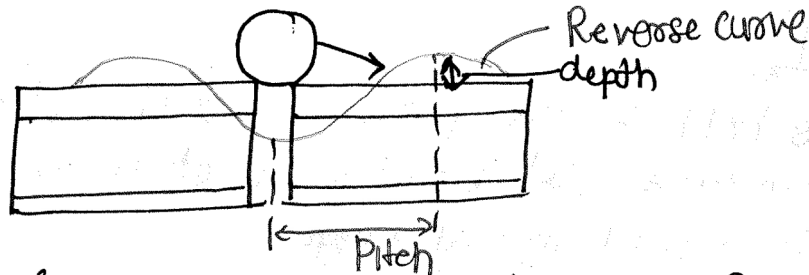
⇒ If joint is close from one side & open from other side  
Signifies Creep

⇒ Closing of joint ⇒ Buckling

Opening of joint ⇒ Hogging, Kinking, Loosening of Ballast.

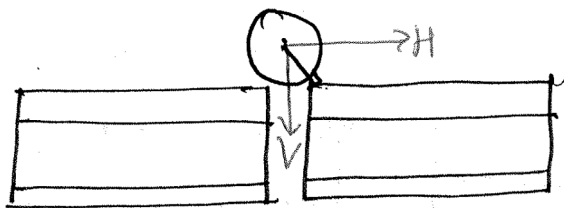
↳ coming out of ballast due to loosening of packing

### ① Wave Theory



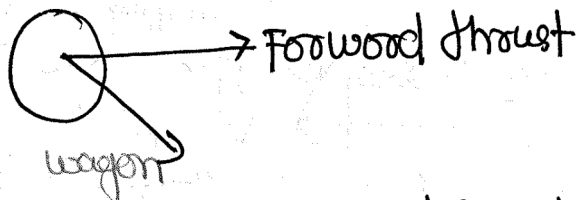
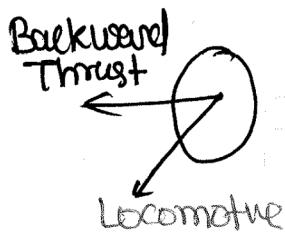
↳ Pitch & depth of wave depend on strength, stability & track modulus.

### ② Percussion Theory



Horizontal component of Impact force will move the rail.

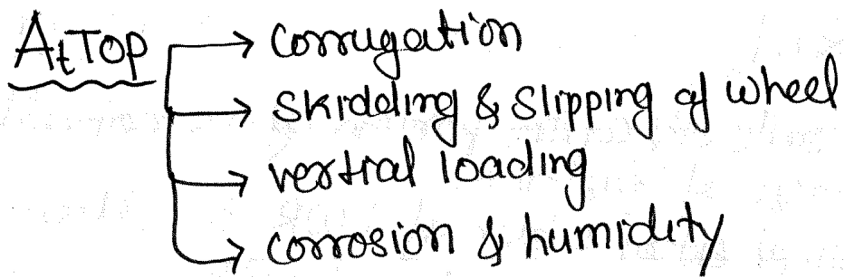
### ③ Drag Theory\*



→ whichever is greater, rail will move in that direction  
(generally forward thrust found to be more)

## 6] wear in Rail

- ↳ Due to abnormal loading, high speed of train when stress on the rails becomes more than the yield stress metal will flow known as wear of the rails
- ↳ It can occur



At Side ⇒ Due to shrinkage of wheel flange

At Ends ⇒ Due to creep, hogging, kinking etc

Total wear > 5%
Top wear > 25%

## # Rail Joint

- ↳ Rail joints are supposed to be weakest portion in a railway track
- ↳ Ideally Rail joint should be elastic
- ↳ As the number of joint increases the chances of creep, hogging, kinking and also increases lots of cost because of the number of fish plates and bolts
- ↳ So to make it economic and more stronger welding of rail is done.
- ↳ welding provides such a restraint at the ends of rail so that fastness can do the work properly (Resisting the buckling)
- ↳ Success of welded rail depends upon strength of fastness
- ↳ welding of rail reduces no. of joint, chances of failure, make it economical also reduces the maintenance



