AIR-1 Notes
Pages: 90

PERT & CPM
Handwritten notes by

Kartikay Kaushik
AIR-1 ESE 2021
IES Master classroom Student

PERT AND CPM

CONTENT

Date 24/05/19

PERT – CPM {rated as the most ~~profitable topic~~}

→ Part of PTE and MCE + Also part of GATE
{10-12 ques/150}

→ Helps in "Project Management" – topic of GS paper.
{4-5 ques/100}

Sub-Topics

1. Project Management
2. Fundamentals of Network
3. PERT
4. CPM
5. Crashing
6. AON diagram
7. Resource Allocation
8. Updating
9. Engineering Economy
10. Construction Equipments → Pure Theory

1. Project Management {Initiation: Defining the objective of the project}

→ Every project has a definite start and end time {temporary nature}

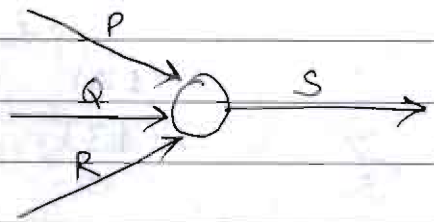
→ Output of project → Product, Service, Result

→ Every project is unique in nature.

PMI (Project Management Institute)
⇓
PMBOK (Book of knowledge)

→ Project is a temporary endeavour undertaken to provide a unique product, service and result.

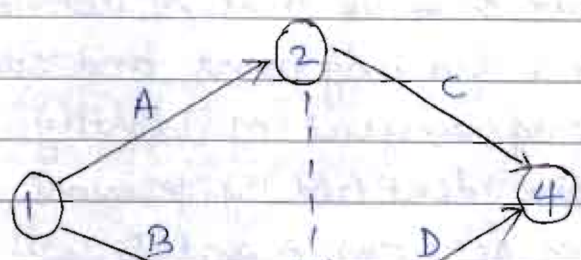
→ Interface Event



→ An interface event is a common event which shows linkage between activities performed by ~~one or~~ more than 1 agents / agencies.

→ It may also denote linkage between 2 or more sub-projects.

3. Dummy Activity / zero time activity



→ Here Dummy 2 3 represent that activity D depends on A and B.

→ Dummy is an artificial activity which neither consumes any resource nor time.

→ Dummy is used to show inter-relationship of activities.

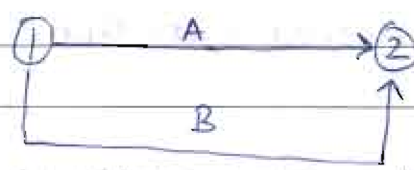
→ Since Dummy is not an activity, it is not represented by arrow. Rather, it is represented by dotted arrow.

→ Dummy is identified by terminal nodes.

→ Dummy are used to keep logical sequence and inter-relationship of activities correct.

→ Use of Dummies

(a) Grammatical purpose



} Conflict of identity (1 2)

Fig (a): Wrong representation

AIR-1 Notes

Pages: 448

Environmental Engineering

Handwritten notes by

Kartikay Kaushik

AIR-1 ESE 2021

IES Master classroom Student

Environmental Engineering

① Water Supply and Treatment → (a) Source
*(b) Quality Parameter
*(c) Treatment
(d) Distribution
} 40%

② Sewage Treatment → (a) Sewage collection
*(b) Characteristics
*(c) Treatment
(d) Disposal.
} 55%

③ Air Pollution
④ Solid waste
⑤ Noise Pollution
} 5%

Ch-① Water Supply & Treatment

Q- A ~~scientif~~ synthetic sample of water is prepared by adding 100 mg of Kaolinite, 200 mg glucose, 168 mg of NaCl, 120 mg of $MgSO_4$ and 111 mg of $CaCl_2$ to 1 litre of pure water. Find the concentration of Total solids and Fixed Dissolved solids in mg/L
↓
Inorganic Dissolved solids.

Total solids = 100 + 200 + 168 + 120 + 111 = 699 mg/L

Kaolinite → Inorganic SS
Glucose → Organic Dissolved
NaCl
$MgSO_4$
$CaCl_2$
} Inorganic Dissolved

So, Fixed Dissolved Solids = 168 + 120 + 111 = 399 mg/L

AIR-1 Notes
Pages: 258

Fluid Mechanics
Handwritten notes by

Kartikay Kaushik
AIR-1 ESE 2021
IES Master classroom Student

FLUID MECHANICS

CONTENT

Fluid Mechanics

1. Properties of Fluid
2. Fluid Statics
   - Fluid Pressure and its measurement
   - Hydrostatic forces on plane and curved surface
   - Liquid in relative equilibrium
   - Buoyancy and Floatation
3. Fluid kinematics
4. Fluid Dynamics
   - energy equations
   - momentum.
5. Flow measurement
6. Laminar Flow
7. Turbulent Flow
8. Boundary layer theory
9. Drag and lift
10. Model Analysis
11. Pipe flow.

Introduction

$\tau = G\gamma \rightarrow$ solids

$\tau \propto \frac{d\gamma}{dt} \Rightarrow \gamma = \tau t + c \rightarrow$ fluid.

1. Substance in liquid or gaseous phase is referred to as fluid. They are capable of deforming continuously under the influence of shear stress, however small the shear stress might be.

2. In solids $\boxed{\tau \propto \gamma}$ but in fluids $\boxed{\tau \propto \frac{d\gamma}{dt}}$

→ Study of fluid at rest is called fluid statics.

→ Study of fluid in motion, when forces responsible for motion are not the point of concern then the study is called fluid kinematics.

→ Study of fluid in motion when forces responsible for motion are the point of concern is called fluid dynamics.

⇒ Continuum Approach

→ We, in fluid mechanics, generally assume that fluid is a continuous homogenous mass with no holes. Thus, at every point in the flow space, we can define the flow parameters like velocity, acceleration etc.

→ This assumption is called continuum approach.

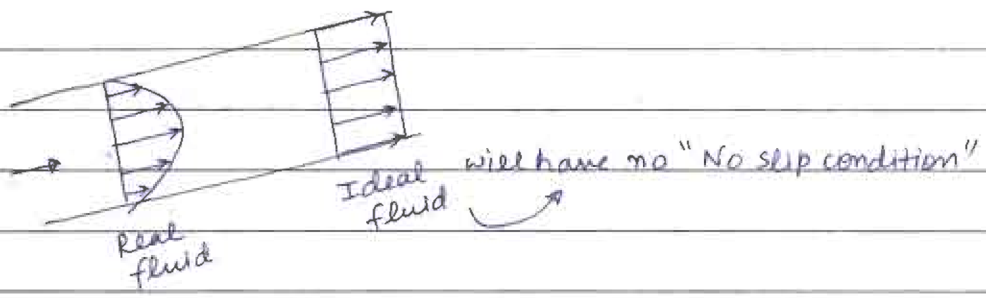
→ The continuum approach will not be applicable when the mean free path becomes large as compared to the characteristic dimensions of study. [alternate → Rarefied Gases Approach]

⇒ Ideal and Real Fluid

→ Fluid having no surface Tension, viscosity and which are incompressible are called ideal fluid.

→ There is no fluid as ideal fluid. It is just a theoretical conception.

⇒ No slip condition



→ A fluid having viscosity will be said to have no slip condition at the boundary of the solid surface i.e. the fluid molecule at the boundary will not move relative to the boundary surface.

→ Hence if boundary is stationary, fluid at the boundary will also be stationary and if boundary is moving, fluid at the boundary will also move with the same velocity in the same direction

NOTE: No wetting property is due to Surface Tension and not due to viscosity or no slip condition.

Properties of Fluid

⇒ Vapour pressure and cavitation

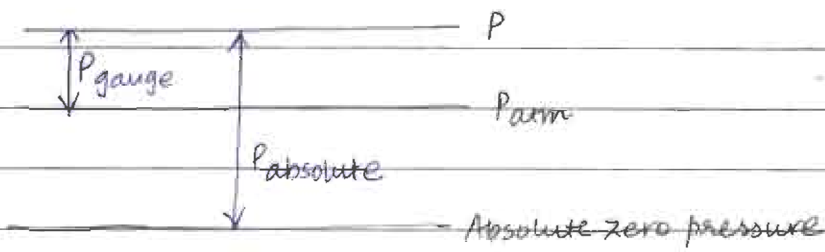
→ Saturation Vapour pressure is the pressure exerted by vapour molecules in phase equilibrium with it's liquid at a given temperature.

→ Saturation vapour pressure increases with increase in temperature and is independent of externally applied pressure.

→ whenever in a flow absolute pressure of flow exceeds the saturation vapour pressure the vapours and liquid will remain in dissolved form, however, if $P_{absolute} < P_{vap\ pressure}$, the dissolved gases and vapour will start coming out and will create cavity in the flow

→ These cavities move due to momentum of flowing fluid and when they go to high pressure zone, cavity collapses giving rize to noise, vibrations, surface pitting (erosion) and fatigue failure This phenomenon is called cavitation.

→ It generally occurs at the inlet of pump, exit of reaction turbine, top of siphon and on the surface of spillway



→ As the saturation vapour pressure increases with temperature, therefore chances of cavitation are more at higher temperature

→ Cavitation can be prevented by maintaining higher pressure in the flow and cavitation damage can be prevented by air entrainment.

→ Rise in Elevation, increase in velocity, decrease in atm pressure and increase in temperature will favour cavitation.

⇒ Bulk Modulus

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

$$m = \rho V$$

$$dm = \rho dV + d\rho V = 0 \Rightarrow \boxed{\frac{-dV}{V} = \frac{d\rho}{\rho}}$$

$$K = \frac{dP}{\left(\frac{d\rho}{\rho}\right)} \Rightarrow \boxed{K = \rho \frac{dP}{d\rho}}$$

$$\boxed{\frac{1}{K} = \text{compressibility} = \frac{1}{\rho}\frac{d\rho}{dP}}$$

→ Ideal gas eq^n → $PV = nRT$ ⇒ $\boxed{P = \rho RT}$

→ Isothermal condition

$$dP = RT\, d\rho \Rightarrow \boxed{\frac{dP}{d\rho} = RT}$$

So, $K = \rho \frac{dP}{d\rho} \Rightarrow K = \rho RT$

$$\Rightarrow \boxed{K_{isothermal} = P}$$

→ Adiabatic condition

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

$$\frac{P}{\rho^{\gamma}} = \text{constant}$$

$$P = c\rho^{\gamma}$$

$$\frac{dP}{d\rho} = c\gamma\rho^{\gamma-1} \Rightarrow \rho\frac{dP}{d\rho} = c\gamma\rho^{\gamma} = \gamma P$$

So, $\boxed{K_{adiabatic} = \gamma P}$ → adiabatic constant $= \frac{C_P}{C_V}$

C_P → specific capacity at constant pressure

C_V → specific capacity at const volume

Q- Density of sea water at free surface is 1030 kg/m³ and atm. pressure is 98KPa. Bulk modulus of elasticity of sea water is 2.34×10^9 N/m² (constant) and the variation of pressure with depth z is given by $\boxed{dP = \rho g dz}$ then determine the density and pressure at a depth of 2500 m.

$$K = \rho\frac{dP}{d\rho} \Rightarrow \boxed{dP = \frac{K d\rho}{\rho}} \Rightarrow [P]_{98000}^{P} = K \ln\left(\frac{1041.24}{1030}\right)$$

$P =$ ~~25487.21 KPa~~ 25495.21 KPa

So, $$K\frac{d\rho}{\rho_{\rho}} = \rho g dz$$

$$K\int_{\cancel{98000}\,1030}^{\rho}\frac{d\rho}{\rho^2} = \cancel{\rho} g\int_0^{2500} dz$$

$$K\left[\frac{-1}{\rho}\right]_{\cancel{98000}\,1030}^{\rho} = g(2500)$$

$$\frac{-1}{\rho} + \frac{1}{\cancel{98000}\,1030} = \frac{2500g}{2.34 \times 10^9}$$

$$\rho = \frac{1}{\frac{1}{\cancel{98000}\,1030} - \frac{2500g}{2.34 \times 10^9}} = 1041.24 \text{ kg/m}^3$$

$$T_{bottom} = T_{top} = \frac{\pi \mu \omega R^4}{2t}$$

For calculation of T_{side}.

$$\tau = \mu \frac{\omega(R+t)}{t} \quad , \quad F = \frac{\mu\omega(R+t)}{t}(2\pi R h)$$

$$T_{side} = \frac{\mu\omega(R+t)(2\pi R h)}{t} \times R$$

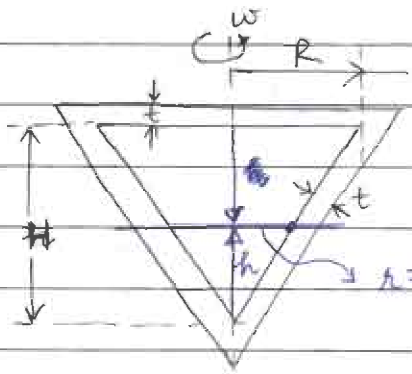
So, Torque experienced by the inner cylinder,

$$\boxed{T = 2\left[\frac{\mu\pi\omega R^4}{2t}\right] + \frac{\mu\omega(R+t)(2\pi R h)}{t} \cdot R}$$

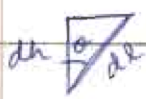
measured from calibrated rotational spring

$\Rightarrow$ Hence μ of the fluid can be calculated.

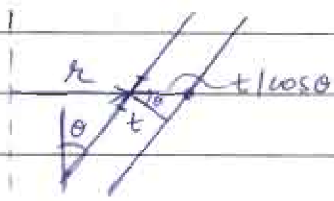
$\Rightarrow$



$$T_{top} = \frac{\pi\mu\omega R^4}{2t}$$



$$dl = \frac{dh}{\cos\theta}$$



$$\frac{du}{dy} = \frac{\omega\left(r + \frac{t}{\cos\theta}\right)}{\left(\frac{t}{\cos\theta}\right)}$$

$$\tau = \frac{\mu\omega\left(r+\frac{t}{\cos\theta}\right)}{\left(\frac{t}{\cos\theta}\right)}$$

$$\boxed{T_{side} = \int_0^H \frac{\mu\omega\left(r+\frac{t}{\cos\theta}\right)}{\left(\frac{t}{\cos\theta}\right)} \, 2\pi r \left(\frac{dh}{\cos\theta}\right) r}$$

$\rightarrow$ Put $r = \frac{Rh}{H}$

AIR-1 Notes

Pages: 178

Highway
Handwritten notes by

Kartikay Kaushik
AIR-1 ESE 2021
IES Master classroom Student

HIGHWAY

CONTENT

Highway Engineering

[ESE → 4-6 Ques, Conventional → 30-60 marks, GATE → 3-5 Ques]

1) Geometric Design
2) Traffic Engineering
3) Pavement Design
4) Highway materials

1. Geometric Design

→ Geometric design of highway deals with the visible elements of the road. Various geometric design components depends on:

1) Type of Road
   (A) Rural Roads
      (i) Expressway: Speed upto 120 kmph
      (ii) National Highway: Joins various states
      (iii) State Highway: Joins various districts.
      (iv) Major District Roads (MDR): Joins areas of population or production with the main highway
      (v) Other District Roads (ODR): Joins rural areas to the market place
      (vi) Village Roads: Joins various villages

NOTE: IRC:73 deals with the geometric design of rural highways

   (B) Urban Roads
      (i) Expressway (120kmph) [Divided Arterial Roads]
      (ii) Arterial Roads (80 kmph)
      (iii) Sub-Arterial Roads (60 kmph)
      (iv) Collector Streets (50 kmph)
      (v) Local streets (30kmph)

2) Type of vehicle : The vehicle for which road elements are designed is called design vehicle.

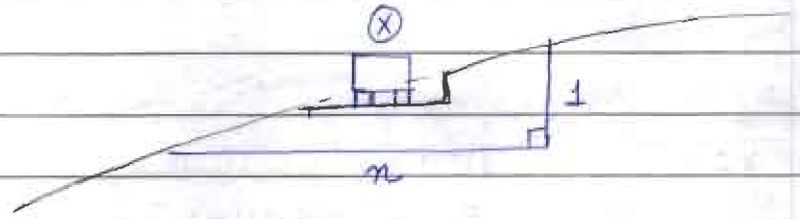
→ Length, width, height of design vehicle are used as design parameters for the roads.

NOTE : IRC: 003 deals with the dimension of design vehicle.

→ Width of vehicle = 2.5 m

→ Height of vehicle = 3.8 to 4.75 m [4.75 m is for Double Decker bus]

3) Topography : It is classified on the basis of general country slope across the road alignment. It is expressed as 1 in n or $x\%$. [$x\% = x$ in 100]



Cross-country slope	Class
0 – 10%	Plain
10 – 25%	Rolling
25 – 60%	Mountaneous } Hill Roads.
>60%	Steep

→ If cross-slope of the country is large then large expenditure has to be made in altering the alignment for design speed to provide a larger radius of curve to counteract against centrifugal force which causes skidding or overturning problems.

→ Hence when cross-country slope is large, the velocity should be restricted.

DATE
PAGE

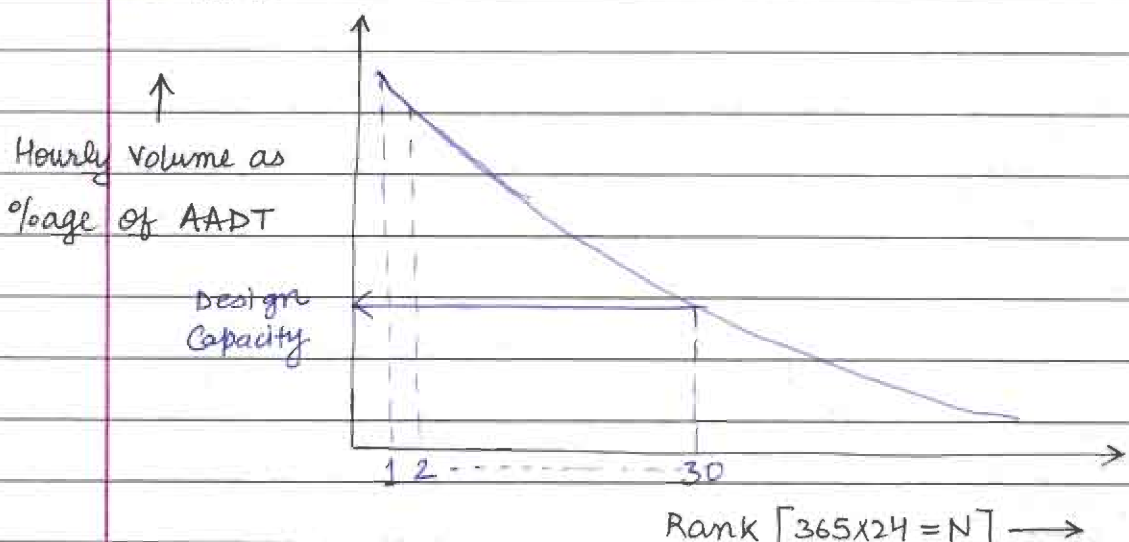
4) ⇒ Traffic Capacity

→ Traffic capacity is the ability of road to accommodate maximum traffic volume.

→ Traffic volume is the no. of vehicles crossing a point or section on the road in unit time.

→ Capacity and volume are both expressed in veh/hr.
[At a particular Level of Service (LOS)]

→ Normally design capacity is taken as 30th highest hourly volume.



AADT → Average annual Daily Traffic i.e. $\left[\frac{\text{Yearly Traffic}}{365}\right]$

→ Generally 30th highest hourly volume for Indian conditions comes around 8-10% of AADT
eg → if AADT = 2000 veh/day
then Design capacity = 160-200 veh/hr
or 30th highest hourly volume

→ Depending upon traffic capacity width of road is decided.

AIR-1 Notes

Pages: 69

Hydraulic Machine

Handwritten notes by

Kartikay Kaushik

AIR-1 ESE 2021

IES Master classroom Student

HYDRAULIC MACHINES

CONTENT

Hydraulic Machines

(ESE (P) → 6 Ques
ESE (M) → 20-25 Marks)

1) Overview of Hydro-electric Projects (HEP's)
2) Hydraulic Turbines { Impulse Turbines, Reaction Turbines }
3) Hydraulic Pumps { Centrifugal pumps, Reciprocating pumps }

Hydraulic Machines

Energy producing

Energy of fluid

3 forms:
① KE
② PE
③ Pressure Energy

↓ Turbine (Hydraulic, Steam, Gas, Wind)

Mechanical Energy

↓ Generator

Electrical Energy

Energy consuming

Electrical Energy

↓ Motor

Mechanical Energy

↓ Pump, compressor, fans, blowers

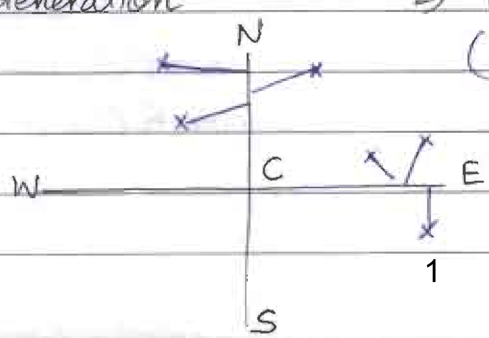
Hydraulic Energy

→ Pumps ~~a~~ increase the PE of fluid, compressors (generally used for gases) increase the pressure energy of fluid and fans and blowers increase the KE of fluid.

Chapter 1 - Overview of HEP

⇒ Basics of Electrical

1) Generation
2) Transmission (PGCIL)
3) Distribution (SEBs)



→ Generation plants supply electricity to grids and grids supply it to us.

	Supply	(Load) Demand
$f = 50Hz$	500MW	500MW
$f < 50Hz$	500MW	600MW
$f > 50Hz$	500MW	400MW

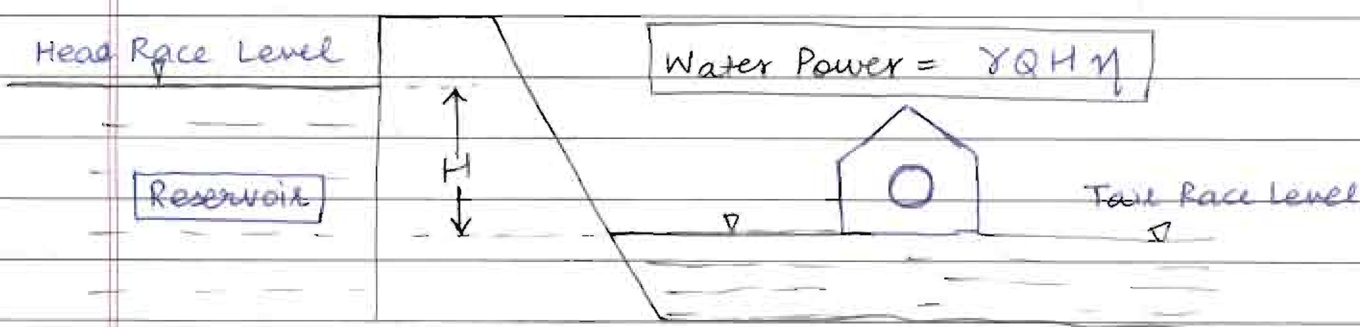
For generation companies,
if Demand is high, price ↑
if Demand is low, price ↓

→ Both of these situations are not desirable as appliances are set to work at 50Hz.

→ frequency (f) directly relates to the speed of rotation of turbines.

$$N = \frac{60 \times f}{P}$$

where $N \rightarrow$ speed of generator
$f \rightarrow$ frequency
$P \rightarrow$ No of Pole pairs.



Water Power = $\gamma Q H \eta$

→ In HEPs, PE of water is utilized to drive a turbine which in turn runs the generator to produce electricity.

→ Apart from producing electricity, these projects can also be used for irrigation, drinking water supply, flood moderation, fishing and recreational activities.

→ Such projects are known as Multi Purpose Projects.

⇒ Components of HEP

① Reservoir

→ Water available in the catchment area is stored in reservoir so as to meet requirement of plant throughout the year. Reservoirs can be natural as well as artificial.

→ Natural reservoirs are lakes in mountains.

(c) Kaplan and Propeller Turbine - Works under low head and hence requires high discharge

④ According to specific speed

→ Specific Speed (N_s) → Speed of a geometrically similar turbine which while working under a head of 1 m produces 1 KW power

$$\boxed{N_s = \frac{N\sqrt{P}}{H^{5/4}}}$$

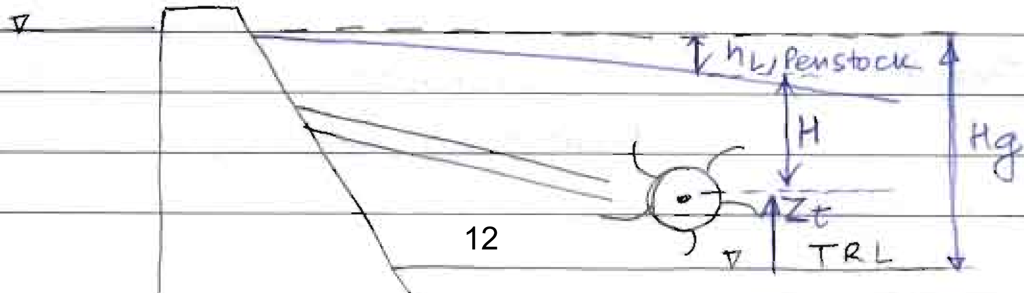
N : speed of runner (in rpm)
P : Power output (in KW)
H : Net Head.

N_s	Type of Turbines
10-35	Pelton wheel with single Jet
>35	Pelton wheel with multiple Jets
60-300	Francis Turbine
300-900	Kaplan Turbine/Propeller
>900	Special type of runners are used

NOTE: Calculation of specific speed is independent of size of turbine and hence this is the most scientific criteria for classification of turbine.

⇒ Head and efficiency of Turbine

① Gross Head (H_g) → It is the difference of Level b/w HRL and TRL



② Net Head

$$\boxed{\text{Net Head} = H_g - h_{L,\text{Penstock}} - Z_t} \rightarrow \text{Impulse Turbine}$$

Z_t → height of turbine above TRL

$$\boxed{\text{Net head} = H_g - h_{L,\text{Penstock}} - \frac{V_{dt}^2}{2g}} \rightarrow \text{Reaction Turbine}$$

V_{dt} → Velocity at the exit of draft Tube.

→ Efficiencies of hydraulic Turbine

Reservoir (H_g) → Water Power, Net Head, H → Running Power → Shaft Power → Generator Power

Losses in Penstock

Hydraulic Loss
- fluid friction Loss
- Leakage Loss
- Nozzle Losses
- $V_2^2/2g$

Mechanical Power
- Bearing friction loss
- Windage Loss (only in impulse turbine)

Generator Losses

① Hydraulic Efficiency (η_h)

$$\eta_h = \frac{\text{Runner Power}}{\text{Water Power}} = \frac{RP}{\gamma Q H \ (\frac{1}{2}\rho Q V_1^2)}$$

② Volumetric Efficiency

$$= \frac{\text{Discharge striking the runner } (Q)}{\text{Discharge supplied to runner } (Q+\Delta Q)}$$

ΔQ → Leakage Losses (generally neglected)

③ Mechanical Efficiency (η_m)

$$\eta_m = \frac{\text{Shaft Power}}{\text{Runner Power}} = \frac{RP - \text{Mechanical Losses}}{WP - \text{Hydraulic Losses}}$$

④ Overall Efficiency (η_o) $= \dfrac{\text{Shaft Power}}{\text{Water Power}}$

Shaft Power → Brake horse Power (BHP)

Water Power → Water horse power (WHP)

$$\boxed{\eta_o = \eta_h \times \eta_m} \qquad \boxed{1\,hp = 745.7\,W}$$

AIR-1 Notes
Pages: 149

HYDOLOGY
Handwritten notes by

Kartikay Kaushik
AIR-1 ESE 2021
IES Master classroom Student

HYDROLOGY

CONTENT

Hydrology

ESE – Objective (3-5 Ques)
– Conventional (25-45 Marks)
GATE – (2-4 Ques)

1) Introduction
2) Precipitation
3) Abstraction from ppt.
4) Surface Runoff
**5) Hydrograph → Test (2)
6) Stream flow Measurement
7) Flood / Flood Routing
8) Ground water

Test (2)

1. INTRODUCTION

→ Hydrology is an earth science involving study of water of earth.

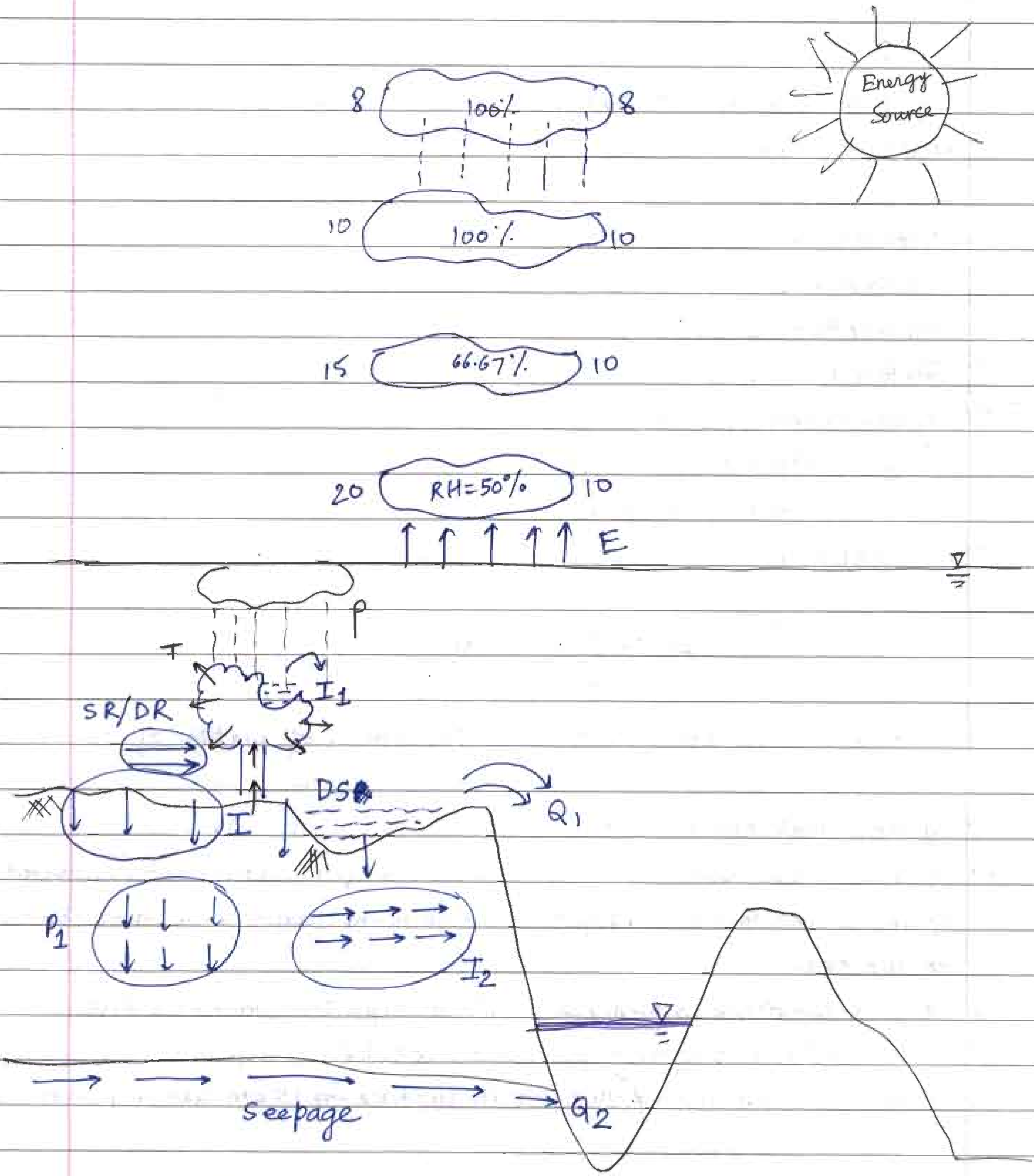
→ Hydrological cycle
→ It is a global sun driven process in which water is transported from oceans to the atmosphere, then to the land and then back to the sea.
→ It is a continuous process with no definite starting point
→ A convenient starting point to describe the cycle is taken as ocean
→ Extent → 1 km below the earth surface to 15 km above earth surface.

→ Relative Humidity

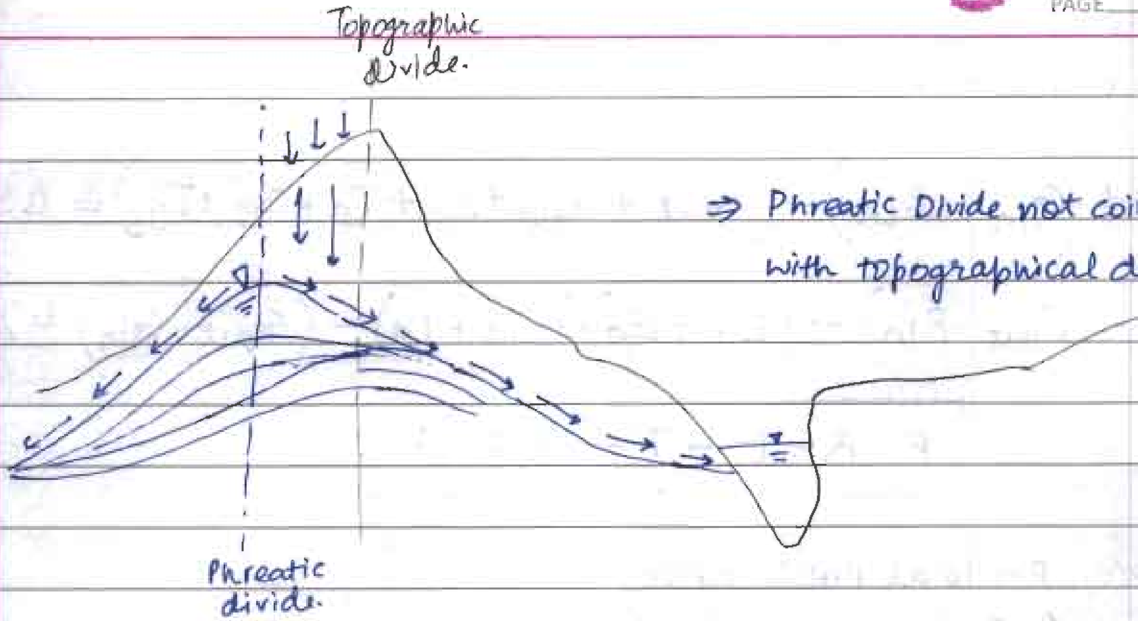
$$RH = \frac{\text{Actual vapour carried}}{\text{Vapour carrying capacity}} \times 100\% \quad \text{(at constant temp.)}$$

DATE
PAGE

→ With decrease in temperature, RH increases and vice-versa



→ Due to ~~solid~~ solar radiation falling on ~~earth~~ ocean surface, water surface, water evaporates and mixes with the dry air → moist air. Moist air being lighter than dry air rises and in the



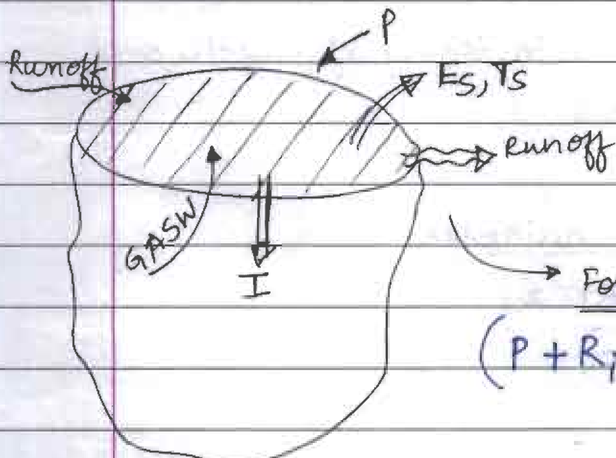
⇒ Phreatic Divide not coinciding with topographical divide.

⇒ Water budget / hydrological budget

→ It is based on law of conservation of mass.

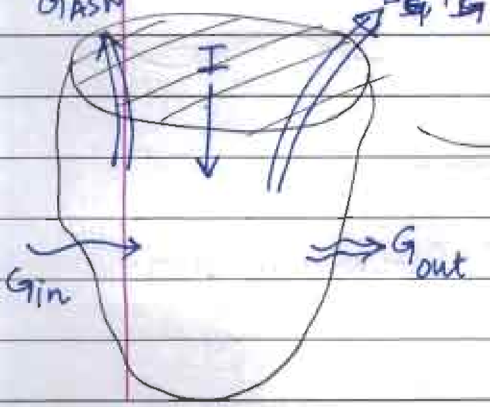
→ It states that:

$$\boxed{\text{Mass inflow} - \text{Mass outflow} = \text{Change in storage } (S_f - S_i)\ (\Delta S)}$$



→ For surface Runoff,

$$(P + R_{in} + G_{ASW}) - (I + E_S + T_S + R_{out}) = \Delta S_{surface}$$



→ For ground water flow

$$(I + G_{in}) - (G_{ASW} + G_{out} + E_G + T_G) = \Delta S_{ground}$$

AIR-1 Notes

Pages: 123

IRRIGATION ENGINEERING

Handwritten notes by

Kartikay Kaushik

AIR-1 ESE 2021

IES Master classroom Student

IRRIGATION ENGINEERING

CONTENT

24/06/19

Irrigation Engineering

Syllabus

1) Introduction
2) Soil Plant Relationship } GATE
3) Water requirement of crops } GATE
4) Canal Design } GATE
5) Sediment Transport
6) Lining of Canal
7) Reclaimation of water logged and saline soil
8) Design of gravity Dams → GATE
9) Theory of seepage
10) Miscellaneous Topics
    (a) River Draining
    (b) Cross Drainage work
    (c) Diversion Headwork
    (d) Modules
    (e) Canal fall

1. INTRODUCTION

→ Irrigation is artificial application of water to the agriculture field for the purpose of cultivation i.e. in accordance with crop requirement throughout the crop period for optimum growth of crops.

> NOTE:
> Crop period is time period from instant of sowing to the instant of harvesting.

⇒ Necessity of Irrigation

1) Inadequate Rainfall
2) Uneven distribution of Rainfall
3) Increasing yield of crops
4) Growing more than one crop in a year.
5) Growing perennial crops like sugarcane.
6) Prevention from drought and famine condition.

⇒ Advantages of Irrigation

(a) Direct advantages

1) Increasing yield of crops
2) Prevention from drought and famine condition
3) Elimination of mixed cropping.

NOTE:

Mixed cropping means growing 2 or more crops simultaneously in the field.

↳ Advantages

↳ Mixed cropping is found economical and necessary when irrigation facilities are lacking i.e if ~~ote~~ weather conditions are not suitable for one of the crop, they may be suitable for other crop and hence farmer will get atleast some yield.

↳ Disadvantages

↳ Diff. crops require diff. types of field preparation, watering pattern, manuring etc. Since it would be difficult to satisfy need of both the crops simultaneously in the field hence, it will result in low yield.

↳ Also at the time of harvesting crops would get intermixed which reduces purity and value of crops in the market.

(b) Indirect Advantages

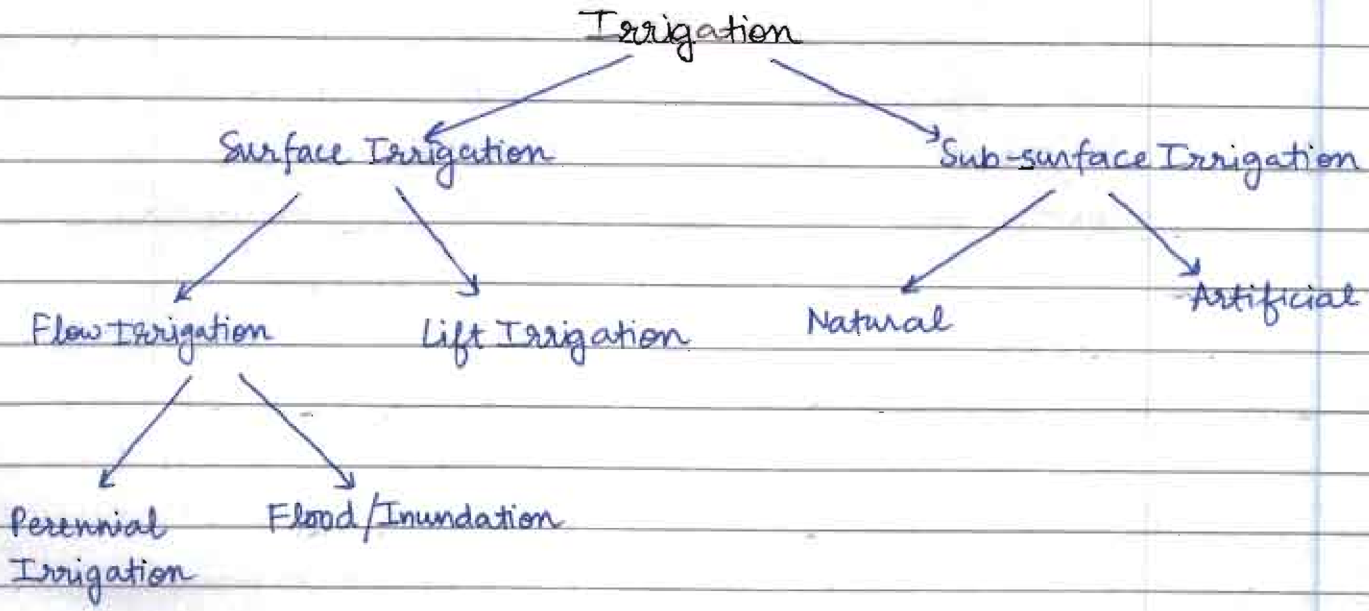
1) Power generation → Ganga Sharda canal system generates 80 MW hydropower.
2) Flood control
3) Transportation → Inland Navigation and Roads
4) Ground water recharge (Percolation)
5) Industrial and domestic water supply
6) Employment generation.

⇒ Disadvantages of Irrigation

1) Water Logging
2) Intense irrigation results in cold and damp climate which may cause spreading of disease like dengue and malaria.
3) Ground water pollution due to percolation of water.

NOTE: Bad effect of irrigation can be overcome by economical and scientific use of water.

⇒ Types of Irrigation



⇒ Surface irrigation

→ Surface irrigation is a method in which water is directly applied to the soil surface either by gravity or pumping.

→ It is best suitable for soil with low to moderate infiltration capacities.

→ It is suitable in the area with rolling terrain. (gentle slope)

→ Surface irrigation can be further classified as:

1) Flow Irrigation – If water is available at higher elevation and it is supplied to the lower elevation under the action of gravity, it is called as flow irrigation.

2) Lift Irrigation – If water is lifted up by some mechanical means or some manual means and supplied to the agriculture field it is called as Lift Irrigation.
eg. – Pump, well and Tube well.
Lift Irrigation is costlier than flow Irrigation.

→ Flow Irrigation can be classified as:

1) Perennial Irrigation – If a constant and continuous water is supplied to the agriculture field as per the requirement of crops throughout the crop period it is called as perennial irrigation.
   (a) Direct Irrigation – By diverting river runoff into a canal with the help of weir or barrage. eg – Ganga canal system.
   (b) Storage Irrigation – System of dam and channels
   eg – Ram Ganga Dam Project.

2) Flood Irrigation / Inundation – In this system of irrigation a large quantity of water flowing in a river during the flood is allowed to flood or inundate the area which is to be cultivated which causes saturation of the area.

When excess water is drained off under the action of gravity, then cultivation can be practised eg- Sunderbans.

⇒ Sub-surface irrigation

→ In this type of irrigation system, water does not wet the soil surface rather it is directly supplied to the root zone of the plants.

→ It is classified into 2 types:

(a) Natural Sub-Surface Irrigation

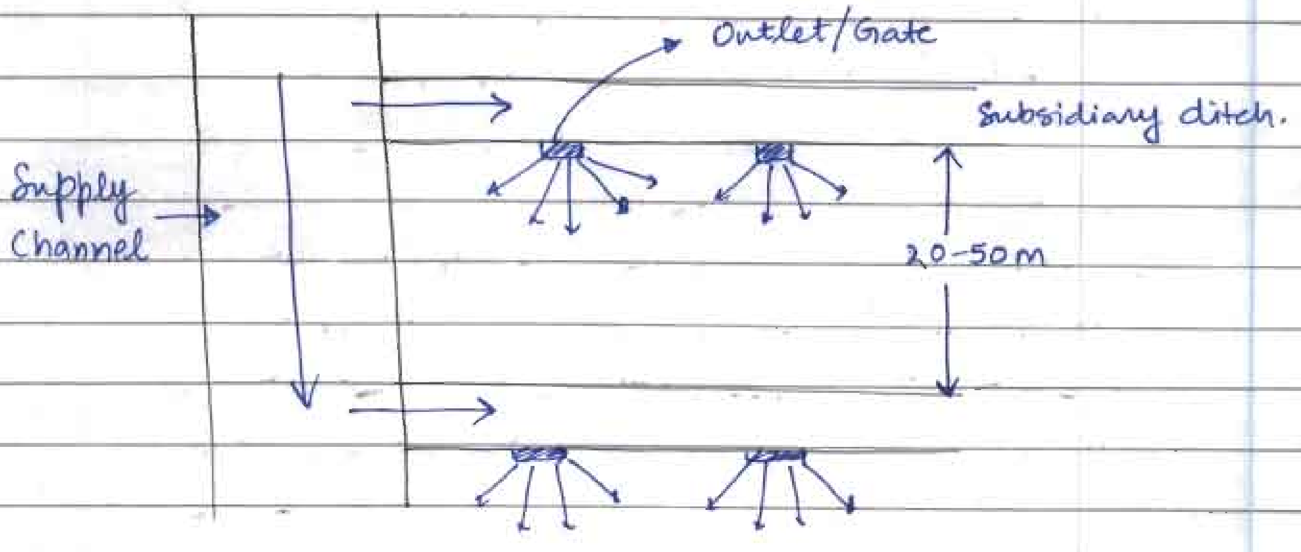
In this system, water seeping through channels and water bodies may irrigate crops grown on lower area by cappilarity.

(b) Artificial Sub-Surface Irrigation

In this system, water is directly supplied to the root zone of plants by a network of perforated pipes, which are laid below the soil surface.

⇒ Techniques of water distribution

1) Free flooding / ordinary Flooding.