## \* Type of welded Rail \*

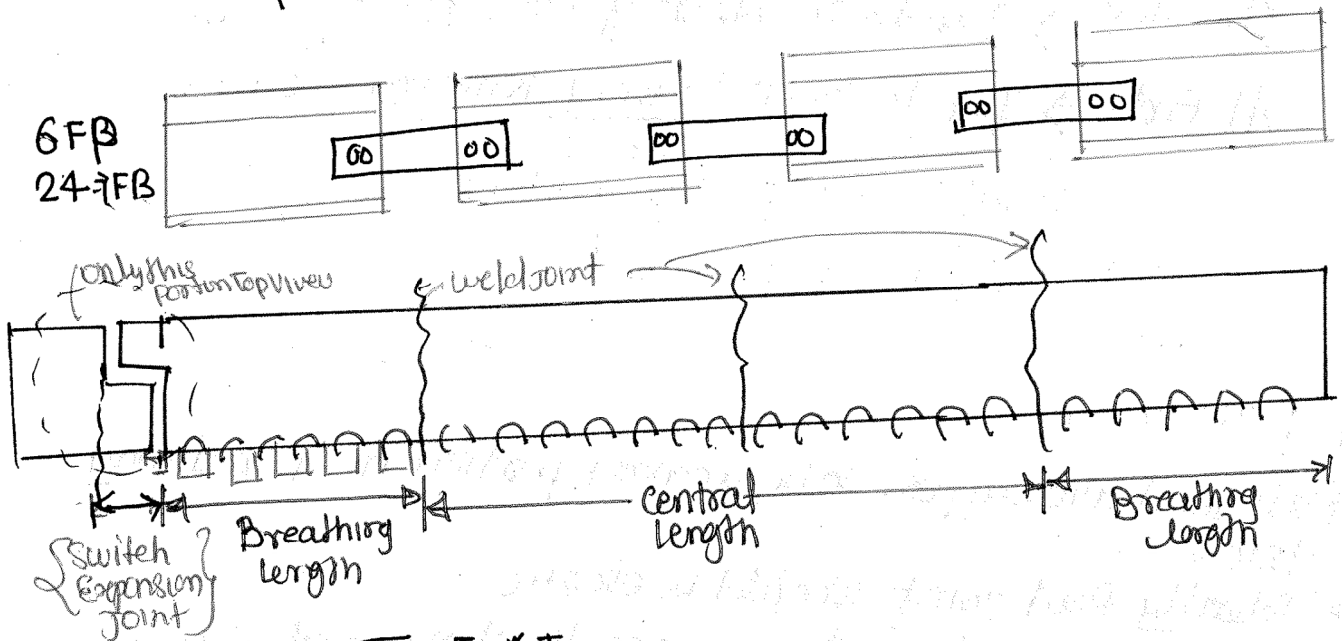
① Short welded Rail  $\Rightarrow$  3, 5 or upto 10 rail \*

$\hookrightarrow$  As a entire length of short welded rail is subjected to temperature. So not suggested that.

② Long welded Rail (LWR)  $\Rightarrow$  200-300m upto 1000m \*

$\hookrightarrow$  In long welded rails the centre portion of - is not allow to expand because of fasteners.

$\hookrightarrow$  The end length of either side of LWR is allow to expand is known as breathing length.



$$\sigma = E \alpha T$$

$\therefore F = A E \alpha T$  (Force to be resisted due to Temperature Increment)

$R =$  Resisting capacity of sleepers

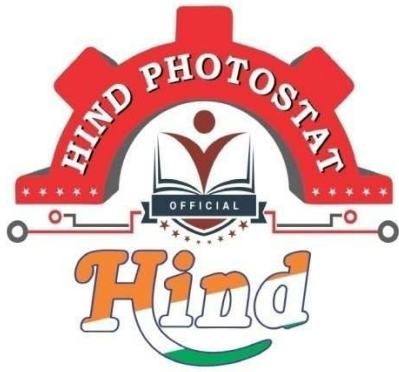
$$\text{No. of sleepers} = (n) = \frac{F}{R}$$

$$\text{Breathing length } (L) = (n-1)S$$

③ Continuous welded Rail (CWR)  $S \Rightarrow$  spacing between sleepers.

- welding  $> 1$  km (Station to Station)

$\rightarrow$  Not suggestable.



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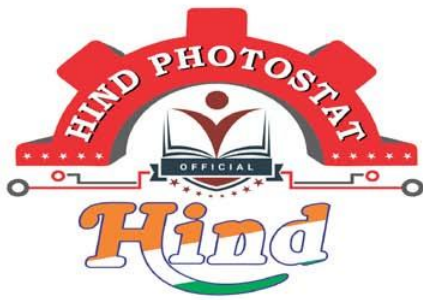
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# ENGINEERING MATHS.