25/06/19

→ In this method ditches are excavated in the field and water from these ditches flows across the field.

→ After water leaves the ditches, no attempt is made to control the flow, hence it is called as wild flooding.

→ Suitable for rolling terrain (gentle slope)

→ Field preparation is low.

→ Water application efficiency is low.

→ Suitable for close growing crop like pasture.

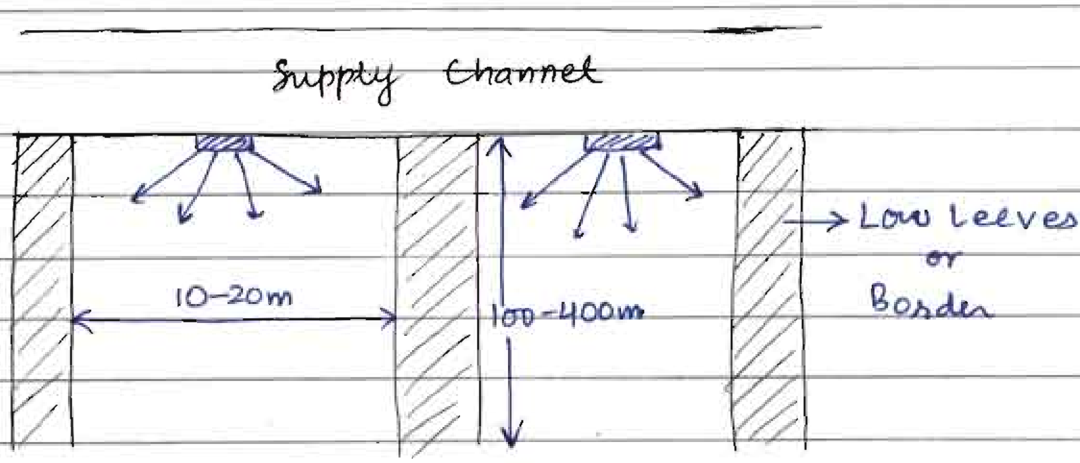
→ Subsidiary Ditch / Lateral Ditch are spaced 20–50 m apart depending on :

(a) Slope

(b) Type of Soil

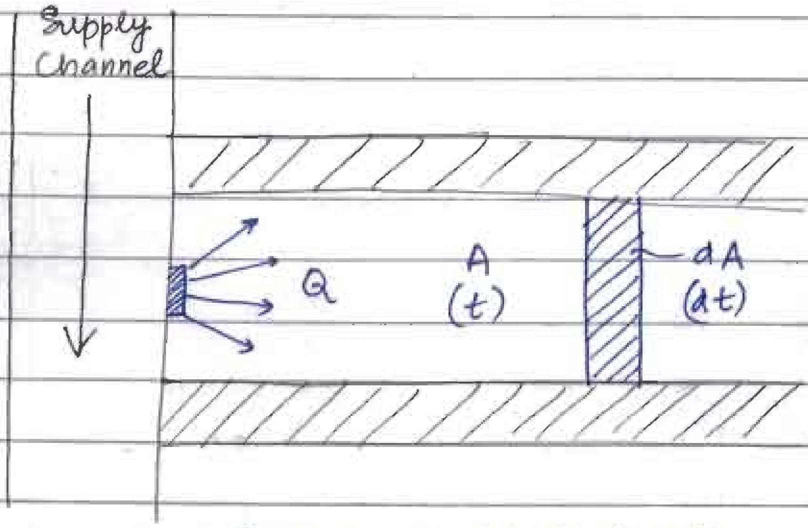
(c) Crop etc.

2. Border Flooding



→ Area is divided into no. of strips separated by low levees called border.

→ Relation between discharge through supply channel (Q), rate of Infiltration of soil (f), average depth of flow over strips (y), area to be irrigated (A) and time required to irrigate the area (t)



$$Q\,dt = y\,dA + f A\,dt$$

→ Assuming Q, y and f as constant.

$$(Q - fA)\,dt = y\,dA$$

$$\int dt = \int \frac{y}{Q - fA}\,dA$$

$$t = \frac{y}{-f}\left[\ln(Q - fA)\right] + c$$

→ If $t = 0$ then $A \to 0$.

$$c = \frac{y}{f}\ln Q$$

$$\Rightarrow t = \frac{y}{f}\ln\left(\frac{Q}{Q - fA}\right)$$

$$\Rightarrow \boxed{t = 2.303\,\frac{y}{f}\log\left(\frac{Q}{Q - Af}\right)}$$

⇒ Maximum area that can be irrigated with a particular amount of discharge

if $t \to \infty$ then $A \to A_{max}$

therefore, $Q - A_{max} f = 0$

$$\Rightarrow \boxed{A_{max} = \frac{Q}{f}}$$

→ Size of the strip will depend on discharge (Q), characteristic of soil (f) and slope of the area.

Q- For Border strip method of irrigation, time required to irrigate a strip of 0.04 hectare from a tubewell with a discharge of 0.02 cumec. Infiltration capacity of the soil is 5cm/hr and average depth of flow on the field is 10cm. Also determine maximum area that can be irrigated from this tubewell.

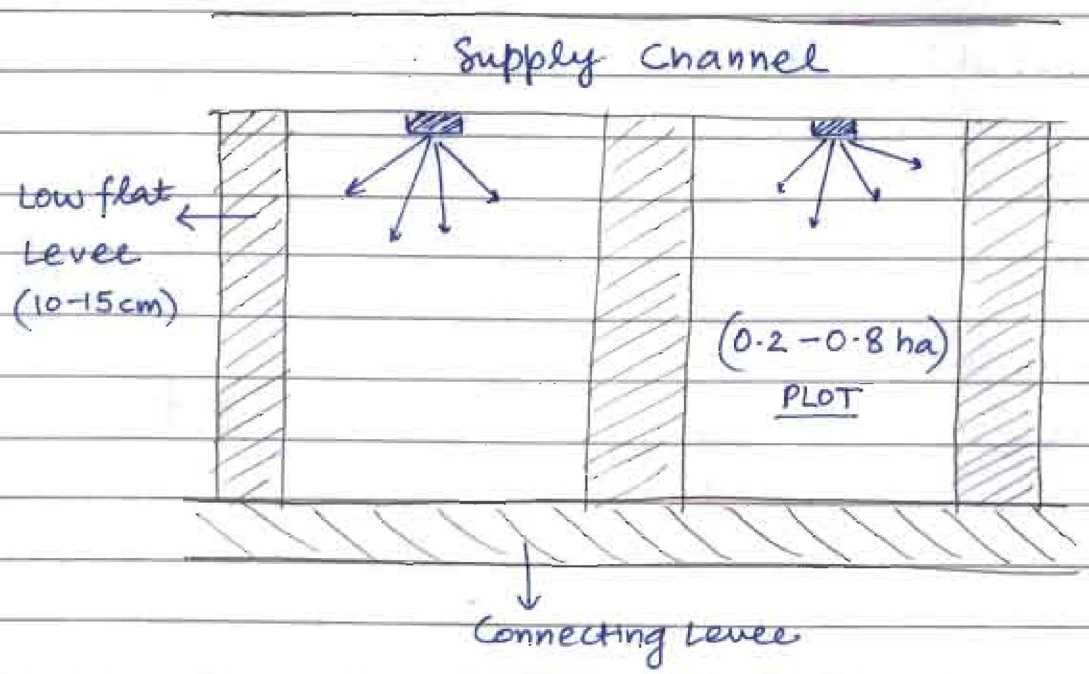
$$t = \frac{2.303y}{f} \log_{10}\left(\frac{Q}{Q-Af}\right)$$

$$t = 2.303 \times \frac{10}{5} \left(\log_{10} \left\{ \frac{0.02}{0.02 - 400 \times \frac{0.05}{3600}} \right\} \right)$$

$t = 39.05$ mins.

$$A_{max} = \frac{Q}{f} = \frac{0.02 \times 3600}{0.05} = 1440 m^2 = 0.144 ha$$

3) Check Flooding / Method of irrigation by plots (Paddy)

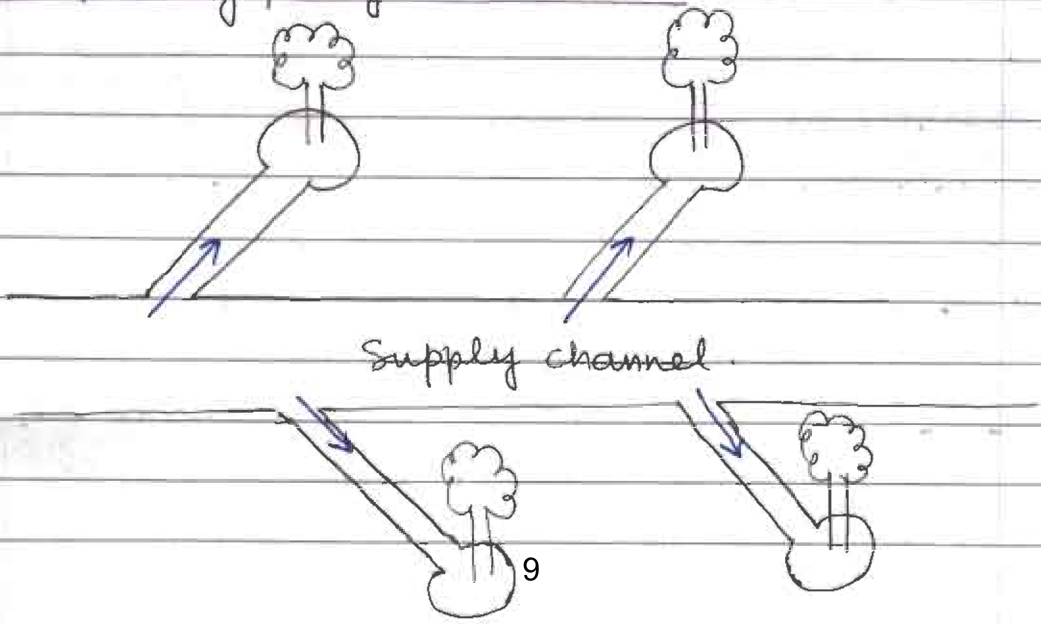


→ In this method, the area to be irrigated is divided into small Plots of area 0.2-0.8 hectares with low flat levees.

→ Each plot has a nearly fair level surface.

→ Irrigation water is applied by filling the plots with water upto desired depth without overtoppling the levees and water is retained there to allow it to infiltrate into the soil.

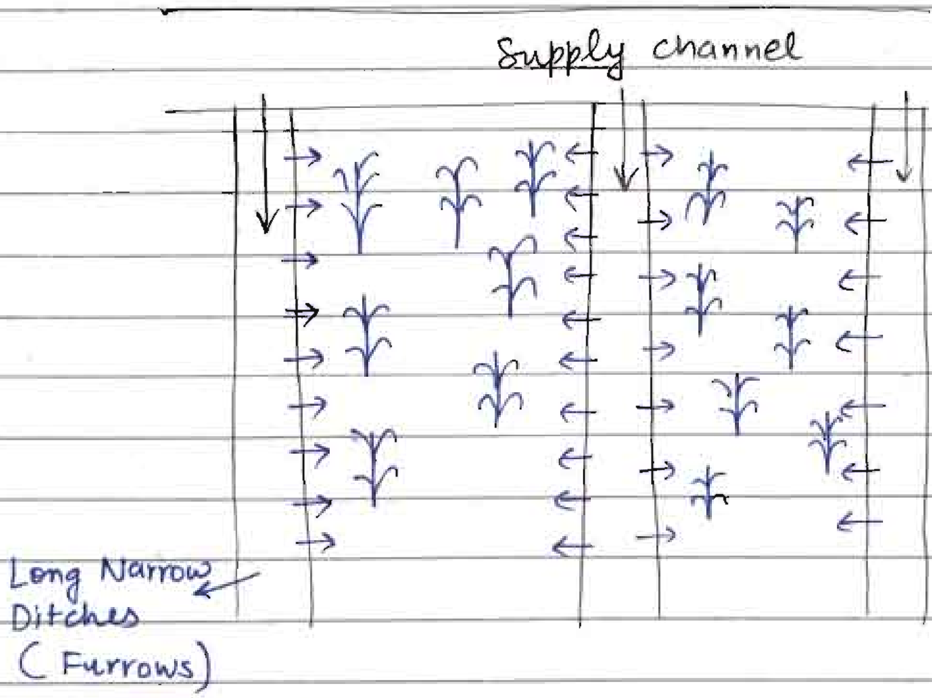
4) Basin flooding / Ring Basin Method



→ This method is a special form of check basin method which is used for irrigation of orchards [enclosure of fruit trees].

→ A separate circular basin is provided for each tree.

5) Furrow Irrigation



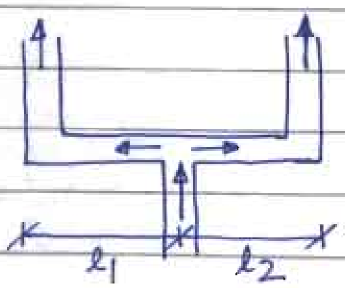
→ In this method water applied to the field to be irrigated by a series of long narrow field channels which are called as furrows, are excavated at regular interval.

→ water entering into these furrows infiltrates into the soil and spreads laterally to irrigate the area between the furrows.

→ In this method, 20–50% area is wetted which results in less evaporation

→ It is suitable for Row crops, cotton, maize, potato, groundnut etc.

6) Sprinkler irrigation



→ In sprinkler irrigation method, water is applied to the land in the form of spray through the network of pipes and pumps.

→ Advantages

(a) It is similar to rain, hence uniform application of water is possible.

(b) It can be used for wide range of topography, soil and crops i.e. irregular topography, steep slope and area in which soil is easily erodable.

(c) No field preparation is required.

(d) Surface runoff and percolation losses are eliminated.

(e) Field application efficiency increases close to 80%.

(f) Fertilizer, insecticide and pesticide can be mixed with water and supplied.

(g) It can be used even when infiltration capacity of soil is high or low.

(h) It can be used even when water table is high.

(i) About 15-20% crop area is increased because no area is lost in ditches and furrows.

→ Disadvantages

(a) Evaporation loss is high.

(b) It causes interference in farming operation due to network system.

(c) Wind may disturb sprinkler pattern which results in non-uniform application of water.
(d) High initial cost.
(e) Requires large electrical power and constant water supply.
(f) Cannot be used for crops requiring large and frequent depth of water. ex- paddy.
(g) Water shall be cleaned from sand and silt because it may cause choking of the system.

7) Drip Irrigation / Trickle Irrigation

→ In this method water is directly and slowly applied to the root zone of the plants by using small diameter plastic pipes with drip nozzles, commonly called as emitters or drippers
→ Water is applied at very low rate (2-10 l/hr) to keep the soil moisture within the desired range of plant growth.
→ Irrigation application efficiency = 90%
→ Evaporation loss, surface run off and percolation loss can be eliminated.
→ Fertilizer can be mixed with water and supplied.
→ Cost of whole system is very high but it is useful ~~for it~~ in the areas where availability of water is less.
→ It is very useful for fruits and vegetables.

⇒ Quality of Irrigation water

1) Sediment
(a) Effect of sediment on quality of irrigation water depends on nature of sediment and characteristic of soil receiving that water.

→ If sediment contains large content of plant nutrients and/or it comes from fertile area then it is quite beneficial particularly for the soil which has low content of plant nutrient and very low water holding capacity.

→ If sediment is not rich in plant nutrients and it is deposited on the surface of fertile area, then it will make area infertile.

2) Concentration of Soluble Salts

→ When salts present in irrigation water are in excess quantity they increase osmotic pressure of soil solution, which causes high soil moisture stress in the root zone and it affects growth of plants and yield of the crops.

→ Bad effect of salts on the plant growth depends on the concentration of salts left in the soil.

→ Concentration of salts in the water may not appear to be harmful initially but with the passage of time the salt concentration in the soil may increase to harmful level as soil solution gets concentrated by evaporation.

→ Salinity concentration of soil solution (C_s) after consumptive use (C_u) is given by:

$$C_s = \frac{C\,Q}{Q - (C_u - R_{eff})} \quad \text{PPM or mg/L}$$

Where, C → Concentration of salts in applied water

Q → Quantity of water applied.

C_u → Consumptive use of water i.e. total quantity of water used by crop for its growth.

R_{eff} → effective rainfall that is stored in the root zone

AIR-1 Notes
Pages: 60

Open Channel Flow
Handwritten notes by

Kartikay Kaushik
AIR-1 ESE 2021
IES Master classroom Student

OPEN CHANNEL FLOW

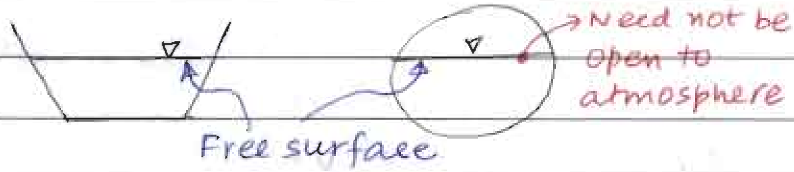
CONTENT

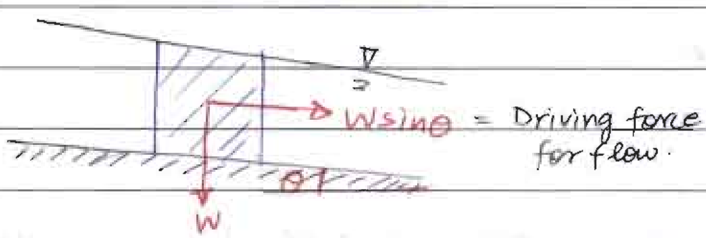
Open Channel Flow

1. Introduction
2. Uniform Flow
3. Energy-depth Relationship
4. Gradually Varied Flow
5. Rapidly Varied Flow
6. Surges (✗ GATE)

Chapter 1 – Introduction

→ Flow having free surface is called open channel flow.
→ open channel flow is due to the gravity effect.





> **NOTE:** On free surface, shear stress is 0.

Type of channel

- **Prismatic channel** – Channel having constant shape, size and bed slope are called prismatic channel. Generally, artifical channels like canals are prismatic
- **Non-Prismatic Channel** – Natural channels are generally Non prismatic canal.
- **Rigid Boundary Channel** – If boundary is non-deformable like – Lined canals or non-erodable unlined canal
- **Mobile Boundary Channels** – They are the ones in which boundary is deformable.

classmate

Date ______
Page ______

→ In rigid boundary channels, only depth of flow will vary with space and time particularly if it is prismatic.

→ The shape and roughness parameter is not a function of flow parameter

→ In mobile boundary channel, the flow carries significant amount of sediments in suspension and in contact with bed.

→ In OCF, we will study the prismatic channel.

⇒ Type of flow

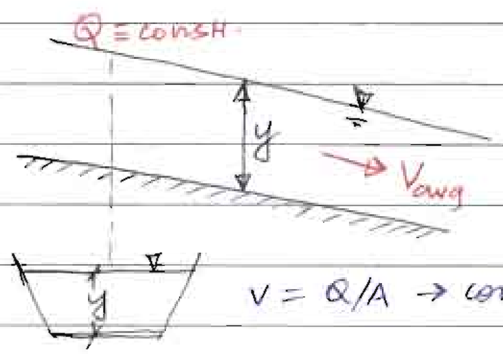
Steady Flow	Unsteady Flow
① Uniform Flow	① GVUF
② Gradually Varied Flow (GVF)	② RVUF
③ Rapidly Varied Flow (RVF)	③ SVUF
④ Spatially Varied Flow (SVF)	

→ If the depth of discharge changes with time, it is unsteady flow otherwise it is steady flow.

→ Steadyness or unsteadyness also depends on observers reference frame.

→ A flow may be unsteady in the inertial frame of reference but may be steady in other frame of reference.

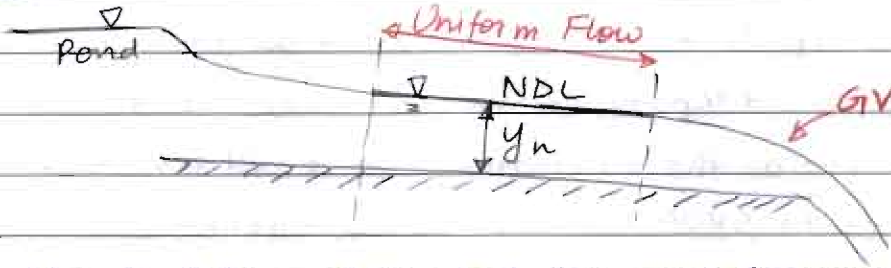
① Uniform Flow



$V = Q/A \rightarrow$ constant.

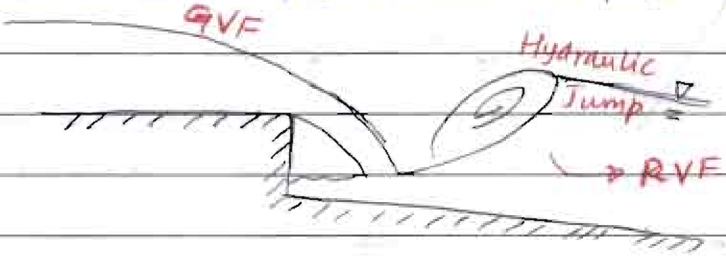
→ If in a prismatic channel, the velocity of flow and depth of flow is constant at various sections, then it is a uniform flow.

→ Depth of flow under Uniform flow is called Normal depth of flow.

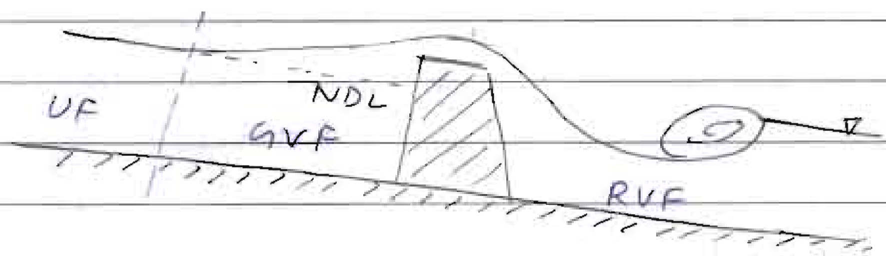


→ Any flow if left undisturbed for some distance, it tries to achieve normal depth of flow.

→ Obstruction to the flow causes the flow to vary



→ If the depth of flow varies gradually along the length of the channel it is called Gradually varied flow. But if the depth of flow varies rapidly varied flow.



→ We know that, if streamlines are straight lines, pressure variation across the depth can be taken as hydrostatic [i.e. piezometric head is constant with depth). Hence, in case of uniform flow, pressure variation across the depth can be taken as hydrostatic.

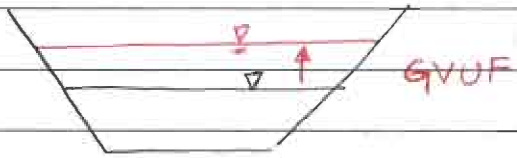
→ In case of GVF, since the streamlines are curved, normal acceleration will exist and pressure distribution truly will not be hydrostatic but since the curvature of streamline is very small in case of GVF, we can take the pressure variation to be hydrostatic, but

→ In case of RVF, since the curvature of streamline is large, pressure distribution across the depth will not be hydrostatic.

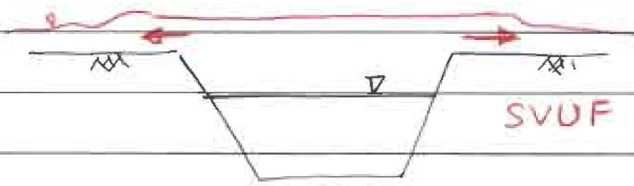
→ Since the GVF profile length is large, friction has significant effect on it but effect of friction on RVF can be neglected.

⇒ SVF – If the flow is added or extracted from the system, the flow will be called spatially varied, like infiltration from runoff. So long as the infiltration rate is not constant, flow will be termed as SVUF but once the infiltration rate becomes constant, flow can be treated as SVF.

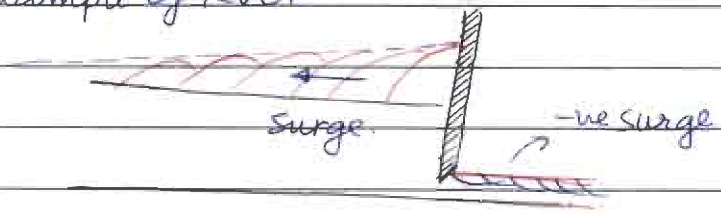
→ Passes of flood wave through a river is an example of GVUF



→ But if the river banks are breached, it is an example of SVUF



→ Surge is an example of RVUF



⇒ Laminar and Turbulent Flow

→ Reynolds no. in OCF, $\boxed{R_e = \frac{VR}{\nu}}$

$V \rightarrow$ average velocity

$R \rightarrow$ Hydraulic Radius $= \frac{\text{Area}}{\text{Wetted Perimeter}}$

→ If $R_e < 500$ → Flow in Open channel is laminar.

→ If $R_e > 2000$ → Flow is taken as turbulent.

→ Generally natural channels and canals have turbulent flow.

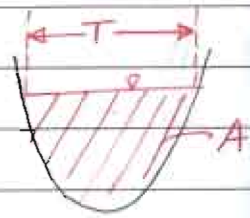
⇒ Critical, Sub-Critical and Super critical flow

$$\boxed{F_r = \frac{V}{\sqrt{gD}}}$$ → average

D = hydraulic Depth $= \frac{A}{T}$

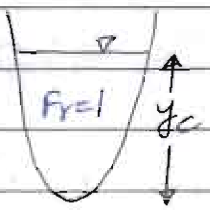
A → Area of flow

T → Top surface width



⇒ $C = \sqrt{gD}$ = celerity → velocity of small gravity wave that occurs in shallow water, generated due to disturbances or obstacles in the channel. It is the velocity of wave wrt water and travels both upstream and downstream → small

$V = C$	$F_r = 1$	→ Critical flow
$V > C$	$F_r > 1$	→ Supercritical flow / Torrential / Shooting / Rapid flow
$V < C$	$F_r < 1$	→ Sub-critical flow / Tranquil flow



$F_r = 1 \rightarrow y = y_c$

$F_r < 1 \rightarrow y > y_c$

$F_r > 1 \rightarrow y < y_c$

$$F_r = \sqrt{\frac{\text{Inertial Force}}{\text{Gravitational Force}}}$$

⇒ Velocity of wave wrt ground

velocity of wave wrt water = c [small wave in shallow water]

Velocity of wave wrt ground = $c \pm V_{water}$

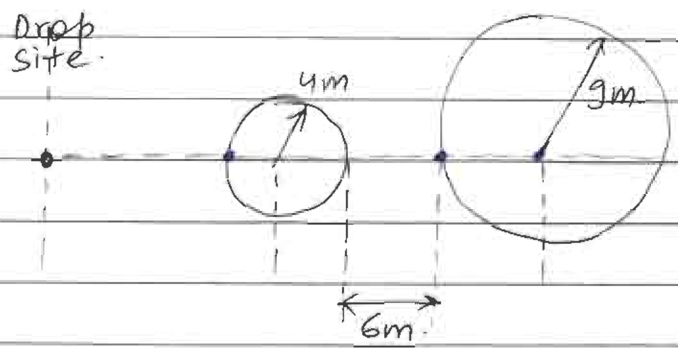
⇒ Upstream travel speed of wave = $C - V$

⇒ Downstream travel speed of wave = $C + V$

→ Under sub-critical flow conditions, since $V < C$, the small disturbance wave can travel upstream, but under super critical flow, since $V > C$, a small disturbance wave cannot travel upstream.

→ This property can be used for identifying the type of flow in field by throwing a small object, creates a ripple which travels in upstream direction also, the flow is subcritical and if does not travel upwards, the flow is supercritical.

Q- Water flows rapidly in a flat wide channel, 0.4 m deep. Pebbles dropped successively in the water at the same spot creates 2 circular ripples as shown in the figure below. Find the speed of water in m/s.



$\frac{V}{\sqrt{gy}} > 1$. $\quad c = \sqrt{gy} = 1.98$ m/s

$V > c$

$(V-c)(t_2-t_1) = 14$

$(V+c)(t_2-t_1) = 24$

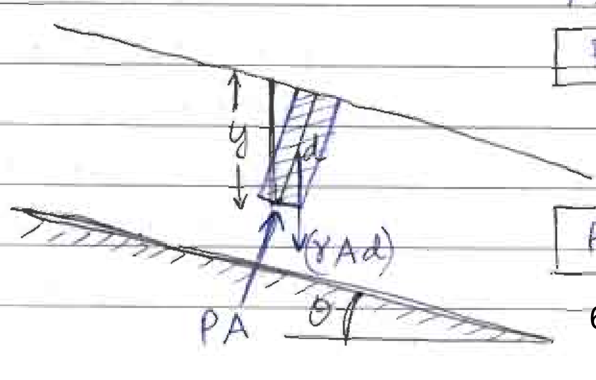
$\frac{V-c}{V+c} = \frac{14}{24} \Rightarrow 24V - 24c = 14v + 14c$

$\Rightarrow V = \frac{38c}{10} = 7.524$ m/s

→ Since disturbance does not travel upstream in super critical flow, it means that the flow upstream of a specified location does not know what is happening on the downstream side. In other words, ~~the~~ to change of flow condition at a section, flow condition must be changed on the upstream side in case of super-critical flow. The super critical flow is said to have u/s control.

→ Sub critical flow is said to have downstream control.

⇒ Pressure Distribution



$PA = (\gamma A d)\cos\theta$

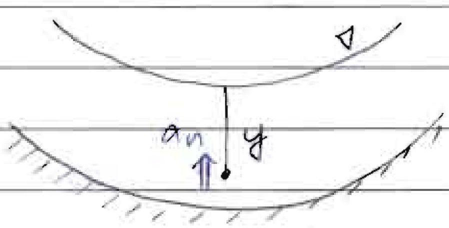
$\boxed{P = \gamma d \cos\theta}$

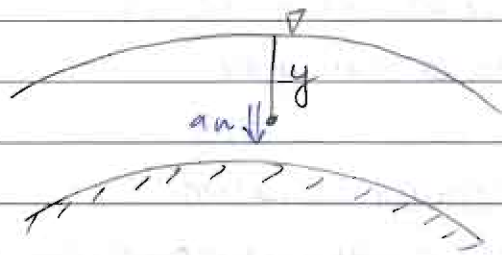
Since, $d = y\cos\theta$

$\boxed{P = \gamma y \cos^2\theta}$

→ Generally for natural channels, $\theta < 6^\circ$ and hence pressure can be taken as γy i.e hydrostatic pressure

→ Generally for large slopes i.e $\theta \geq 6^\circ$, we consider the effect of θ in pressure





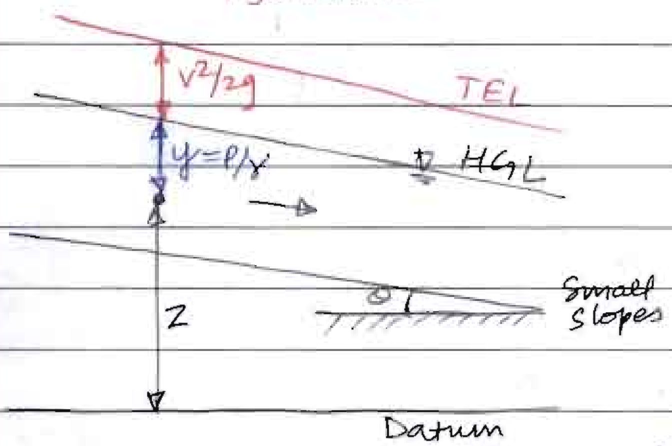
$P = \rho\, g_{eff}\, h$

$\boxed{P = \rho(g + a_n)y}$

↳ $P > P_{hydrostatic}$

$\boxed{P = \rho(g - a_n)y}$

↳ $P < P_{hydrostatic}$

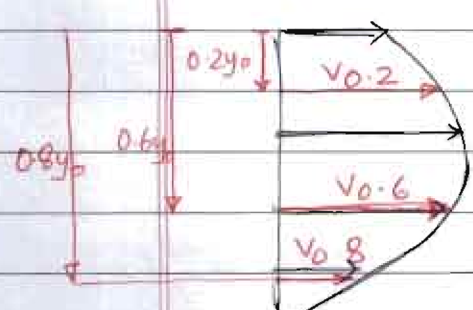


→ Generally for small slopes, HGL coincides with the free surface

$$\boxed{H_{large\ slope} = y\cos^2\theta + z + \frac{v^2}{2g}}$$

→ For large slopes, HGL lies below the free surface.

NOTE: In OCF, free surface coincides with HGL if the channel slope is small, vertical curvature of the flow lines and acceleration are negligible.

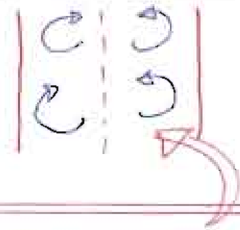


$$\boxed{V_{avg} = V_{0.6} = \frac{V_{0.2} + V_{0.8}}{2}}$$

→ V_{max} occurs slightly below the free surface

→ V_{avg} is taken as $K\, V$ ~~avg~~ free surface

i.e $\boxed{V_{avg} \simeq K\, V_{free\ surface}}$ → where $K = 0.8$ to 0.95

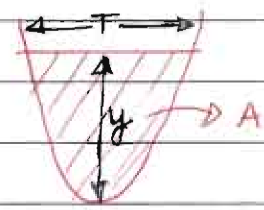


- The dip in the flow profile is due to secondary currents.
- Wind effects are negligible
- if $B > 10y$ [5-10 times of y], the channel is treated as wide channel and in wide channel in the central part, the velocity dip is negligible.

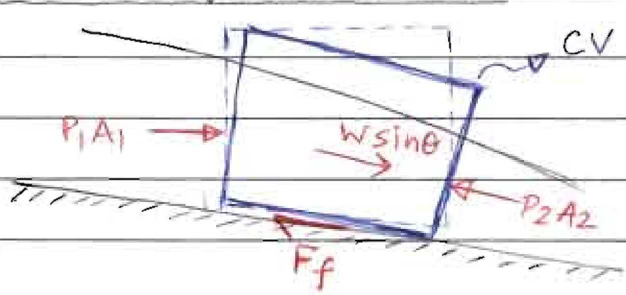
⇒ Continuity Equation

- For steady incompressible flows, the continuity equation in open channel is taken as $\boxed{Q = \text{constant}}$ i.e. $A_1V_1 = A_2V_2$
- For unsteady incompressible flows, the continuity equation is taken as:

$$\boxed{\frac{\partial Q}{\partial x} = -T\frac{\partial y}{\partial t}}$$



⇒ Momentum equation in OCF



$\beta_2 \approx 1$ $\beta_1 \approx 1$

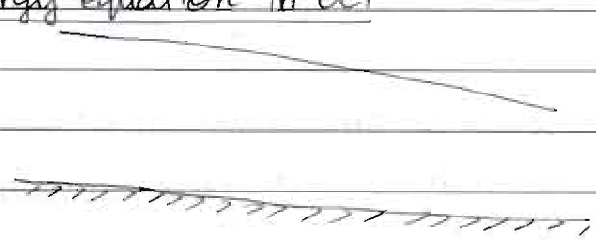
$$P_1A_1 - P_2A_2 + W\sin\theta - F_f = M_2 - M_1 = \beta_2 \rho Q V_2 - \beta_1 \rho Q V_1$$

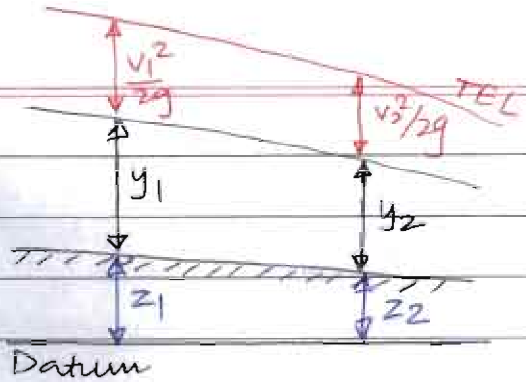
for horizontal and frictionless channel,

$$P_1 - P_2 = M_2 - M_1$$

$$\boxed{\frac{P_1 + M_1}{\gamma} = \frac{P_2 + M_2}{\gamma}} \Rightarrow \boxed{\frac{P+M}{\gamma} = \text{specific force.}}$$

⇒ Energy equation in OCF





$$\frac{P_1}{\gamma} + z_1 + \frac{v_1^2}{2g}\alpha_1 = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g}\alpha_2 + h_L$$

$(\alpha \simeq 1)$

$$\boxed{y_1 + z_1 + \frac{v_1^2}{2g} = y_2 + z_2 + \frac{v_2^2}{2g} + h_L}$$

$$\boxed{\text{Specific energy} = \frac{v^2}{2g} + y = E}$$

→ Specific energy can be said to be the distance b/w channel bed and TEL.

NOTE: Critical Flow

→ Under critical state of flow, flow is under unstable state i.e. even a small change in the energy i.e. even a small disturbance can cause significant change in the depth of flow.

→ water surface will appear to be wavy and unsteady.

→ Under critical condition,

① Specific energy is minimum for a given discharge.

② Discharge is maximum for a given specific energy.

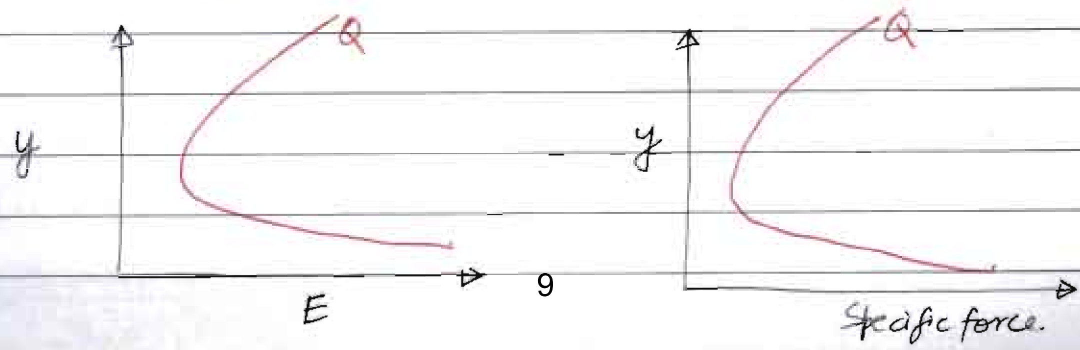
③ Specific force is minimum for a given discharge.

→ Froude No. = 1

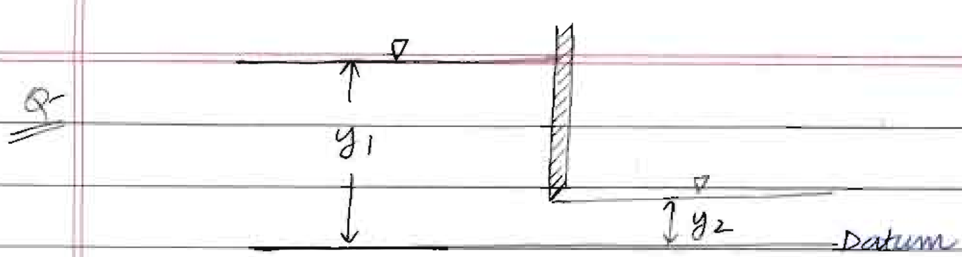
→ Velocity head = $\frac{1}{2}$ × (hydraulic depth) $\left[\frac{v^2}{gD} = 1 \Rightarrow \frac{v^2}{2g} = \frac{D}{2}\right]$

→ Velocity of flow in channel of small slope with uniform velocity distribution equals celerity (c) of small gravity wave in shallow water caused by local disturbances.

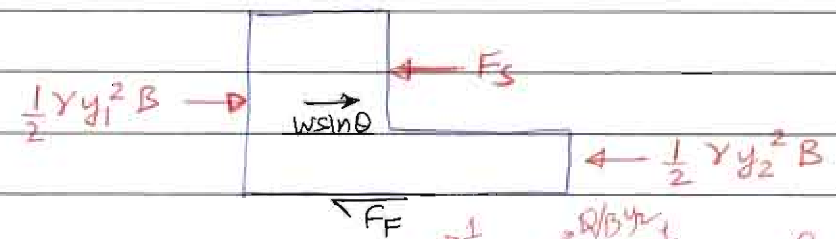
→ Slight change in ~~depth~~ energy causes significant change in depth of flow



Q-



Find the force exerted by water on the sluice gate assuming negligible losses.



$$\frac{1}{2}\gamma(y_1^2-y_2^2)B - F_s = \underbrace{\beta_2}_{1}\rho Q \underbrace{V_2}_{Q/By_2} - \underbrace{\beta_1}_{1}\rho Q \underbrace{V_1}_{Q/By_1}$$

$$F_s = \frac{B\gamma(y_1^2-y_2^2)}{2} + \frac{\rho Q^2}{B}\left(\frac{1}{y_1}-\frac{1}{y_2}\right)$$

Now, applying energy eq^n

$$y_1 + \frac{V_1^2}{2g} = y_2 + \frac{V_2^2}{2g}$$

$$\frac{Q^2}{2gB^2} = \frac{y_1-y_2}{\frac{1}{y_2^2}-\frac{1}{y_1^2}} = \frac{y_1^2 y_2^2}{y_1+y_2}$$

$$F_s = \frac{B\rho g(y_1^2-y_2^2)}{2} + 2\rho g B\left(\frac{y_1^2y_2^2}{y_1+y_2}\right)\left(\frac{1}{y_1}-\frac{1}{y_2}\right)$$

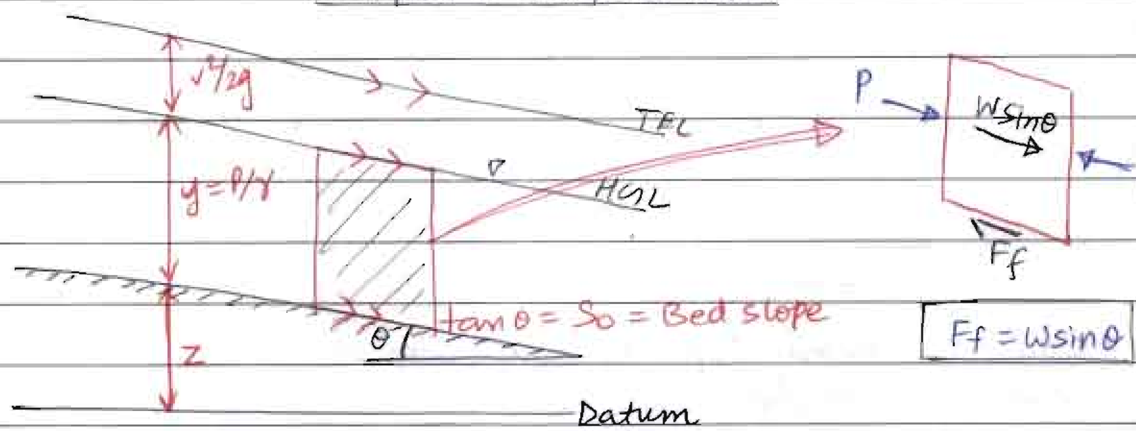
$$\frac{F_s}{B} = \frac{\gamma_w}{2}\quad y_1^2-y_2^2 + 4\frac{y_1^{\cancel{2}}y_2^{\cancel{2}}}{y_1+y_2}\left(\frac{y_2-y_1}{\cancel{y_1y_2}}\right)$$

$$\frac{F_s}{B} = \frac{\gamma_w}{2}(y_1-y_2)\left[y_1+y_2 - \frac{4y_1y_2}{y_1+y_2}\right]$$

$$\boxed{\frac{F_s}{B} = \frac{\gamma_w}{2}\frac{(y_1-y_2)^3}{y_1+y_2}}$$

NOTE: If we have the discharge given in the above problem then we should not use the formula for force per unit width as given above

Chapter-2 Uniform Flow



→ If the depth of flow, velocity of flow remains constant along the channel length, then the flow is said to be uniform.

→ velocity of flow can vary along the depth but velocity profile at every section will remain same.

→ For establishment of uniform flow certain length is required as transitiory zone. If the length of channel is less than the transitory zone length, uniform flow will not get established.

→ In case of uniform flow since the velocity is not changing, the weight component in the direction of flow must be balanced by the frictional force.

→ The constant depth of flow under uniform flow is called normal depth of flow (y_n). Any flow if left undisturbed for sufficiently long distance, it will try to achieve, the normal depth of flow.

→ Under uniform flow condition, since y and v are constant, the total energy line, the water surface line & bed of the channel will all be parallel, Hence, $\boxed{S_f = S_0}$ (S_f is the energy line slope)

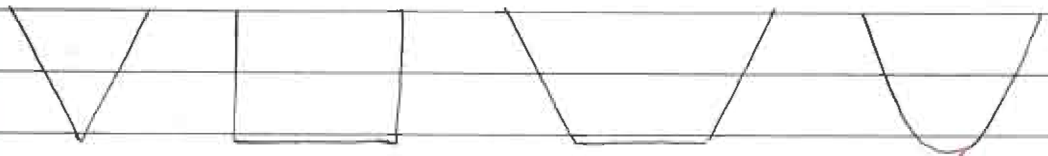
$$\boxed{Q = \frac{1}{n} A R^{2/3} S_f^{1/2} = \frac{1}{n} A R^{2/3} S_0^{1/2}}$$ ⇒ Manning's Equation

$$\boxed{Q = CA\sqrt{RS_f} = CA\sqrt{RS_0}}$$ ⇒ Chezy's Equation.

→ Since, in uniform flow, $S_f = S_0$.

$$\frac{Qn}{\sqrt{S_0}} = R^{2/3} \cancel{S_0^{1/2}} A \Rightarrow \boxed{\frac{Qn}{\sqrt{S_0}} = \underbrace{AR^{2/3}}_{f(y)}}$$

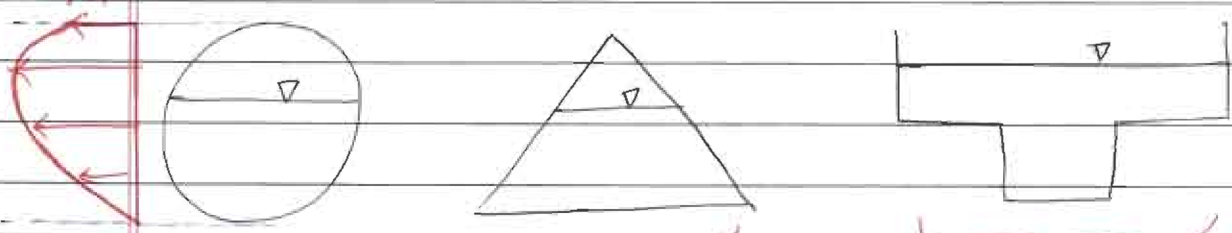
→ Depth of flow obtained from this equation is $y = y_n$ i.e. normal depth of flow.