## \* SYLLABUS:- \*

1. MATRICES.
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4. VECTOR CALCULUS.
- 5.

\*\* GATE : 13 - 14 Marks \*\*

\*\* ESE (pre) : Minimum 20 Marks \*\*

\*\* [ 2018 - 24 ] \*\*  
[ 2021 - 38 ]



# CH. MATRICES.

$$A = [a_{ij}]_{m \times n}$$

$$1 \leq i \leq m$$

$$1 \leq j \leq n$$

$$= \begin{bmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & a_{m3} & \dots & a_{mn} \end{bmatrix}_{m \times n}$$

upper diag. elements

lower diagonal elements

(1) Square Matrix:

No. of rows = No. of column.

"If in a Matrix, Diagonal exist, it must be Square Matrix.

(2) Determinant is defined only for square Matrix.

(3) Corresponding elements

$$a_{12} \leftrightarrow a_{21}$$

$$a_{31} \leftrightarrow a_{13}$$

(4)

$ A  = 112$ $\begin{bmatrix} 2 & -3 & 1 & 0 \\ 0 & 4 & 0 & 1 \\ 0 & 0 & 7 & 5 \\ 0 & 0 & 0 & 2 \end{bmatrix}_{4 \times 4}$ UTM	$ A  = 0$ $\begin{bmatrix} 2 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 1 & 5 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}_{4 \times 4}$ LTM	$\begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & 7 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}_{4 \times 4}$ Diagonal Matrix	$\begin{bmatrix} 5 & 0 & 0 & 0 \\ 0 & 5 & 0 & 0 \\ 0 & 0 & 5 & 0 \\ 0 & 0 & 0 & 5 \end{bmatrix}_{4 \times 4}$ Scalar Matrix.
--	--	---	---

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Identity.

Note:

(1) In order to find the Determinant of U.T.M, L.T.M, Diag. Matrix, Scalar Matrix, identity Matrix

"Just Multiply the diagonal elements".

(Note) (2): Find  $|A|$  for  $A = \begin{bmatrix} 0 & -1 & -2 & -3 \\ 1 & 0 & -4 & -5 \\ 2 & 4 & 0 & -2 \\ 3 & 5 & 2 & 0 \end{bmatrix}_{4 \times 4}$ .

Since  $A$  is not a U.T.M, L.T.M, diagonal Matrix, Scalar Matrix.

So, We can not use the concept discussed in above Point. (note 1)

We Will solve it by using Conventional Approach.

Using  $R_3 \rightarrow R_3 - 2R_2$  &  $R_4 \rightarrow R_4 - 3R_2$

$$A = \begin{bmatrix} 0 & -1 & -2 & -3 \\ 1 & 0 & -4 & -5 \\ 0 & 4 & 8 & 8 \\ 0 & 5 & 14 & 15 \end{bmatrix}$$

↑

Expand about Column 1

$$|A| = +0 \begin{vmatrix} 0 & -4 & -5 \\ 4 & 8 & 8 \\ 5 & 14 & 15 \end{vmatrix} - 1 \begin{vmatrix} -1 & -2 & -3 \\ 4 & 8 & 8 \\ 5 & 14 & 15 \end{vmatrix} + 0 \begin{vmatrix} ? \\ ? \\ ? \end{vmatrix} + 0 \begin{vmatrix} ? \\ ? \\ ? \end{vmatrix}$$

$$= -1 \left[ -1(120 - 112) - 4(-30 + 42) + 5(-16 + 24) \right]$$

$$= 16$$

Ex: Evaluate determinant of  $\begin{vmatrix} 2 & 1 & 1 & 1 \\ 1 & 2 & 1 & 1 \\ 1 & 1 & 2 & 1 \\ 1 & 1 & 1 & 2 \end{vmatrix}$

$$R_1 \rightarrow R_1 - 2R_2 \quad R_3 \rightarrow R_3 - R_2 \quad R_4 \rightarrow R_4 - R_2$$

$$A = \begin{vmatrix} 0 & -3 & -1 & -1 \\ 1 & 2 & 1 & 1 \\ 0 & -1 & 1 & 0 \\ 0 & -1 & 0 & 1 \end{vmatrix}$$

Now, expanding about Column 1

$$-1 \begin{vmatrix} -3 & -1 & -1 \\ -1 & 1 & 0 \\ -1 & 0 & 1 \end{vmatrix} = 0$$

Now, expanding along  $R_1$ .

$$= \cancel{0} -1 \left[ -3(1) + 1(-1) - 1(1) \right]$$

$$= -1 \left[ -3 - 1 - 1 \right]$$

$$|A| = 5$$

Note: Elementary oper



## Elementary Operations:

There are 3 types of elementary operations:

$$\left. \begin{array}{l} R_i \leftrightarrow R_j \\ R_i \rightarrow k R_i \end{array} \right\} \text{ Don't apply 1}^{\text{st}} \text{ two operations} \\ \text{While calculating Det. of Matrices}$$

$$R_i \rightarrow R_i + k R_j \Rightarrow \text{"only 3}^{\text{rd}} \text{ operation does not} \\ \text{alter the Determinant Value."}$$

### Note:

~~\*\*~~ (1) If  $A$  and  $B$  are two Matrices such that

$$AB = BA = I \quad \text{then} \begin{cases} A^{-1} = B \\ B^{-1} = A \end{cases} \quad \text{i.e. Both} \\ \text{are inverse} \\ \text{of each other.}$$

$$AA^{-1} = I$$

$$(2) \quad A^{-1} \neq \frac{1}{A}, \quad A^{-1} = \frac{\text{adj } A}{|A|} = \frac{(\text{cof } A)^T}{|A|}$$

~~(1)~~ Ex: If  $M$  is such that  $M \neq I$ ,  $M^2 = I$ ,  $M^3 \neq I$   
but  $M^4 = I$  then  $M^{-1} = ?$

$$(a) M^{4k+1} \quad (b) M^{4k+2} \quad (c) M^{4k+3} \quad (d) M^{4k}$$

$$k \in \mathbb{N}.$$

$$M^4 = I$$

$$M \cdot M^3 = I$$

On comparing with  $(M \cdot M^{-1}) = I$ .

$$\Rightarrow M^{-1} = M^3.$$

$$\Rightarrow M^8 = M^4 \cdot M^4 = I \cdot I \\ = I^2 = I$$

$$M^{12} = M^4 \cdot M^8 = I \cdot I \\ = I$$

$$M^{4k} = I$$

$$(a) M^{4k+1} = M^{4k} \cdot M = M$$

$$(b) M^{4k+2} = M^{4k} \cdot M^2 = M^2$$

$$(c) M^{4k+3} = M^3 \quad (\checkmark)$$

$$(d) M^{4k} = I$$

Note: (1)  $AA^{-1} = A^{-1}A = I$

→ Singular Matrix : if  $|A| = 0$

→ Non-Singular Matrix : if  $|A| \neq 0$

→ Invertible Matrix = if  $A^{-1}$  exist.

Necessary Matrix : "Matrix should be non-singular"  
 $|A| \neq 0$ .

$$\therefore A^{-1} = \frac{\text{adj}}{|A|}, \quad |A| \neq 0, \quad A^{-1} \text{ exist.}$$

## ⇒ % Shortcut Method for finding Inverse of 2x2 Matrix

Very Important

$$\text{if } A = \begin{bmatrix} a & b \\ c & d \end{bmatrix} = \text{then } A^{-1} = \frac{1}{|A|} \begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$$

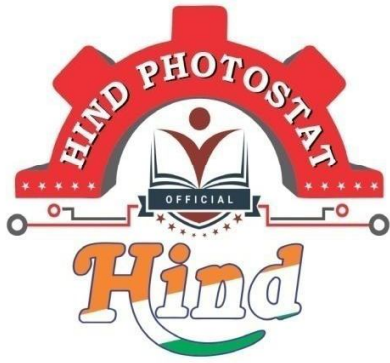
eg: if  $A = \begin{bmatrix} (3+2i) & -i \\ i & (3-2i) \end{bmatrix}$  then  $A^{-1} = ?$

$$\begin{aligned} i &= \sqrt{-1} \\ i^2 &= -1 \\ i^3 &= -i \\ i^4 &= 1 \end{aligned}$$

$$\begin{aligned} |A| &= (3+2i)(3-2i) - (i)(-i) \\ &= 9 - 4i^2 + i^2 \\ &= 9 - 3i^2 = 9 - 3(-1) \\ |A| &= 12. \end{aligned}$$

i.e.  $|A| \neq 0 \Rightarrow A^{-1}$  exist.