Only one normal depth of flow for a fixed Q, n, So.

↳ Type 1 channel (Regular channels)

$AR^{2/3}$



There can be more than one depth for which the flow is uniform, for fixed Q, n, So

↳ Type 2 channel

Irregular Geometry

① Type 1 channel – Top surface width is increasing or remains constant with increasing depth.

② Type 2 channel – Top surface width is decreasing with increasing depth.

> NOTE: $AR^{2/3}$ increases with increase in depth of flow for type 1 channels but for Type 2 channels it increases and then decreases.

→ If n and So are known, there is only one discharge possible for uniform flow.

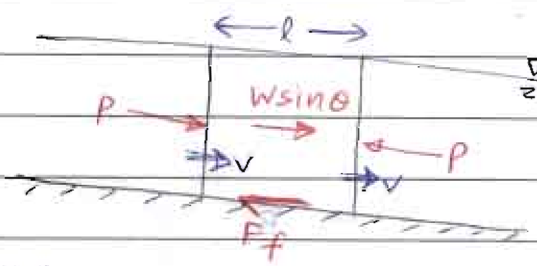
→ Value of chezy's constant is $\boxed{c = \sqrt{\frac{8g}{f}}}$ $f \rightarrow$ Darcy weischback friction factor.

→ Manning's n can be written as $\boxed{n = (n_b + n_1 + n_2 + n_3 + n_4)\, m}$

$n_b \rightarrow$ base value for straight, uniform and smooth channel
$n_1 \rightarrow$ depends on surface irregularity
$n_2 \rightarrow$ depends on shape and size of X-section
$n_3 \rightarrow$ depends on obstruction
$n_4 \rightarrow$ depends on vegetation
$m \rightarrow$ depends on meandering of channel

→ For lined canals, value of n ranges b/w 0.011 to 0.016
For natural channels, value of n ranges b/w 0.025 to 0.050

→ Momentum equation for uniform flow



$P - P + W\sin\theta - F_f = \rho QV - \rho QV$

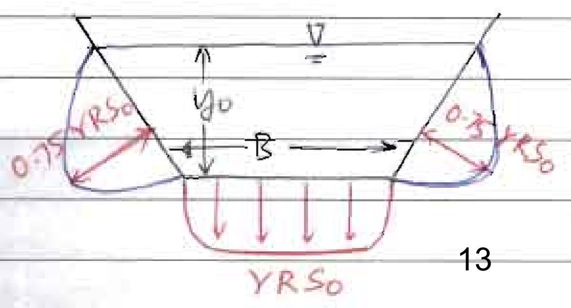
$\boxed{F_f = W\sin\theta}$

$W = \gamma A l$

$F_f = \tau_{bed} \times P \times l$

As θ is very small, $\sin\theta \simeq \tan\theta = S_0$

So, $\tau_{bed} = \frac{\gamma A l S_0}{P l} = \gamma R S_0 \Rightarrow \boxed{\tau_{bed} = \gamma R S_0}$ → Average shear on the bed.



Valid for $B > 6y_0$

AIR-1 Notes

Pages: 41

PLASTIC ANAYSIS

Handwritten notes by

Kartikay Kaushik

AIR-1 ESE 2021

IES Master classroom Student

PLASTIC ANALYSIS

→ In the conventional design, a section is assumed to have failed if any point in the section reaches the permissible stress for atmost yield stress (f_y).

→ However, if one point in the cross-section reaches the f_y value the section still has capacity to resist loading before collapse.

→ Thus in plastic analysis, we use the strength beyond the point of first yield i.e. Reserve of strength.

→ Plastic analysis is mostly used for indeterminate structures.

→ In case of determinate structures, beam might fail in deflection criteria before collapse load is reached whereas in case of indeterminate structures, even near collapse loading, deflection may not be significant.

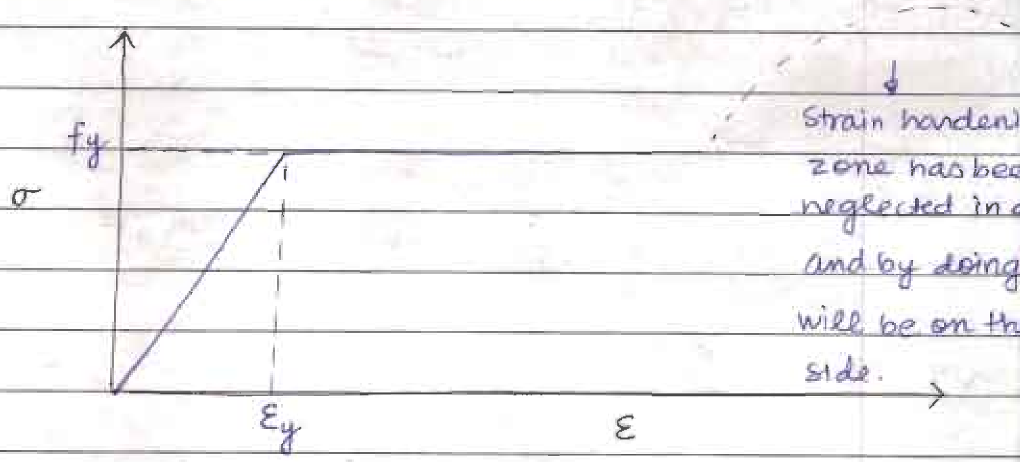
→ Hence, failure mode will be material failure only.

⇒ Assumptions in Plastic Analysis

① Material must possess ductility so that it can be deformed to plastic state.

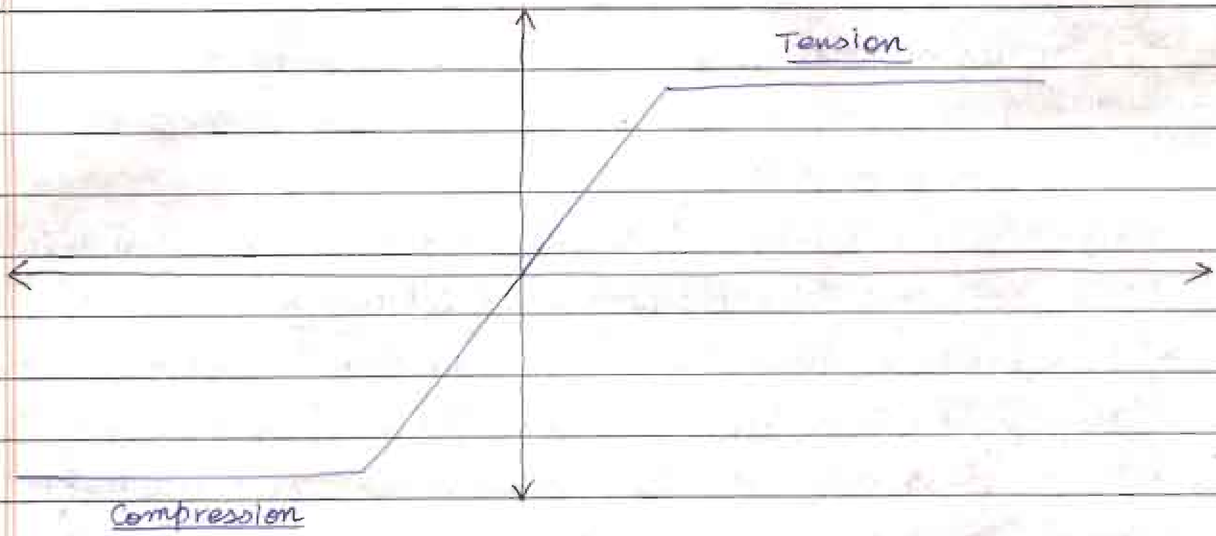
② Strain distribution diagram is linear i.e. plane section before bending remains plane after bending.

③ Stress-strain diagram is idealised elasto-plastic.



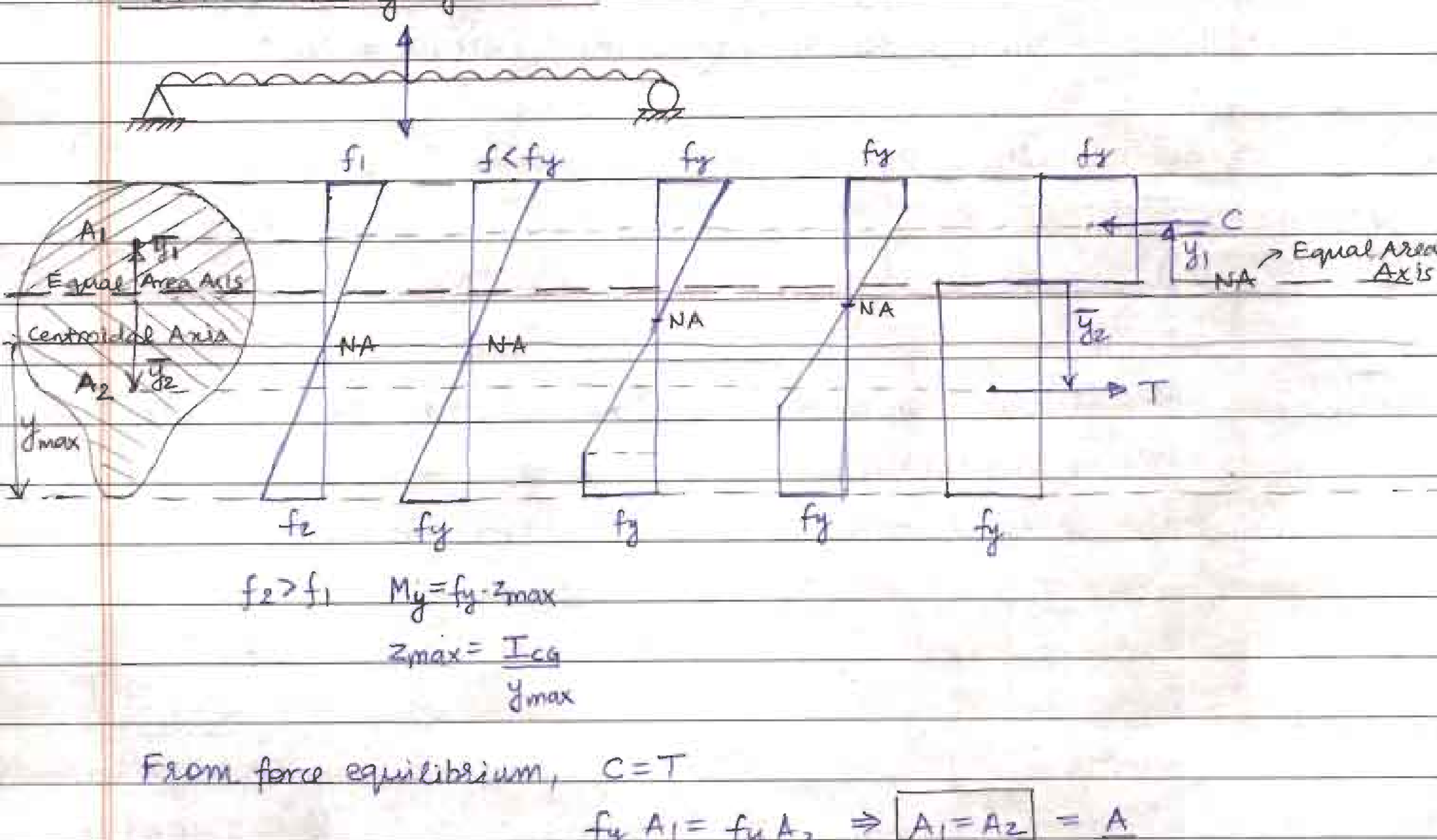
Strain hardening zone has been neglected in design and by doing so we will be on the safer side.

④ Relation between stress and strain is same in tension and compression



⑤ Joints should be sufficiently rigid to transfer the moments.

⇒ Plastic Bending of Beam



$f_2 > f_1$ $\quad M_y = f_y \cdot z_{max}$

$z_{max} = \dfrac{I_{CG}}{y_{max}}$

From force equilibrium, $C = T$

$$f_y A_1 = f_y A_2 \Rightarrow \boxed{A_1 = A_2} = \frac{A}{2}$$

and $M_P = C(\bar{y}_1 + \bar{y}_2) = T(\bar{y}_1 + \bar{y}_2)$

$= f_y \dfrac{A}{2} (\bar{y}_1 + \bar{y}_2)$.

So, $\boxed{M_p = \frac{f_y A}{2}\left(\bar{y}_1 + \bar{y}_2\right) = f_y Z_p}$

$\boxed{\text{where } Z_p = \frac{A}{2}\left(\bar{y}_1 + \bar{y}_2\right)}$

$M_p \rightarrow$ Fully Plastic Moment Capacity

$Z_p \rightarrow$ Plastic Modulus.

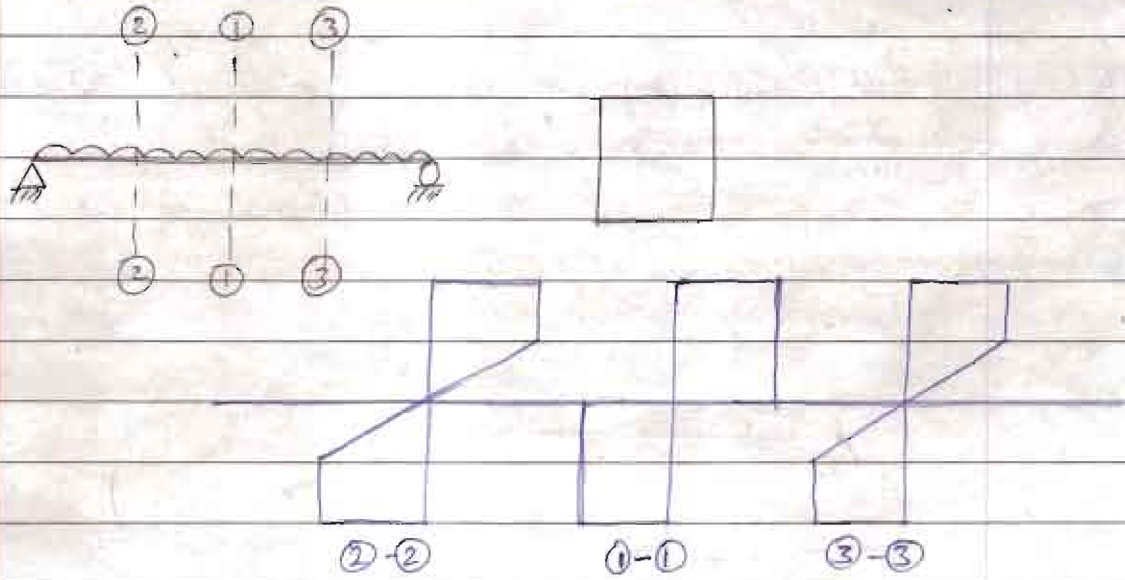
$\bar{y}_1, \bar{y}_2 \rightarrow$ are centre of Gravity of Equal Areas above and below equal area axis.

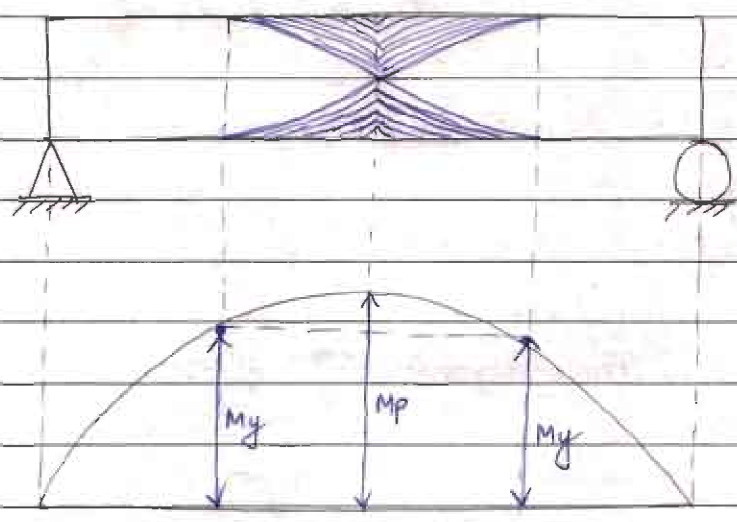
→ Upto elastic bending, NA coincides with centroidal axis whereas under fully plastic bending NA coincides with equal area axis.

→ When BM @ a section becomes M_p, it is said to develop a plastic hinge in which moment capacity $= M_p$

→ Moment capacity of a mechanical hinge $= 0$.

→ Plastic hinge can be thought of as a rusted hinge in which upto BM, M_p, there is a resistance against rotation but the instant, the applied BM becomes M_p, the moment resisting capacity of this section (beyond M_p) becomes equal to 0.





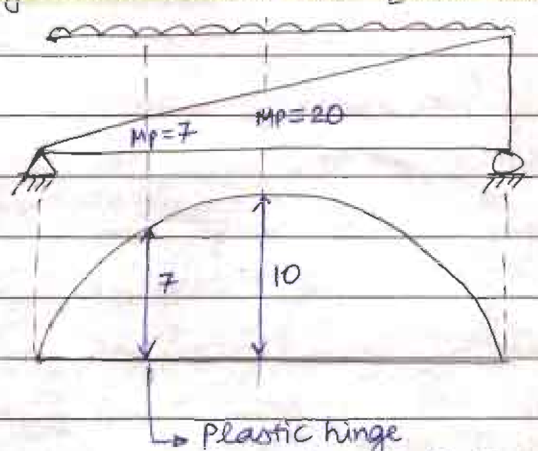
→ Plastic hinge can be defined as a yielded zone due to flexure in a structure in which infinite rotation can take place at a constant resisting Moment, Mp of that section.

NOTE: However, for calculation purpose, plastic hinge will be assumed to be at a single section where the applied BM = Mp.

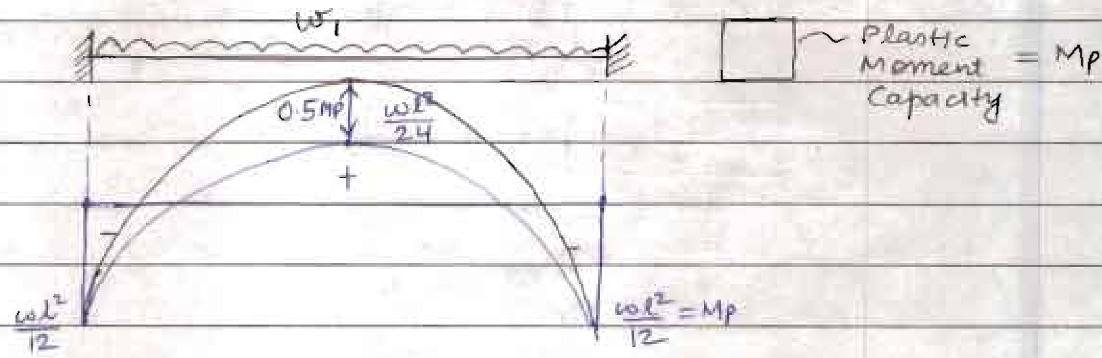
⇒ Important Points

① A section is said to develop plastic hinge when flexural stress at every point of the section becomes equal to fy.

② In the span of a beam, plastic hinge forms first at a section subjected to greatest curvature [Not always greatest BM]



③ Due to formation of plastic hinges one after the other, redistribution of moment takes place and because of this, load carrying capacity of the structure becomes greater than the load at which first plastic hinge forms.



when $w = \frac{12 M_P}{l^2}$, the ends become plastic hinge.

When $w_2 = \frac{4 M_P}{l^2}$, the mid-span will become a plastic hinge and the beam collapses. So collapse load $= w_1 + w_2 = \frac{16 M_P}{l^2}$

④ No of plastic hinges required for complete collapse of the structure $= R+1$, where R is the degree of static indeterminacy of the structure.

NOTE: However, partial collapse of structure due to no of plastic hinges less than $R+1$.

→ If at collapse,
No. of plastic hinges are:

① $< R+1$ → Partial collapse
② $= R+1$ → Complete collapse
③ $> R+1$ → Over complete collapse

PAGE NO.

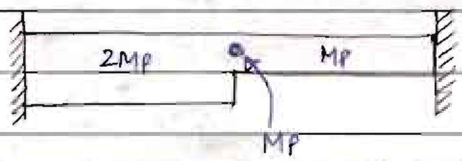
⑤ Length of plastic hinge depends on loading as well as cross section shape.

⑥ Plastic hinge is expected to form at:

(a) At fixed ends.

(b) At location of concentrated load

(c) At section of sudden change in geometry



→ When 2 sections join at ~~at~~ point plastic hinge forms in the section of smaller Mp

(d) At point of zero shear in a span subjected to distributed loading for beams of constant cross section.

⑦ For analysis of collapse, maximum no. of plastic hinges that we have to think of is R+1. If ~~at coll~~ no. of plastic hinges >(R+1) is formed, it will be at a load ≥ the load at which (R+1) hinges are formed.

⇒ Condition for plastic condition

In plastic analysis following must be satisfied:

1) Equilibrium condition [$\Sigma F = 0$ and $\Sigma M = 0$]

2) Yield condition [At collapse, BM @ any section must not be greater than the fully plastic moment capacity of that section]

3) Mechanism condition [At collapse sufficient no. of plastic hinges must develop, so as to transform a part or whole of the structure into a mechanism leading to collapse.]

→ if all the above 3 conditions are satisfied simultaneously, we get a lowest unique value of collapse load [Uniqueness Theorem]

→ In analysis using plastic method, we have 2 more theorems:

1) Lower Bound Theorem [Static method]

→ It satisfies equilibrium and yield condition.

→ Load determined on the basis of any assumed collapse BMD in which BM at any section is not greater than fully plastic moment capacity of that section will always be ≤ the correct collapse load.

2) Upper Bound Theorem [Kinematic method]

→ It satisfies equilibrium and mechanism condition.

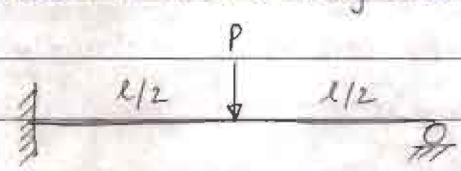
→ Load determined by assuming a mechanism is always greater than or equal to the correct collapse load.

OR

→ Of various possible mechanism, the correct mechanism is one for which loading is minimum.

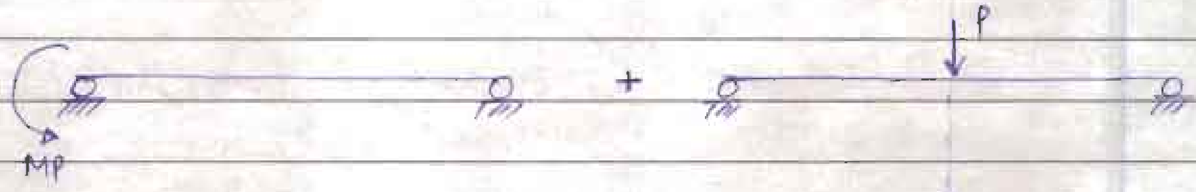
⇒ Static method of analysis

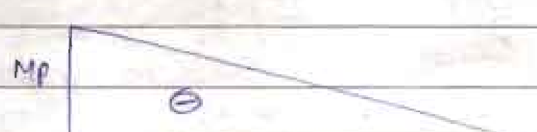
In static method we select moments as unknowns (Redundants) then, redundant BMD and free BMD is drawn. Finally combined BMD is drawn in such a way that a mechanism forms.

Q.


$R = 1$, So no. of plastic hinges required $= 2$

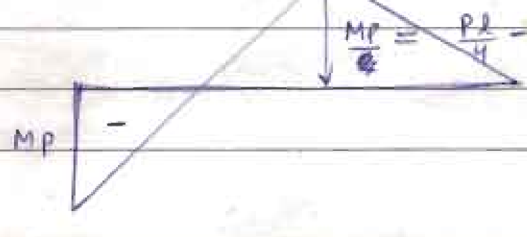
Find the collapse load P.





End moment Diagram

Free moment diagram



$\frac{M_p}{2} = \frac{Pl}{4} - \frac{M_p}{2} \Rightarrow M_p = \frac{2}{3}\frac{Pl}{4} = \frac{Pl}{6}$

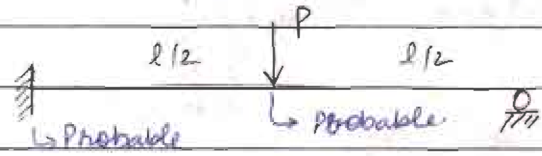
$\Rightarrow \boxed{P = \frac{6M_p}{l}}$

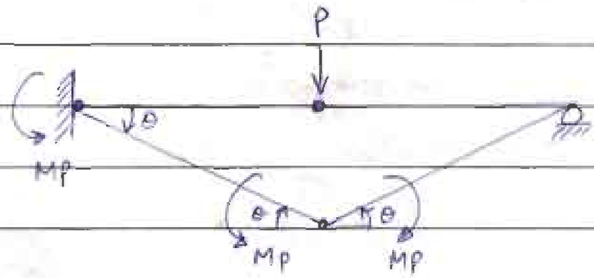
⇒ Kinematic method of analysis

→ Locate the possible places of plastic hinges.

→ Various possible mechanisms are ascertained and the collapse load is calculated working out principle of virtual work.

Q-





From principle of virtual work,

External Virtual Work = Internal virtual work

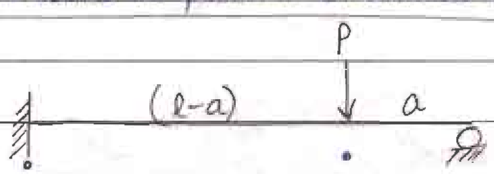
$$P \frac{l}{2} \phi = 3 M_p \phi$$

$$\boxed{P = \frac{6 M_p}{l}}$$

NOTE: Mp will always be shown opposite to the direction of θ

~~work~~ If the displacement is in the direction of load, the work done is positive otherwise negative.

Q-



~~Find collapse load P and Mp if~~

Find

(a) Find Mp if P is the collapse load. (Assume Mp unknown)

(b) Find the position of load for which collapse load is minimum. (Assuming Mp known)

AIR-1 Notes
Pages: 25

AIRPORT
Handwritten notes by

Kartikay Kaushik
AIR-1 ESE 2021
IES Master classroom Student

AIRPORT

CONTENT

Date
Page

Chapter - Airports

→ ICAO → International Civil Aviation Organization, Montreal, Canada.
→ FAA → Federal Aviation Administration, USA.
→ DGCA → Directorage General of Civil Aviation (Watchdog over AAI)
(Indian govt regulatory body for civil Aviation

⇒ Classification of Airports

1) General - Based on Takeoff and Landing

		Runway Length
CTOL →	Conventional Takeoff & Landing.	>1500m
RTOL →	Reduced Takeoff & Landing	1000-1500m
STOL →	Short Takeoff & Landing	500-1000m
VTOL →	Vertical Takoff & Landing	25 to 50m^2

2) Based on FAA code

Primary airport → Passenger >10000 per year
Non-Primary airport → Passenger <10000 per year

3) Based on ICAO code

(a) Based on Runway length

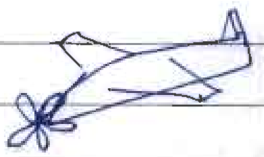
Code	Basic Runway Length (m)
1	<900
2	[900 - 1200)
3	[1200 - 1800)
4	≥ 1800

(b) Based on wingspan and distance b/w outside edge of main wheel gear

Code	Wingspan (m)	Dist. b/w -- (m)
A	<15	<4.5
B	[15-24)	[4.5-6)
C	[24-36)	[6-9)
D	[36-52)	[9-14)
E	[52-65)	[9-14)
F	[65-80)	[14-16)

Q ⇒ Classify Aerodrome as per ICAO, which is designed to accomodate Boeing 747 with outer main wheel gear span width of 10.44 m Wingspan = 48 m and requiring Basic runway length of 1830m. D, 4 ⇒ $\boxed{4D}$

⇒ Aircraft characteristics



1) Engine (Piston)
→ Propellor Driven aircraft
→ operate at low altitude and moderate speed.
→

2) Turbo Prop
→ Refers to propellor driven aircraft powered by turbine engine.

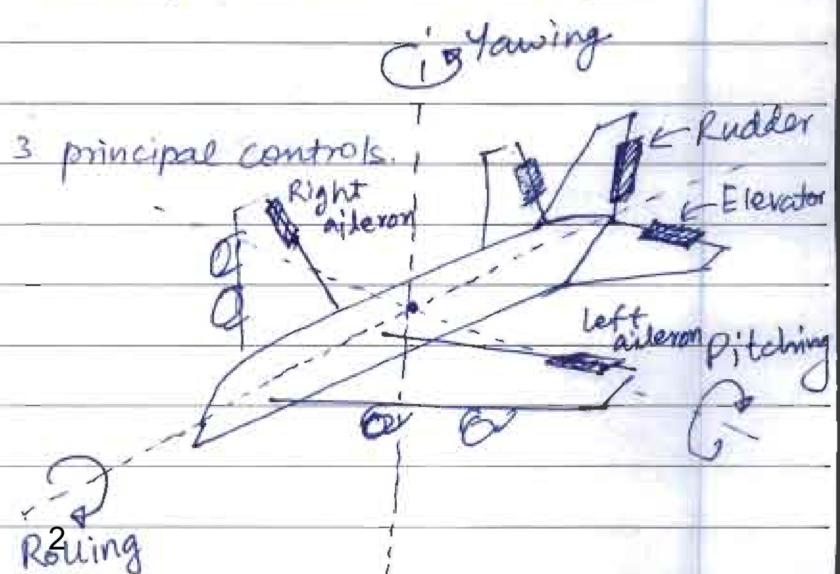
3) Turbofan / Steam jet
→ Refers to those aircraft which are not dependent on propellor for thrust
→ Nearly all commercial aircrafts are lined with turbofan

4) Ramjet
→ No moving part. Must be operated at high speed for fighter planes

⇒ Wing - Purpose of wing is to provide lift. It also carries fuel.

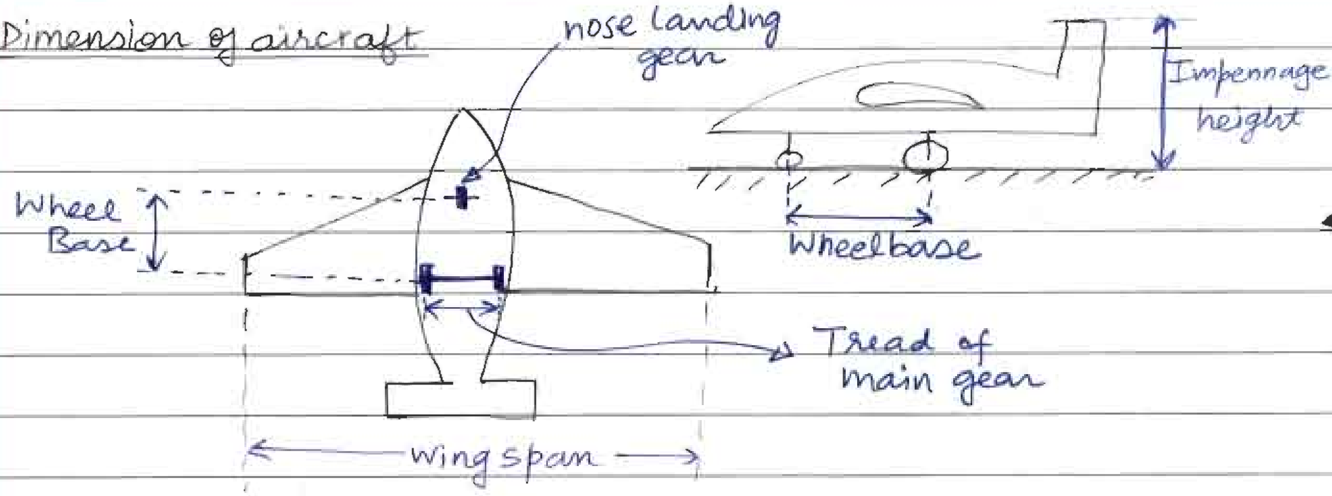
⇒ 3 - control surface
→ Aeroplane is provided with 3 principal controls.

1) Elevator → Pitching
2) Rudder → Yawing
3) Aileron → Rolling



Fuselage - Main body of the aircraft - Carries payload.

→ Dimension of aircraft



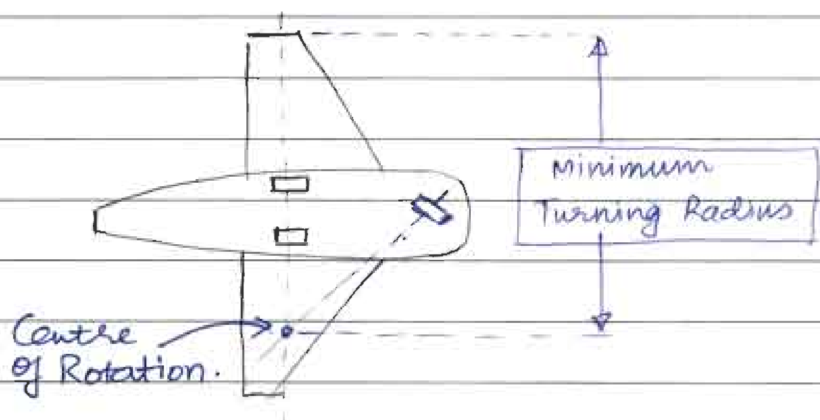
→ Minimum Turning Radius

→ For deciding the radius of taxiway, position of aircraft at apron and hangar it is essential to study about minimum turning radius.

→ To determine the minimum turning radius, draw a line through the axis of nose gear when it is at maximum angle of rotation.

→ Intersection point of this line and line drawn through the axis of 2 main gears is called centre of rotation

→ Distance of farther wing tip from the centre of rotation represent minimum turning radius.



→ Circling Radius

→ The minimum radius with which the aircraft can take turn in space.

→ Jet Blast

→ Aircraft eject hot exhaust gases with high speed

→ Fuel Spillage

→ At apron and hangar it is difficult to avoid spillage, hence it is necessary to provide constant supervision and monitoring.

→ Noise

→ Perceived Noise (Decibal → PNdB

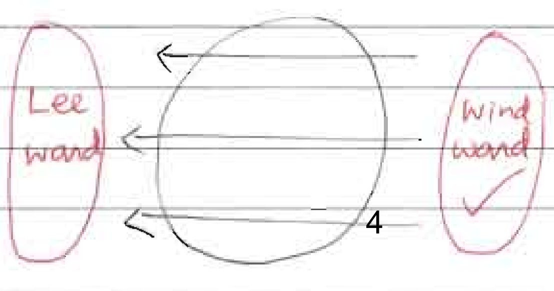
→ upto $1 km^2$ → 90 PNdB

$3 km^2$ → 80 PNdB.

Chapter - Airport Planning

→ Airport Site Selection factor

1) Use of airport → Civil/Military
2) Ground accessibility → Site should be accessible to users
3) Regional Plan → The site should fit well into the regional plan
4) Proximity to other Airport
5) Topography → Raised ground, plateau is ideal site for airport due to less obstruction, more uniform wind, natural drainage, better visibility.
6) Wind → Runway is oriented in the direction of wind.
   → The wind data of direction, duration and intensity should be collected from wind rose diagram over a minimum period of 5 years
   → The site should be located to windward dir^n of setting so that minimum smoke from city is blown over site.



classmate
Date
Page

7) Noise → should not be any residential development in the vicinity of airport.

A buffer area may be covered by vegetation b/w airport and heavily populated area to reduce noise level.

8) Future development

9) Drainage and soil characteristics

10) Obstruction and visibility

⇒ Imaginary surfaces

→ Zoning Law - These are the laws made by competent authorities in order to prevent future development in the vicinity of airport and also to prevent activities which will produce smoke and flume.

→ Imaginary surfaces - These are the established surfaces in relation to the airport and to each runway above which no obstruction should project. It depends on type and approach planned for runway, aircraft characteristics.

① Primary surface - Surface which is longitudinally centered on the runway. When the runway is paved, the primary surface extends 200feet beyond each end of runway. The elevation is same as that of runway.

(40:1)

② Approach surface - It is a surface which is longitudinally centered on the runway center line. It extends outwards and upwards from each end of the ~~runway~~ primary surface

→ Trapezoidal in shape

③ Take off climb surface - Similar to approach surface.

→ Provided at takeoff end of runway.

→ Trapezoidal in shape.

classmate

Date ______
Page ______

④ Inner horizontal surface (IHS) - It is the surface located in a horizontal plane above an aerodrome and its surrounding.

→ The shape need not be necessarily circular.

→ The radius of outer limit of IHS shall be measured from ARP (Airport Reference Point) and it goes from 2000m to 4000m

→ This surface is 45m above the elevation of ARP.

⑤ Conical Surface - It extends upwards and outwards from the periphery of IHS with a slope of 20:1. The slope of conical surface shall be measured in a vertical plane.

⑥ Transition surface - It is a surface along the side of the ~~straight~~ strip and part of the side of approach surface that slopes at 7:1, upward and outward.

Limit → Upper edge located in the plane of IHS.

→ Slope is measured in vertical plane.

⑦ Outer Horizontal Surface (OHS) - It is a circular, in plane with centre at ARP.

→ Height of OHS is 150m ~~is~~ above ARP

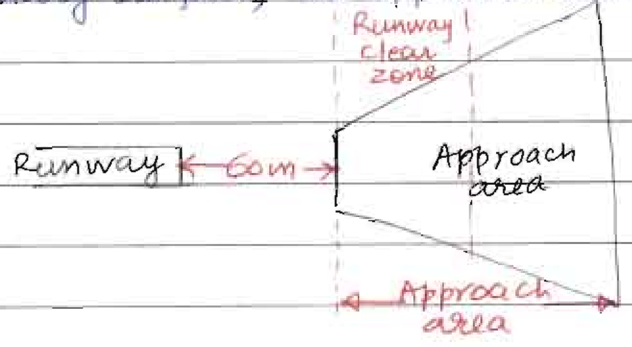
→ OHS extends to 15000 m from ARP.

⑧ Balked Landing Surface - A balked landing for an aircraft means an attempted landing that is abandoned during the final approach stage of the flight

→ This landing surface is an inclined plane originating at a specified distance after the threshold and extending b/w the inner transition surface.

⑨ Approach zone: The wide clearance area known as approach zone are required on either side of runway along the direction of landing and takeoff. → It represents the area on ground directly below the Imaginary approach surface

→ Over this area, the aircraft can safely ~~loose~~ lose or gain altitude.
→ The whole area has to be kept free from obstruction.
→ The plane of approach zone is same as approach surface. The only difference b/w the 2 is while approach surface is an imaginary surface, the approach area indicates actual ground.

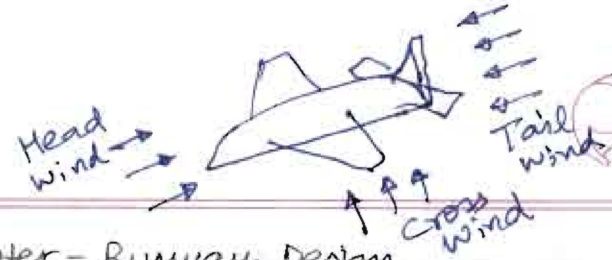


⑩ Runway Clear zone / Protection zone – The innermost portion of approach zone which is most critical from obstruction viewpoint is called clear zone.
→ For Instrumental landing → 750m (ILS)
For Non-instrumental landing → 600 m.

⑪ Turning zone – During the takeoff, if engine fails or pilot select to land for any reason, the aircraft will have to take a turn and come in line with runway before landing.
→ The area of airport other than approach area used for turning operation is known as turning zone.

⑫ OFZ (Obstacle free zone) – The inner approach, inner transition ~~turning zone~~ and balked landing surface together define a volume of airspace known as OFZ.
→ This zone shall be kept free from fixed objects other than navigational aids.

ALS – Approach Lighting System



Chapter - Runway Design

→ Runway is usually oriented in the direction of prevailing wind.

⇒ CW component and wind coverage

→ Limiting value of CW component as per ICAO

→ Design Length of Runway

Length of reference field (m)	Max. CW component (kmph)
>1500	37
1200-1500	24
<1200	19

⇒ Wind coverage

→ The %age of time in a year during which CW component remains within the permissible limit, is called wind coverage.

→ Runway for mixed air traffic should be planned with wind coverage of 95% and CW component 25 kmph

→ For busy airport, wind coverage may be increased to 98-100%.

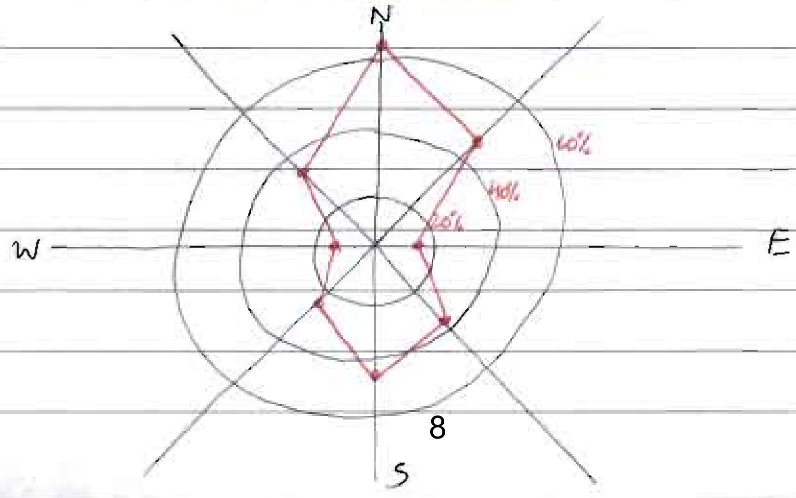
⇒ Wind rose

→ The graphical representation of wind data i.e. direction, duration and intensity is called wind rose.

→ The wind data of atleast 5 years and preferably 10 years should be considered while designing an airport.

→ Wind rose is used to determine the best orientation of runway.

→ Based on True North Orientation.



→ Type 1 showing direction and duration of wind

→ The radial lines indicate wind dirⁿ and each circle represent duration of wind.

→ The best direction of runway is usually along the direction of longest line on wind rose diagram.

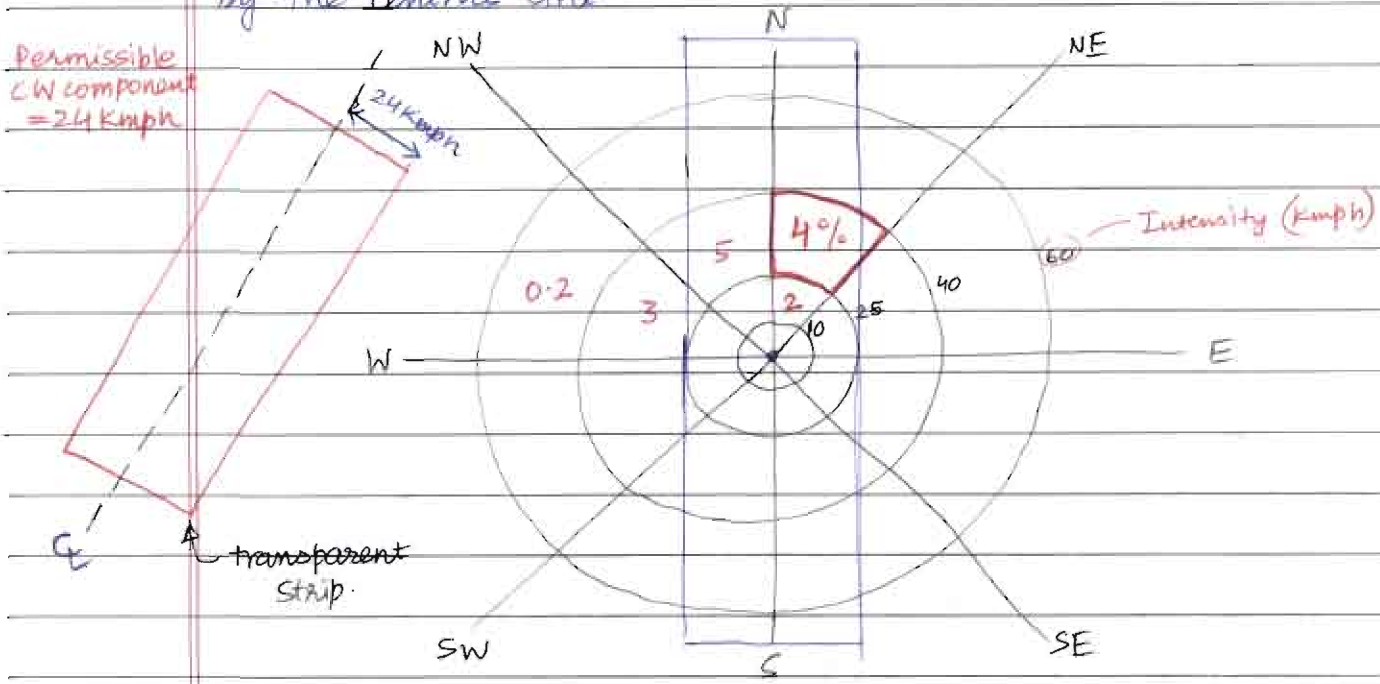
→ Type 2 - showing direction, duration and intensity of wind

→ Each circle represents wind intensity to some scale.

→ The value entered in each segment represents the %age of time in a year during which the wind having a particular intensity blows from respective direction.

→ Wind coverage can be calculated by summing up all the %ages shown in a segment.

→ The runway should be oriented along the direction represented by the central line.



⇒ How to use Wind Rose

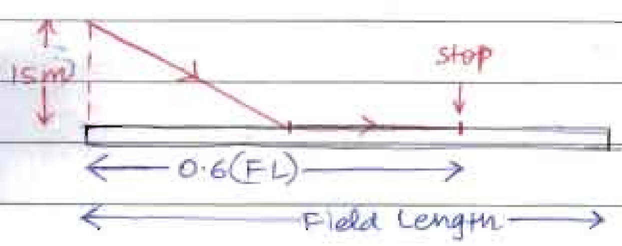
→ A transparent template with 3 parallel lines are used to get best orientation through wind rose

→ The middle line of template represents the runway ℄ and distance b/w it and each end of outside line is equal to allowable CW comp.