$$A^{-1} = \frac{1}{12} \begin{bmatrix} 3-2i & +i \\ -i & 3+2i \end{bmatrix}$$



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# Reasoning + Aptitude

27/08/2019

Ashutosh. Sharma

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Gate = 10-13 Marks

ESE = 22 means 10%

# chapt 1. Number System.

Factors :-

Factors are the set of ~~set~~ numbers which will divide a given number completely.

$$N = a^p \times b^q \times c^r$$

$$TF = (p+1)(q+1)(r+1)$$

Where,  $a, b, c$  are distinct Prime Numbers  
 $p, q, r$  are natural Numbers.

$$\textcircled{1} N=72 = 2^3 \times 3^2 = 4 \times 3 = 12f$$

1, 2, 3, 4, 6, 8, 9, 12, 18, 24, 36, 72

$$\textcircled{2} N=120 = 2 \times 3 \times 5 = 4 \times 2 \times 2 = 16f$$

1, 2, 3, 4, 5, 6, 8, 10, 12, 15, 20, 24, 30, 40, 60, 120

$$N = 9000 = 2^3 \times 3^2 \times 5^3$$

$$TF = \cancel{4} (p+1) (q+1) (r+1) = 4 \times 3 \times 4 = 48$$

Odd factor = 2 को हटाओ और बाकी वालों का T.F निकालो.  
 $(q+1)(r+1) = 3 \times 4 = 12 = \text{odd factor.}$

$$\text{Even factor} = 48 - 12 = 36 \text{ factors.}$$

## ≠ Prime and Composite factors.

Prime has only two factors.

$$\text{e.g. } 7 = 7, 1$$

$$5 = 5, 1$$

\* Composite has more than two factors.

$$\text{e.g. } 4 = 1, 2, 4$$

$$6 = 1, 2, 3, 6$$

## \* Prime & compo. factors.

$$\text{e.g. } 9000 = 2^{\textcircled{3}} \times 3^{\textcircled{2}} \times 5^{\textcircled{3}}$$

$$= \text{Total factors} = 48$$

= Don't go for higher power of No. ह्यांता का कुल टाका.

$$= \text{Prime factors are} = 2, 3, 5 \quad (3)$$

$$= \text{Neither prime nor composite} = 1 \quad (1)$$

$$= \text{Composite factors} = TF - (P.F + N.P.N.C)$$

$$= 48 - (3 + 1)$$

$$\text{composite factors} = \textcircled{44}$$

e.g.  $72 = 2^3 \times 3^2$

# Total factors =  $4 \times 3 = 12 = T_f + c_f + 1$

# Prime factors =  $2, 3 = (2)$

For prime remove higher power of factors

# Not composite nor prime =  $1 = (1)$

# Composite factors = Total factors - (P.F + N.P.N.C)  
 $= 12 - (2+1)$   
 $= \underline{\underline{9}}$

\* Formula :-

Total factor = Prime factor + Compo. factor  
 $+ 1$

# NOT IMPORTANT

$N = a^p \times b^q \times \dots$

Sum of all factors =  $\frac{(a^{p+1} - 1)}{(a-1)} \times \frac{(b^{q+1} - 1)}{(b-1)}$

Eg

$N = 72 = 2^3 \times 3^2$

Sum of all factors =  $\frac{(2^{3+1} - 1)}{(2-1)} \times \frac{(3^{2+1} - 1)}{(3-1)}$

$= \frac{15}{1} \times \frac{26}{2}$

$= 15 \times 13$

Sum of all factors = 195



$$N = a^p \times b^q$$

Product of all factors  $\rightarrow (N)^{\frac{TF}{2}}$

$$= \cancel{(72)}$$

e.g. = 72

$$N = 72 = 2^3 \times 3^2$$

$$TF = 4 \times 3 = 12$$

~~Product of~~

Product of all factors = ~~(72)~~  $(72)^{\frac{12}{2}}$   
 $= (72)^6$

NOT IMPORTANT

for Gate.