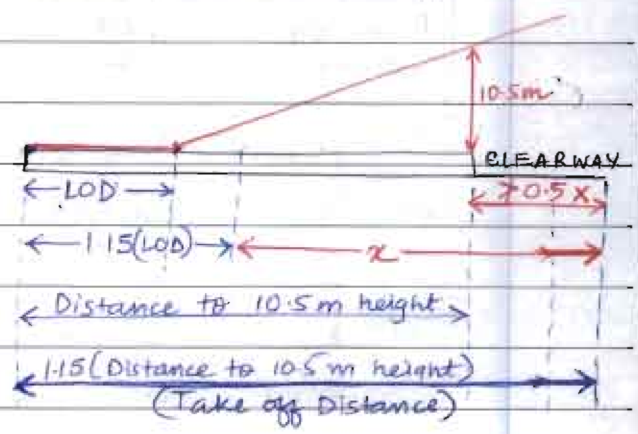
→ The ℄ of template placed on the centre of wind rose diagram.
→ The values inside the template is summed up to get total %age of time and hence to decide best orientation of runway for maximum %age time by rotating the template in different direction.
→ If single runway is not sufficient to provide the recommended coverage, then 2 or more runways should be planned.

→ Basic runway length
→ It is calculated under the following assumed condition at airport
1) → Airport altitude is at sea level.
2) Temperature at airport is standard (15°C)
Combined Correction ≯ 35%
3) Runway is levelled in longitudinal direction.
4) No wind blowing on runway
5) Aircraft is loaded at it's full loading capacity.
6) Enroute dirⁿ temp is standard and no wind is blowing.

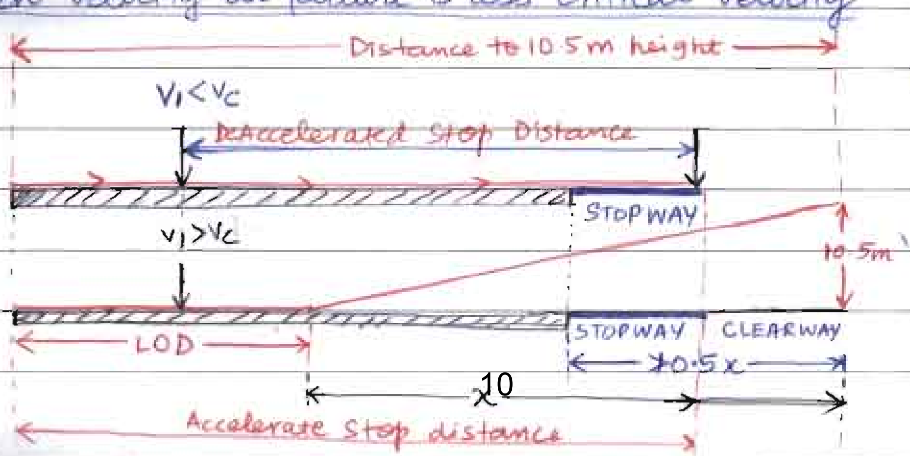
→ Case I Normal Landing



Case II Normal Takeoff



→ Case III Engine failure
① When velocity at failure is less critical velocity



V1 → engine failure speed.

② When velocity at failure is more than critical velocity

→ The basic runway length is determined by these 3 cases.

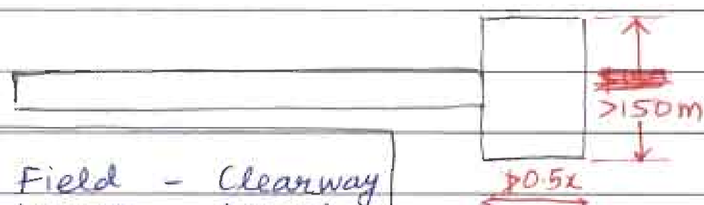
Case I Normal Landing - In this case the aircraft should come to stop within 60% of landing distance / Runway Length.
→ Entire landing distance is provided with full strength pavement.

$$\boxed{\text{Field Length} = \text{Landing Distance} = \frac{\text{Stop Distance}}{0.6}}$$

Case II Normal Take off case - In this case, minimum clearway width should be 150 m.

$$\boxed{\begin{aligned}\text{Field Length} &= \text{Take off Distance} \\ &= 1.15 \times (\text{Distance to } 10.5\text{ m height})\end{aligned}}$$

$$\boxed{CL_{max} = 0.5\,[\text{T.O.D.} - 1.15 \text{ of LOD}]}$$



$$\boxed{\text{Runway Length} = \text{Field Length} - \text{Clearway Length}}$$

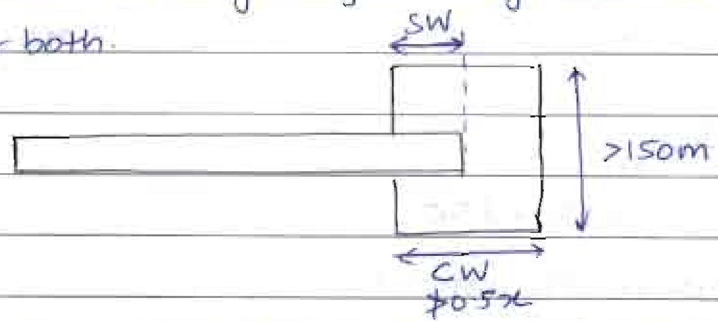
Full strength Pavement = F.L. - CL
or Take off Runway (TOR) length

Q. What is the FL and max^m clearway distance for a turbine powered aircraft with following performance.
(a) Normal Take off → LOD = 2133 m
b → Distance to height @ 10.5 m = 2438 m.

FL = 2803.7 m
CL = 175.375 m
Runway length = 2803.7 - 175.375 = 2628.325 m

Case IV Engine failure case – It describes as the case of 1 engine failure at a critical point during an aircraft take off.

→ In this case, basic runway length may consider either clearway or stopway or both.



→ SW is the area beyond the ~~rain~~ runway and centrally located in alignment with ~~to~~ the centre line of runway.

→ The strength of stopway should be sufficient to carry weight of aircraft without structural damage to aircraft

→ If the engine has failed at speed less than the critical ~~speed~~ engine failure speed, Aircraft decelerates with use of stopway.

→ If engine fails at at speed higher than critical speed then there is no option except to continue to take-off and turn in turning zone and land again.

> NOTE: critical engine failure speed or decision speed (V_c) is the speed at which engine fails and this is selected by manufacturer

(a) Engine failure takeoff

$$\boxed{F.L. = T.O.D = \text{Distance to } 10.5\,m \text{ height}}$$

$$\boxed{CL_{max} = 0.5\,[TOD - LOD]}$$

$$\boxed{\text{Full strength Length / T.O.R Length} = FL - CL}$$

(b) Engine failure aborted takeoff

$$FL = \text{Accelerate Stop Distance} = \underset{\text{Pavement}}{\text{Full strength}} + SW$$

Q: Calculate the length of full strength pavement as per specification for a turbine powered aircraft for engine failure ~~takeoff~~.
LOD = 2500 m
Distance to height 10.5 m = 2774 m

FL = 2774 m
CL = 0.5 [2774 − 2500] = 137 m
Full strength Pavement = 2774 − 137 = 2637 m

⇒ Correction for Elevation, Temperature & gradient
→ Necessary corrections for BRL are to be applied for elevation, temperature and gradient for actual site of construction.

① Correction for Elevation
According to ICAO, BRL should increase at the rate of 7% for every 300 m rise in elevation above MSL.

② Correction for Temperature

$$\boxed{\text{Airport Reference Temperature (ART)} = T_a + \frac{T_m - T_a}{3}}$$

T_a = monthly mean of average daily temp. of hottest month.
T_m = monthly mean of maximum daily temp.

→ According to ICAO, BRL after having been corrected for elevation, should be further increased by 1% for 1°C rise in ART above the standard atm. temperature at that elevation.
→ Temperature gradient of standard atm temperature from MSL to elevation at which the std. atm temp. is −60°C is 6.5°C / km.

③ Check for total correction [Elevation + Temperature]
→ According to ICAO, if the combined correction exceeds

AIR-1 Notes

Pages: 54

Railway

Handwritten notes by

Kartikay Kaushik

AIR-1 ESE 2021

IES Master classroom Student

RAILWAY

CONTENT

Railway

Ch-1 Rail, Railway and Rail Joint

→ A mode of transportation
→ IR is second largest in the world. (1st is Russia)
→ IR has 5 training institutes,
1) Indian Railway Institute of CE, Pune.

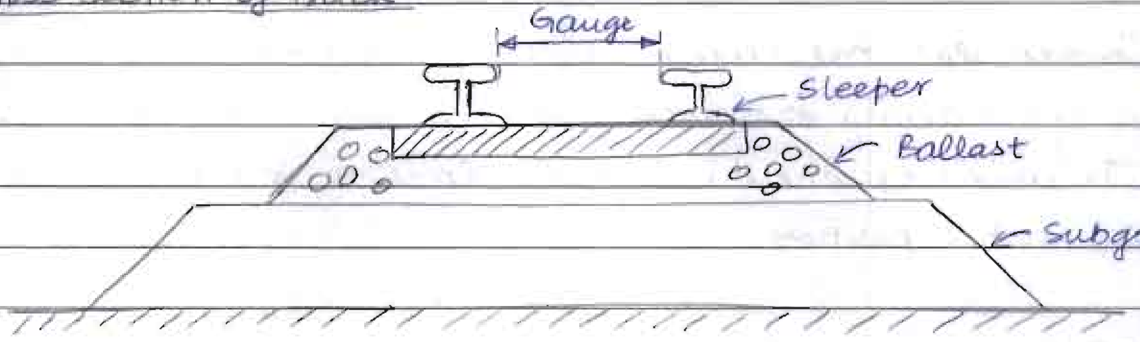
→ For R & D, IR has it's own unit RDSO, Research, Design and Standards Organisation at Lucknow. It's function is to provide input support to almost all disciplines to R&D wing of IR.

⇒ Classification of Railway Route
→ Done on the basis of importance, traffic carried and the maximum permissible speed of train

→ B.G. Route
① Group A → Speed upto 160 kmph
② Group B → Speed upo 130 kmph
③ Group C → Suburban railway of Delhi, Chennai, Mumbai, Kolkata.
④ Group D → Speed upto 110 kmph, traffic density < 20 GMT
⑤ Group D (special) → speed upto 110 kmph and annual traffic density more than 20 GMT (Gross million Tonne)
⑥ Group E → All other sections and speed < 100 kmph
⑦ Group E (special) → Speed upto 100 kmph and section where traffic density is very high or likely to grow.

→ M.G. Route
① Q > 75 kmph
② R ≤ 75 kmph
③ S < 75 kmph

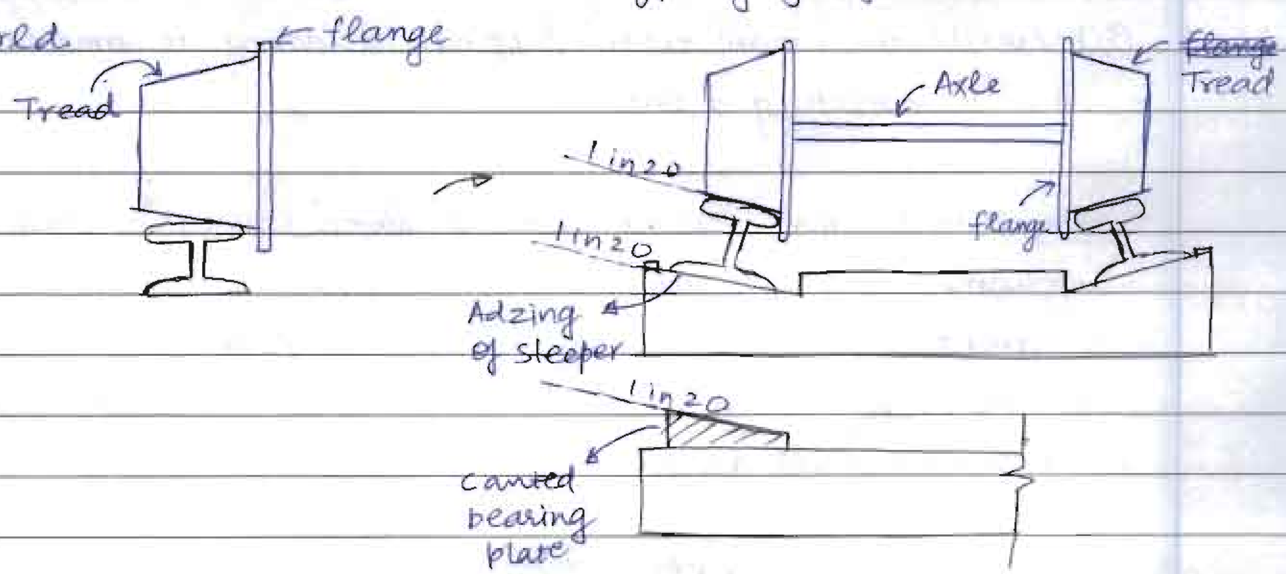
→ Cross-section of Track



→ The track consists of parallel lines of rail. fitting and fastening, ballast etc. To provide hard, smooth and stable passage.

→ Gauge: It is the distance b/w the inner edge of the heads of rail.
→ It is measured 16 mm below the plan of rail running table.
→ In India we have 3+1 type of gauge.
① Broad gauge → 1.676 m
② Metre gauge → 1.000 m
③ Narrow gauge → 762 mm, 610 mm (Darjeeling)
④ Standard gauge → 1.435 m (Used in Metro)

→ In India, approx 63% BG, 31% MG and 6% NG exist.
→ Whereas, in world 62% Standard gauge and 15% BG exist.
→ Other than these more than 20 type of gauges are there in the world.



→ Coning of wheel - The head of wheels of railway vehicle are not made flat but sloped at 1:20 and this sloping of surface along the circumference forms a part of cone.

→ The coning of wheel is mainly done to maintain the vehicle in central position

→ Behaviour of coned wheel -

(1) On straight track - Keeps the train in central position. Hence reducing wear and tear of wheel flange. If at any moment the wheel goes out of it's central position, the dia of contact point will become different and there fore, the wheels retreat till they are at central position once again with equal dia.

(2) On curved track - When train moves on curved track, the distance covered by outer wheel is more than the inner wheel. Centrifugal force shifts the outer wheel outwards, thus causing an increase in diameter. which helps it in moving longer distance compared to inner wheel. Hence more length of outer rail is partly adjusted due to coning.

→ Advantage of coning

(1) Produces self centering effect

(2) Reduces wear and tear of wheel flange and rail.

(3) Prevents the wheel from slipping / skidding to some extent when negotiating a curve.

⇒ Adzing of Sleeper - Coning of wheel alone without tilting the rail has some disadvantages like:

(a) Lateral Bending stress on rail due to eccentric loading

(b) High concentration of stress at inner edge of rail and on tread of wheel as well.

→ Tilting of rail in 1:20 is done to control above problems.

→ It can be done by either directly making groove on sleeper or with the help of canted Bearing Plate.

→ Now, making groove on sleepers at 1:20 is known as Adzing of sleeper.

Ch-2 Geometric Design

⇒ Gradient - Any rise or fall in the track level is known as gradient.

→ Gradient are represented either by 1 in x form or p%

eg - 1 in 200 ⇒ 0.5%

→ Type of Gradient on Railway track

① Ruling Gradient

→ In most general case, the maximum gradient allowed is known as Ruling gradient.

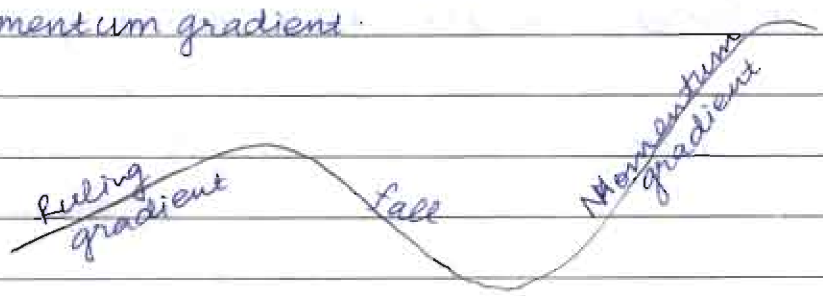
→ It is the gradient where there may not be any appreciable loss of speed.

→ In general, for plain areas → 1 in 150 - 1 in 250 → Ruling gradient

for hilly areas → 1 in 100 - 1 in 150 →

② Momentum Gradient

If rising gradient is followed by falling gradient, the train while coming down in a falling gradient acquires sufficient momentum which enables the train to negotiate a steeper gradient than the ruling gradient. This rising gradient is called momentum gradient.



③ Pusher / Helper gradient

→ In hilly areas to reduce the length of railway line, gradient steeper than ruling gradient is provided.

→ In such situation, instead of limiting the train load, the train is run by an assistant or helper engine. Such gradients are called as pusher gradient [Generally steeper than 1 in 75]

(4) ⇒ Gradient in Station yard

→ In station yard, gradient is provided for drainage.

→ It should be sufficiently low so as to:

① To prevent the movement of standing vehicle.

② To prevent additional resistance at the start of vehicle.

→ Maximum → 1 in 400 and minimum → 1 in 1000.

⇒ Grade compensation

→ Due to curvature on the grade, resistance to motion of train increases.

→ In order to avoid resistance beyond allowable limit, the gradients are reduced on the curve.

→ This reduction in gradient is known as grade compensation.

** → For IR,

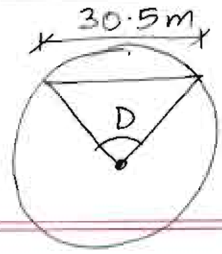
(a) For BG → 0.04 % per degree

(b) For MG → 0.03 % per degree

(c) For NG → 0.02 % per degree

Q → If curve of 4 degree accompanied by ruling gradient of 1 in 150 on BG track, the permissible gradient would be

$\boxed{1 \text{ in } 197.37}$ → permissible / allowable / steepest grade.



⇒ Radius / Degree of curve

→ A curve is defined either by it's radius or by it's degree. The degree (D) of curve is the angle subtended at it's centre by 30·5m (100 feet) chord.

$$\boxed{D = \frac{1750}{R}}$$

→ Maximum Degree of curve or minimum radius:

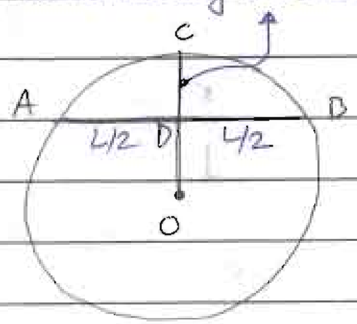
BG → 10° → $R_{min} = 175\,m$

MG → 16° → $R_{min} = 109\,m$

NG → 40° → $R_{min} = 44\,m$

⇒ Versine of curve

→ It is used to check the accuracy of curvature. For a chord AB, CD is known as versine of curve.



→ Using property of circle i.e. Intersecting chord theorem

→ $\frac{L}{2} \times \frac{L}{2} = CD \times (2R - CD)$

→ Assuming $2R - CD \simeq 2R$

So, $\boxed{CD = \frac{L^2}{8R}}$

Q- For 20 m chain length and 600 m radius of curve, Degree of curve will be → $\frac{1146}{R} = \frac{1146}{600} = 1{\cdot}91^\circ$

⇒ Super elevation

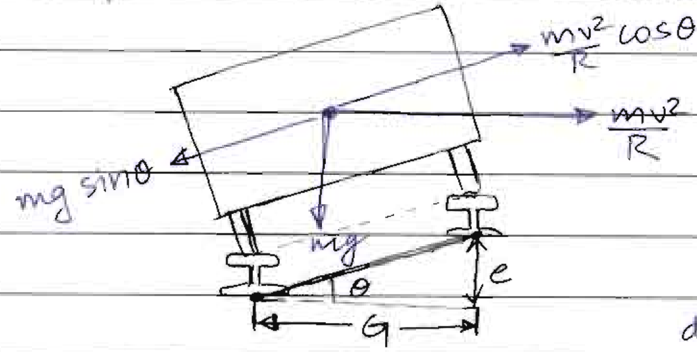
→ When train negotiates a horizontal curve it is subjected to centrifugal force which pushes the train away from the curve, hence results in increase of pressure on outer rail.

→ To encounter the effect of centrifugal force, the level of outer rail is raised above the inner rail by certain amount known as super elevation

classmate
Date
Page

→ Objective of s/e

① To encounter the effect of centrifugal force.
② To provide equal distribution of wheel load on 2 rails
③ To provide smooth and comfortable ride. with safety.
→ Friction force is not considered while deriving s/e.

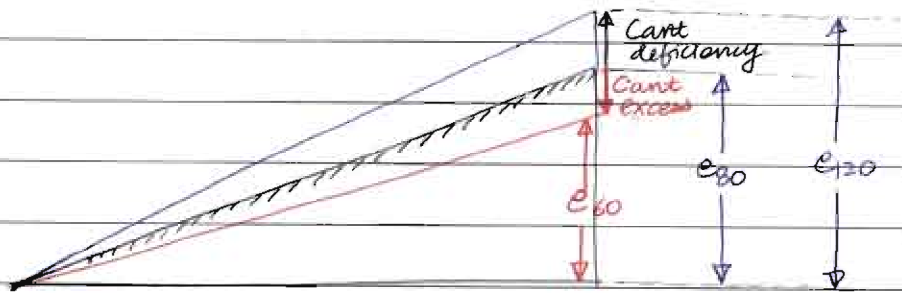


G = { 1750 mm for BG ; 1058 mm for MG }
↓
dynamic Gauge

$$mg\sin\theta = \frac{mv^2}{R}\cos\theta$$

$$\tan\theta = \frac{v^2}{gR} = \frac{e}{G} \Rightarrow \boxed{e = \frac{Gv^2}{gR} = \frac{GV^2}{127R}}$$

m/s (v), kmph (V)



e_{60}, e_{80}, e_{120} → equilibrium cant provided for 60 kmph, 80 kmph, 120 kmph
e_{80} → Cant provided → Called Actual Cant. (C_a)

→ G: Dynamic gauge is the c/c horizontal distance b/w the ~~gauge~~ rails
→ whereas wheel gauge is defined as the distance b/w inner face of rails
→ Track gauge of BG is 1676 mm

→ Maximum superelevation
→ Maximum value of superelevation in 1/10 to 1/12 of the gauge

classmate
Date
Page

Gauge	Group	Under Normal Conditions (mm)	With permission of CE (mm)
BG	A	** 165	185
	B, C	~~140~~ 165	–
	D, E	140	–
MG	Q R S	90	100
NG		65	75

** ⇒ Equilibrium speed and Equilibrium cant

→ Mixed traffic of fast and slow trains moves on the track. Cant provided for slow train will not suit fast train and vice versa. So actual cant provided for an average speed [equilibrium speed] so that all trains with different velocities can be allowed.

→ When load on both the rails is equal then, the cant provided is known as equilibrium cant.