e.g. = 36

$$= 2^3 \times 3^2$$

$$= 3 \times 3$$

$$TF = 9$$

Product of all factors = ~~(36)~~  $(36)^{\frac{TF}{2}}$

$$= (36)^{9/2}$$

$$= (36)^{4.5}$$

## # Base System

$$(25)_{10} \equiv (\downarrow \overset{2^4}{1}, \downarrow \overset{2^3}{1}, \overset{2^2}{0}, \overset{2^1}{0}, \overset{2^0}{1})$$

2	25	Reminder
2	12	1
2	6	0
2	3	0
	2	1
	1	

$$= 8 \quad 16 + 8 + 1$$

$$= 25$$

Q. IF  $137 + 276 = 435$  how much  $731 + 672$  ?  
 (a) 534 (b) 1403 (c) 1623 (d) 3162.

$$\begin{array}{r} \Rightarrow 1 \ 3 \ 7 \\ + \ 2 \ 7 \ 6 \\ \hline 4 \ 3 \ 5 \end{array}$$

Here base = 8

$$\begin{array}{r} 7 \ 3 \ 1 \\ + \ 6 \ 7 \ 2 \\ \hline 1 \ 6 \ 2 \ 3 \end{array} \quad b=8$$

Q. IF  $137 + 276 = 435$  how much  $731 + 672$  ?

$$\begin{array}{r} 1 \ 3 \ 7 \\ + \ 2 \ 7 \ 6 \\ \hline 4 \ 3 \ 5 \end{array} \quad \text{base}=8$$

$$\begin{array}{r} \overset{8}{\curvearrowright} \overset{8}{\curvearrowright} \\ \cancel{7} \ 6 \ \cancel{3} \ 2 \ 1 \\ (-) \ 6 \ 7 \ 2 \\ \hline 0 \ 3 \ 7 \end{array}$$

Q.

$$\left( \begin{array}{r} 2 \ 2 \ 4 \ 6 \\ (+) \ 4 \ 4 \ 2 \ 2 \\ \hline 1 \ 0 \ 0 \ 0 \ 1 \end{array} \right)$$

$$\left( \begin{array}{r} \overset{7}{\curvearrowright} \overset{7}{\curvearrowright} \overset{7}{\curvearrowright} \\ 2 \ 1 \ \cancel{3} \ 2 \ 4 \ 3 \ 2 \\ (-) \ 1 \ 6 \ 5 \ 6 \\ \hline 0 \ 3 \ 5 \ 3 \end{array} \right)$$

$$6+2 = b+1 = \underline{\text{base}=7}$$

Q. Consider the equation  $(7526)_8 - (Y)_8 = (4364)_8$ ,  
 where  $(x)_N$  stands for  $x$  to the base  $N$ . Find  $Y$ .

(a) 1634 (b) 1737 (c) 3142 (d) 3162.

~~7526~~

$$a - Y = b$$

$$Y = (a - b)$$

$$\begin{array}{r}
 \cancel{72} \quad \quad \quad \overset{\curvearrowright}{754} \overset{\curvearrowright}{26} \\
 - \quad \quad \quad 4364 \\
 \hline
 \text{ANS } \checkmark \quad 3142 \quad \text{base}=8
 \end{array}$$

# Cyclicity :- 4 Cycle  $\rightarrow$

N	Reminder	Formula	NO.	NO.	NO.
<u>2</u>	1	$4n+1$	3	<del>7</del>	8
<u>4</u>	$\xrightarrow{\text{Rem } 2}$	$4n+2$	$\frac{9}{u=}$	9	4
<u>8</u>	$\xleftarrow{\text{Rem } 3}$	$4n+3$	7	<del>3</del>	2
<u>6</u>	4	$4n+4$	1	1	6

e.g.  $\frac{2(27)}{4}$  remainder = 3  
 $(732) = u = ?$   
 $u = 8$

e.g.  $\frac{2(22)}{4}$  remainder = 2  
 $(453) = u = ?$   
 $u = 9$

2. Cyclic  $\rightarrow$

★ N N  
 odd 4 odd=9  $\Rightarrow (79) \begin{matrix} g_1 = \text{odd} \\ \end{matrix} = \text{Ans} = 9$   
 even 6 even=1  $\Rightarrow (79) \begin{matrix} g_2 = \text{even} \\ \end{matrix} = \text{Ans} = 1$

# No. that NOT follows Cyclicity

[0, 1, 5, 6]

Q. The numeral in the units position of  $211^{870} + 146^{127} * 3424$  is

L →  $211^{870} + 146^{127} * 3424$  remainder = 1.  
 $= 1 + 6 * 1$

Ans = 7

Q. The last digit of  $(2171)^7 + (2172)^9 + (2173)^{11} + (2174)^{13}$  is

$\frac{7}{4} + 2 + 7 + 4$

L → Ans = 4

# # Factorial

It is product of natural numbers.

$$1! = 1 \times 2 \times 3 \times 4$$

$$2! = 1 \times 2 \times 3 \times 4 \times 5 = 120$$

$$3! = 6 \times 5! = 720$$

$$4! = 7 \times 5! = 5040$$

$$D = 1! + 2! + 3! + 4! + 5! + \dots + 99! = 4 = ?$$

↓   ↓   ↓   ↓   ↓   ↓   ↓   ↓   ↓

$$1 + 2 + 6 + 24 + 0 + 0 + 0 + \dots + 0$$

$$= 33 + 0 + 0 + 0$$

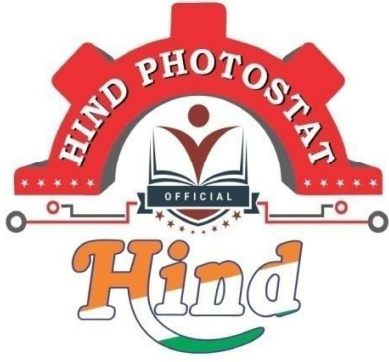
so unit place is 3

$$100! = 1 \times 2 \times 3 \times 4 \times 5 \times 6 \dots \times 100$$

$$\frac{100}{5} = 20 \quad [5, 10, 15, 25, \dots, 100] \approx 5^1$$

$$\frac{20}{5} = 4 \quad [25, 50, 75, 100] \approx 5^2$$

$$\underline{\underline{24}}$$



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# ENGLISH

\* 1. Correction of sentences.

\* 2. Vocabulary

3. Critical Reasoning.

4. Analogy.

✓ 1. Question Tag

✓ 2. Usage of

a) As soon as

b) No sooner than

c) Hardly when

d) Scarcely when  
before

•

✓ 3. Degree of comparison

✓ 4. Articles.

✓ 5. Tenses + If Clause.

✓ 6. Reported speech.

✓ 7. Preposition

✓ 8. Parts of speech.

✓ 9. Concord and corrections.



Sentences: 4 kinds

- (i) Assertive 
 ┌ Positive  
 └ Negative
- (ii) Interrogative
- (iii) Imperative
- (iv) Exclamatory

Special verb (24)

am, is, are, was, were

has, have, had, do, does, did

may, might, must, need, dare

used to, ought to

will, would, shall, should, can, could.

Negative:

To make a negative sentence, put not after the special verb.

Interrogative:

To make an interrogative sentence, put the special verb at that starting of the sentence.

Example: Dhoni is a perfect Gentleman (Positive)

Dhoni is not a perfect Gentleman (Negative)

Is Dhoni a perfect Gentleman (Interrogative)

Non special Verb:

borrow : do / does / did

do : Present tense without 's'

does : present tense with 's'

did : Past tense.

NOTE: When we borrow do, does and did put the root verb in negative and interrogative.

Example: He goes to temple.  
He does not go to temple.  
Does he go to temple?

Example: He went to temple.  
He did not go to temple.  
Did he go to temple?

DO, Does, Did, these three always take root verb.

### Question Tag

After giving a statement we sometimes confirm if the listener is accepting or not with our statement. This confirmation is called Question Tag.

NOTE: Question Tags are of mainly two kinds:

(i) To a positive statement, Negative Tag is added.

Only short forms are used.

In the place of nouns use pronouns.

Question tag should be ended with special verb pronoun.

Example: The clock is running fast, isn't it?

I am a teacher of English, aren't I?

We are the ilk of middle class, aren't we?

↓  
meaning: family

My ~~drive~~ neighbour comes tomorrow, doesn't he?

If the gender is not specified give preference to male.

All the students went to picnic, did not they?

(ii) If the statement is negative, the question tag is ~~negative~~ <sup>positive</sup>.

Example: I am not a teacher of English, am I?

My friend does not know the address, does he?

Formula: Special verb + pronoun.

### Usage of:

Hardly, rarely, scarcely, barely, never, seldom

NOTE: These words always give negative sense. In the case of these words, the question tag is +ve.

Example: He hardly comes to my house, does he?

Barking dogs seldom bite, do they?

They never came to my house, did they?

### Usage of:

have, has, had

These three act as two kinds:

(i) main verb (give the meaning of possessing)

(ii) Special verb (does not give any meaning)

Example:

He has a car, ~~does he?~~ doesn't he?  
M.V.

He has purchased a car, hasn't he?  
S.V.

He had solved the problem, hadn't he?  
S.V.

He had a problem earlier, didn't he?  
M.V.

5.

### Usage of

Everyone, Everybody, Someone, somebody, noone, nobody.

NOTE: These six verb words take singular verb at the time of statement but in question tag, these words take plural verb.

In the place of all these words we have to write they.

Singular verb	Plural verb
is	are
was	were
has	have
does	do

Example: Everyone is coming, ~~isn't everyone~~ X  
aren't they?

Everyone likes music, don't they?

Every one has mobile, don't they?

Every one has given mobile, haven't they?

None is coming, aren't they?

No one supports corruption, do they?

10/10/2021

### Usage of

a few = positive

few = Negative

a little = positive

little = negative

Example: He asked me a few books, didn't he?

He asked me few books, did he?

He wants a little, doesn't he?

He wants little, does he?

## Usage of

making imperative in as question tags.

Imperative:

Rule:

1. Subject YOU is absent (But the meaning is implied in it)
2. Sentence begins with V<sub>1</sub>
3. Expresses command or request

NOTE: Imperatives generally take will you in question tags.

Example: come here, will you?

A sentence that is satisfied with these three rules is called imperative.

Example: Go there, will you?

Don't come here, will you?

shut up, can't you?

Get lost, can't you?

Keep silence, can't you?

← Expresses command only.

\* If the statement begins with Let's or let us, the question is always "shall we?"

Example: Let's start the work, shall we?

Let's not start the work, shall we?

\* Let him go, will you?

\* If the statement begins with so, a) to a positive statement Question tag is also positive.  
b) to a negative statement, Question tag is also negative.

Example:

So, you are coming, are you?

So, you are not coming aren't you?

Usage of

- a) as soon as
- b) No sooner than
- c) Hardly-when
- d) Scarcely when  
before

These four words are called Idiomatic Expression. These four words give the same meaning. i.e. "immediately."

Usage of No-sooner than:

No sooner connects with than.

- Rules:
1. put no sooner in the place of as soon as.
  2. change the as soon as into interrogative form.
  3. Put than before the second sentence.

Example: As soon as I went home, I had rest.

No sooner did I go home than I had rest.

} same meaning

As soon as the baby sees the doctor, she will cry.

No sooner does the baby see the doctor than she will cry.

Usage of hardly when:

1. Put hardly in place of as soon as.
2. change the as soon as sentence into had + V<sub>3</sub> form. and then change into interrogative form.
3. Put when before the second sentence.

8.

Example:

As soon as I went home, I had rest.

Hardly had I gone home when I had rest.

Usage of scarcely when  
before

Rule: The same rules of hardly-when are applicable.

Example: As soon as the principal entered the class room, all the students stood up.

Scarcely had the principal entered the classroom when all the students stood up.

→ As soon as he had explained the topic, students felt happy.  
No sooner, had he explained the topic than students felt happy.  
Scarcely had he explained the topic when students felt happy.  
Hardly had he explained the topic when students felt happy.

Degree of comparison:

Three forms of the adjective and adverbs are called as "Degree of comparison."

a) Positive degree — 1. as-as (accepting sense)

2. so-as (negative sense)

b) Comparative degree — (Takes than.)

c) Superlative degree — (Takes the)

Important Pt.

i) Positive degree, comparative degree sentences are always ended with the special verb.

ii) Positive degree comparative degree sentences always take subjective person.



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**By-Himadri Shekhar Sir**

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- Explanation
- Derivation
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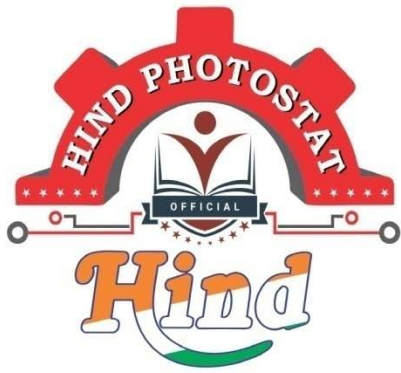
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