⇒ Equilibrium speed

(a) > 50 kmph

(i) Speed from Martin formula

(ii) $V_{eq} = 0.75 \times V_{max}$

(b) < 50 kmph

(i) Martin formula or super elevation formula

(ii) $V_{eq} = V_{max}$

Not much useful. {Not used by IR currently}

**

(c) Weighted average method

$$V_{eq} = \frac{v_1 n_1 + v_2 n_2 + \dots}{n_1 + n_2 + \dots} = \frac{\Sigma v_i n_i}{\Sigma n_i} = \frac{\Sigma v_i w_i n_i}{\Sigma w_i n_i}$$

weight

where $n_1, n_2, \dots$ are no. of trains at a speed of $v_1, v_2, \dots$

Q. Calculate the equilibrium speed of BG curve of 3° if the speed of several trains running on the line are

No of trains	Speed of train (kmph)
10	60
8	50
3	70

$V_{eq} = 57.62$ kmph

⇒ Cant Deficiency

→ The actual cant is provided on the basis of equilibrium or average speed. For the trains running at higher speed, the actual cant requirement is more than the provided cant for equilibrium speed. This shortage of cant is called cant deficiency

$$\boxed{C_d = C_{th} - C_a}$$

⇒ Limitation of Cant deficiency

Cant deficiency is limited because:

1. Higher cant deficiency gives much discomfort
2. Extra pressure on outer rail.

⇒ Allowable Cant deficiency

Gauge	Group	Normal C_d (mm)	Remark
BG	A & B	** 75	For BG group of A and B route 100mm Cd is permitted with the approval of CE
	C, D & E	75	
MG		50	
NG		40	

⇒ Cant Excess

→ Cant excess occurs when train travels around a curve at a speed less than the equilibrium speed.

$$\boxed{C_{ex} = C_a - C_{th}}$$

⇒ Maximum Cant Excess → For BG ⇒ 75 mm
→ For MG ⇒ 65 mm

NOTE: Book speed of the goods train should be taken into account for working out cant excess.

⇒ Speed of train

→ Safe speed on Railway track should be minimum of the following

(a) → Safe speed on curve as per Martin's formula (Not in use Nowadays by IR)

(b) Speed calculated as per cant Formula allowing cant deficiency

(c) Maximum speed as per transition length

(d) Maximum specified speed as per Railway Board

⇒ Calculation of speed on curve

~~I/ When speed < 100 kmph~~

(a) Martin's formula

(i) When speed < 100 kmph

① On transition curve → $V_{max} = 4.4\sqrt{R-70}$ kmph (BG, MG)
→ $V_{max} = 3.65\sqrt{R-6}$ kmph (NG)
(subjected to max. of 50 kmpn)

R → Radius (in metres)

② On Non-transition curve

80% of the speed given by ① is allowed for respective gauge

classmate
Date
Page

(ii) When speed > 100 kmph

$$V_{max} = 4.58\sqrt{R}$$

NOTE: All the Martin's formulae are not in use by IR

(b) Used by IR

For BG, $V_{max} = 0.27\sqrt{R(C_a+C_d)}$

For MG, $V_{max} = 0.347\sqrt{R(C_a+C_d)}$

For NG, $V_{max} = 3.65\sqrt{R-6}$

Here, $C_a \rightarrow$ actual Cant in mm

$C_d \rightarrow$ Cant deficiency in mm

$R \rightarrow$ Radius of curve in m

Q- S/e provided for 70 kmph locomotive running on 900 m radius curve. $= \frac{Gv^2}{127R} = 75.022$ mm

Q- What is the maximum speed of train which can run on a curved BG track with radius 650 m and s/e of 5.5 cm.

$$e = \frac{Gv^2}{127R} \Rightarrow v = \sqrt{\frac{127 \times 650 \times (55+75)}{1750}} = 78.3 \text{ kmph}$$

Q- Minimum velocity of rolling stock permitted to run on BG track with radius 500 m and equilibrium cant 12 cm.

$$v = \sqrt{\frac{127 \times 500 \times (120-75)}{1750}} = 40.41 \text{ kmph}$$

Q- What actual cant will be provided in 3° curve of BG railway track for a maximum speed of Rolling stock 100 kmph.

$$R = \frac{1750}{3} = 583.33 \text{ m.} \Rightarrow 100 = \sqrt{\frac{127 \times 583.33 \times (e+75)}{1750}}$$

$$\Rightarrow e = 16.12 \text{ cm} < 16.5 \text{ cm}$$

So, OK

classmate
Date
Page

→ Determining minimum Radius of curve for given permissible speed (V_m) and book speed (V_g) [Here cant and Radius both are unknown]

① Assume maximum permissible value of C_d and C_{ex} has reached

$$C_a = \frac{G V_m^2}{127R} - C_{d,max} \rightarrow \text{based on } C_{d,max}$$

$$C_a = \frac{G V_g^2}{127R} + C_{ex,max} \rightarrow \text{based on } C_{ex,max}$$

Equating both, we get

$$\boxed{R_{min,1} = \frac{13.76\,(V_m^2 - V_g^2)}{C_{d,max} + C_{ex,max}}}$$

② Considering maximum permissible limit of C_a and C_d are reached

$$C_{a,max} = \frac{G V_m^2}{127R} - C_{d,max}$$

$$\boxed{R_{min,2} = \frac{13.76\, V_m^2}{C_{a,max} + C_{d,max}}}$$

→ Provide $R_{provided} = \max(R_{min_1}, R_{min_2})$

Q. Determine the minimum radius on BG where max^m permissible speed is 120 kmph, $V_g = 65$ kmph

$$165 = \frac{13.76\,(120)^2}{R_{min}} - 75 \Rightarrow R_{min} = 825.6 \text{ m}$$

$$\frac{13.76\,(120)^2}{R_{min}} - 75 = \frac{13.76\,(65)^2}{R_{min}} + 75 \Rightarrow R_{min} = 933.4 \text{ m}$$

So, provide $\boxed{R = 933.4 \text{ m}}$

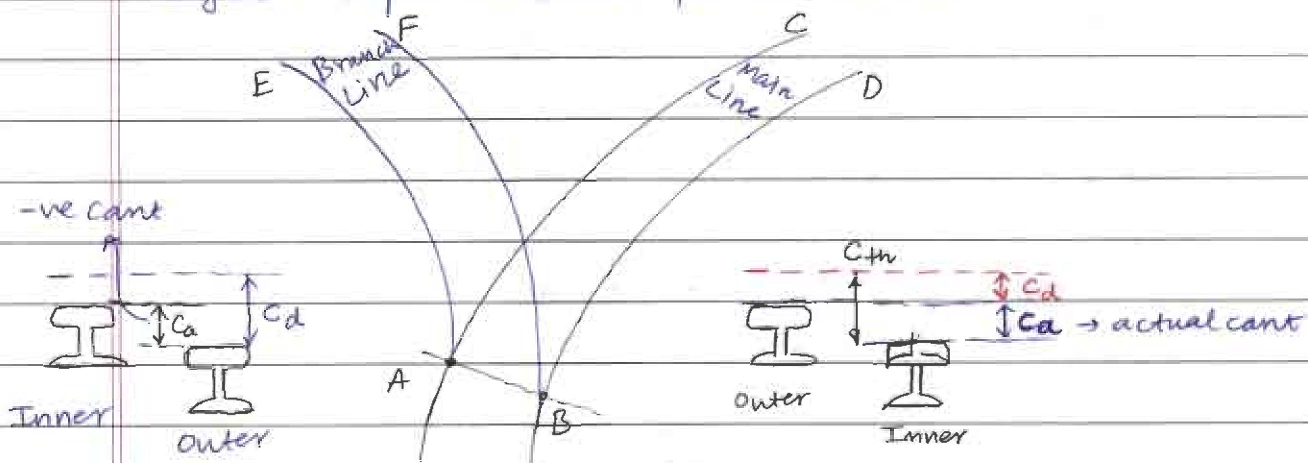
Q. Find the minimum permissible radius on a BG high speed route to permit a maximum speed of 140 kmph

→ $165 = \frac{13.76 V_m^2}{R_{min}} - 75 \Rightarrow R_{min} = 1123.73$ m

⇒ Negative ~~Relative~~ superelevation

→ If the level of outer rail in curve is above the level of inner rail, then the s/e is called positive s/e and if the level of outer rail is below the level of inner rail, the s/e is known as negative s/e.

→ When a mainline on curve has a turnout of opposite curvature, leading to a branch line, then the level of outer rail in branch line is kept lower than level of inner rail, this leads to negative super elevation for branch line.



→ Steps to calculate speed on mainline

① → Calculate theoretical cant on branch line by assuming some velocity, $e_{th} = \frac{G V^2}{127 R}$

② → By deducting cant deficiency in branch line, calculate the actual cant, $e_a = e_{th} - e_d < 0$

③ → This negative s/e will become actual s/e for main line.

④ → Permissible speed on main line is obtained based on

$$e_{th} = e_a + e_d$$

AIR-1 Notes

Pages: 350

RCC & Prestressed Concrete Structures

Handwritten notes by

Kartikay Kaushik

AIR-1 ESE 2021

IES Master classroom Student

RCC

CONTENT

classmate
Date 10/07/19
Page

Design of Concrete and Masonry Structures

[Pre → 15-20 ques.
Conventional → 100 + marks]

1) Footing
2) Column
3) Slab
4) Beam
5) Lintel
6) Water Tank
7) Staircase
8) Retaining wall.

⇒ RCC → IS 456:2000 [with amendment No.4, May 2013]
⇒ Steel → IS 800

1. Introduction

⇒ **Purpose of IS code:**

1) Ensure adequate structural stability by specifying minimum requirements (like minimum reinforcement)
2) Provides simple design tables and charts.
3) Ensure consistency among different designers.
4) Some legal validity.

→ SP-16, SP-24 and SP-34 [SP — Special publication]

SP-16 → Design Tables
SP-24 → explanatory code for IS 456-1978
SP-34 → Reinforcement Detailing.

→ Plane and Reinforced Concrete [PCC and RCC]

PCC → Plain Cement Concrete
RCC → Reinforced Cement Concrete.

Date
Page

→ It is a mixture of cement, fine aggregate (sand), coarse aggregate (gravel) and water that results in a solid mass.

→ Sometimes admixtures are also used.

→ A concrete with no reinforcement is called as PCC.

→ PCC is generally used where significant tensile stress does not develop like in the construction of dam, levelling coarse of foundation etc.

→ Concrete is very strong in compression but weak in tension. It's tensile strength is approximately 1/10th of compressive strength.

NOTE: → Portable water shall be used in concrete and pH shall not be less than 6. Sea water shall not be used.

→ For most concrete work, nominal max. size of coarse aggregate is 20 mm

Nominal size → Expected size

Actual size → Nominal ± tolerance.

→ <u>Reinforced concrete</u>

→ A concrete with reinforcement embedded in it. The embedded reinforcement makes the section capable of resisting higher tension.

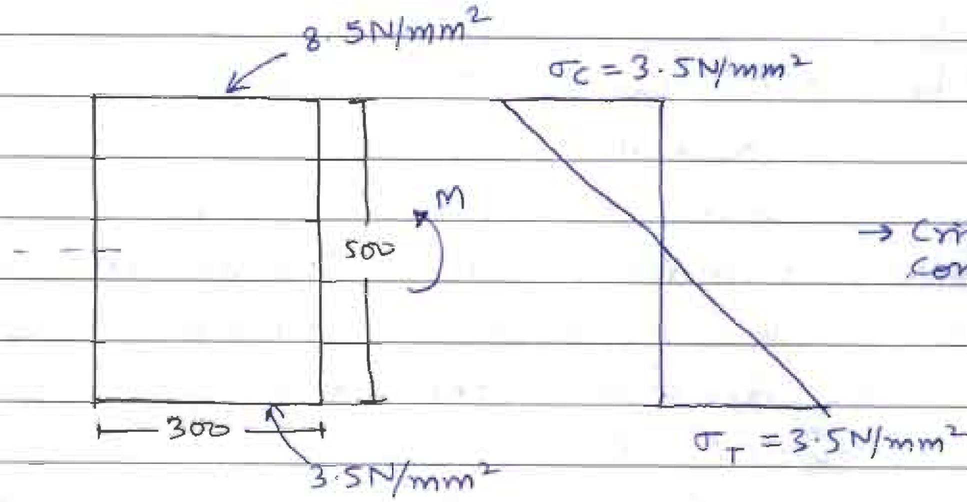
→ All of the tension is assumed to be taken off by the reinforcement (In cracked section analysis). without separating from concrete.

→ The bond between steel and surrounding concrete ensure strain compatibility i.e. the strain in steel is equal to the strain in surrounding concrete.

→ Reinforcement also impats ductility to the concrete which otherwise is a brittle material.

DPP

Q-1

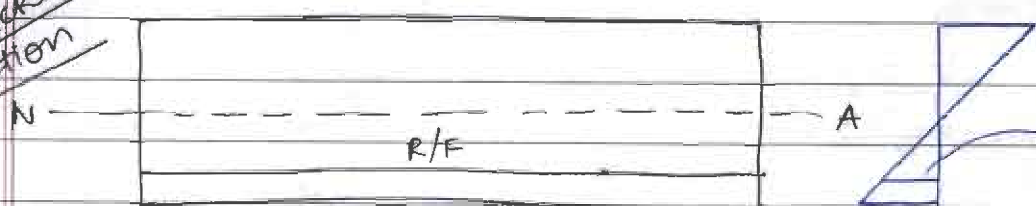


→ Critical condition.

$$MOR = 3.5 \times \frac{(300)(500)^3}{12 \times 250} = 43.75 \text{ kNm}.$$

→ MOR of the section (concrete) will be governed from the tension side.

Uncracked Section



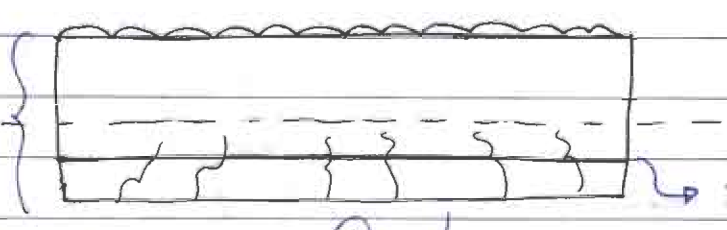
$$f_{st} = \varepsilon_s \cdot E_s$$
$$= \varepsilon_c \cdot E_s$$
$$= \frac{f_c}{E_c} E_s$$

$f_c = 0.7\sqrt{f_{ck}}$, $E_c = 5000\sqrt{f_{ck}}$

So, $f_{st} = \frac{0.7}{5000} \times 2\times10^5 = 28 \text{ MPa}$

{ St → 250
 ↳ 415
 ↳ 500 }

Section becomes smaller



↳ 250MPa can be utilized

DL on building ↑

1

↳ gives sufficient warning before collapse [as compared to PCC]

→ Ductility means large deflection and this is due to yielding of steel. Ductile members give prior warning before impending collapse.

NOTE: We generally design cracked sections in RCC to use the higher permissible stress of steel.

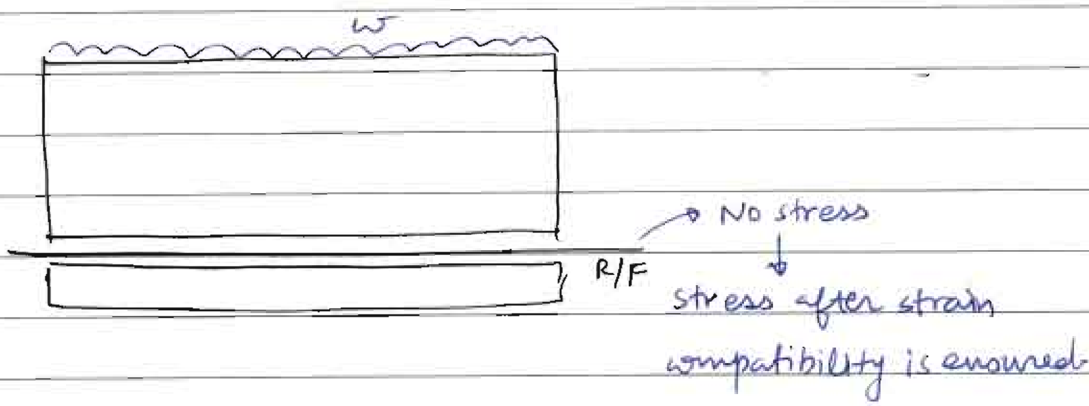
→ Also, the section size required will be less in cracked section compared to uncracked section. However, crack width shall not be high to avoid corrosion of reinforcement.

→ Permissible crack width as per code:

(a) In general → ≤ 0.3 mm

(b) Structure exposed to moisture or in contact with soil or ground water → ≤ 0.2 mm.

(c) Very severe and extreme weather condition → ≤ 0.1 mm.



→ <u>Compressive Strength of concrete</u>

→ The most important property of concrete and can be easily tested.

→ Many other properties like tensile strength, bond strength, shear strength, impermeability, durability, Modulus of Elasticity can be inferred from compressive strength.

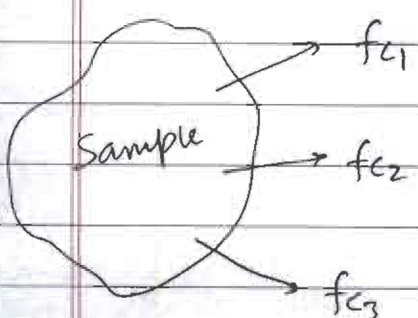
→ Strength of concrete in uniaxial compression is determined by loading the standard test cube [150 mm size] to failure in compression testing machine.

→ The test specimen is generally tested 28 days after casting and continuous curing.

→ Cube is always tested on sides i.e. faces in touch with mold are in contact with the platen (small plate) of the machine

→ ~~The~~ Three specimen of the sample are taken to report the strength and compressive strength is average of 3 specimen

→ Individual variation shall not be more than ±15% of the average. If the variation is more, the test result of the sample are invalid.



f_{c_i} → specimen strength.

$$\text{Sample strength } (f_{c,avg}) = \frac{f_{c_1} + f_{c_2} + f_{c_3}}{3}$$

$$\frac{f_{c,avg} - f_{c_i}}{f_{c,avg}} \times 100 \leq 15\%$$

$$\boxed{0.85\, f_{sample} \leq f_{specimen} \leq 1.15 \times f_{sample}}$$

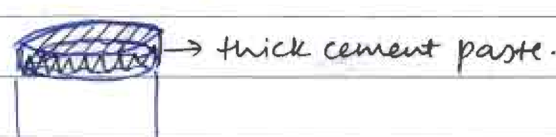
* Why 3 samples → ~~as~~ concrete is a non-homogeneous material.

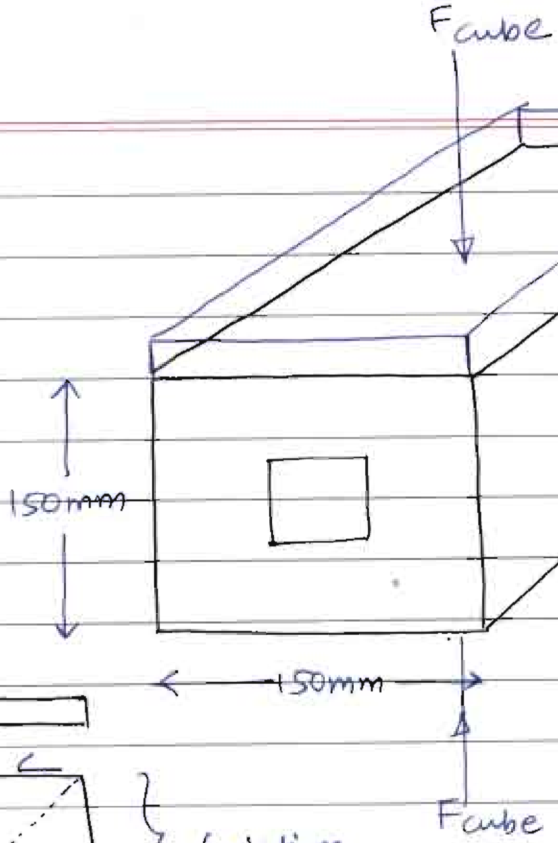
⇒ Comparison of strength of cube (IS456) and cylinder (IS516)

→ Standard cube size → 150mm

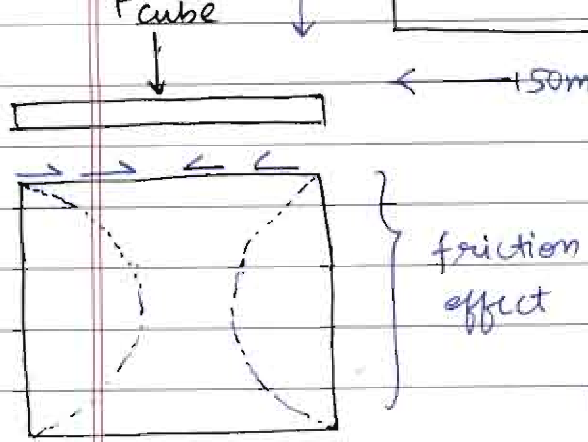
→ Standard cylinder size → 150 mm dia X 300mm height.

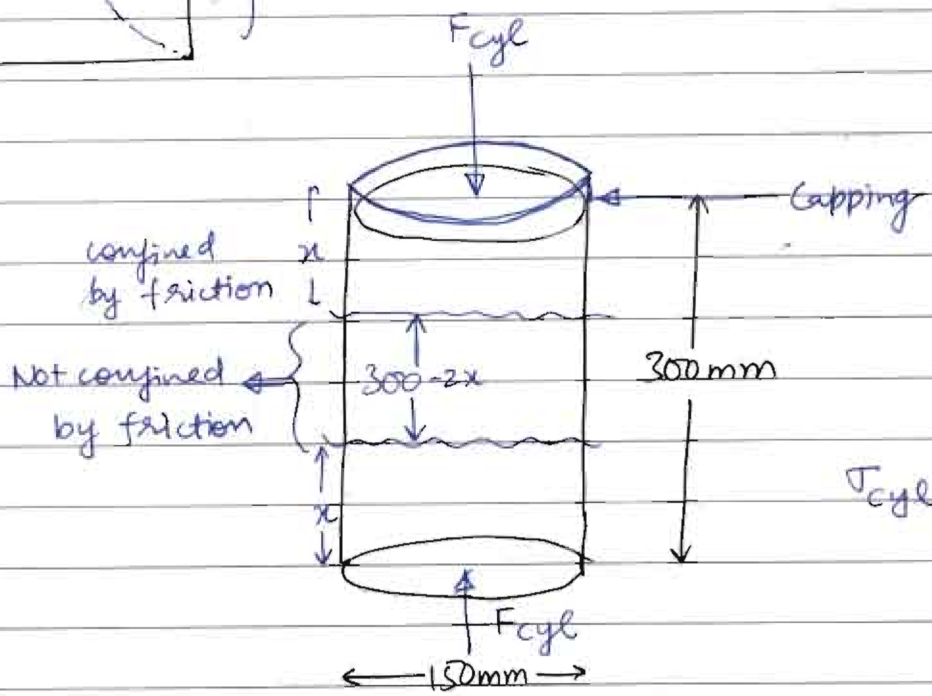
→ Cube tested without capping (neat cement paste) and cylinder tested with capping.





$$\sigma_{cube} = \frac{F_{cube}}{(150)^2}$$





$$\sigma_{cyl} = \frac{F_{cyl}}{\frac{\pi}{4}(150)^2}$$

$$\sigma_{cube} > \sigma_{cylinder}$$

$$\sigma_{cylinder} = 0.8 \times \sigma_{cube}$$

→ $\sigma_{cylinder}$ is closer to the practical value as there is generally no confinement practically.

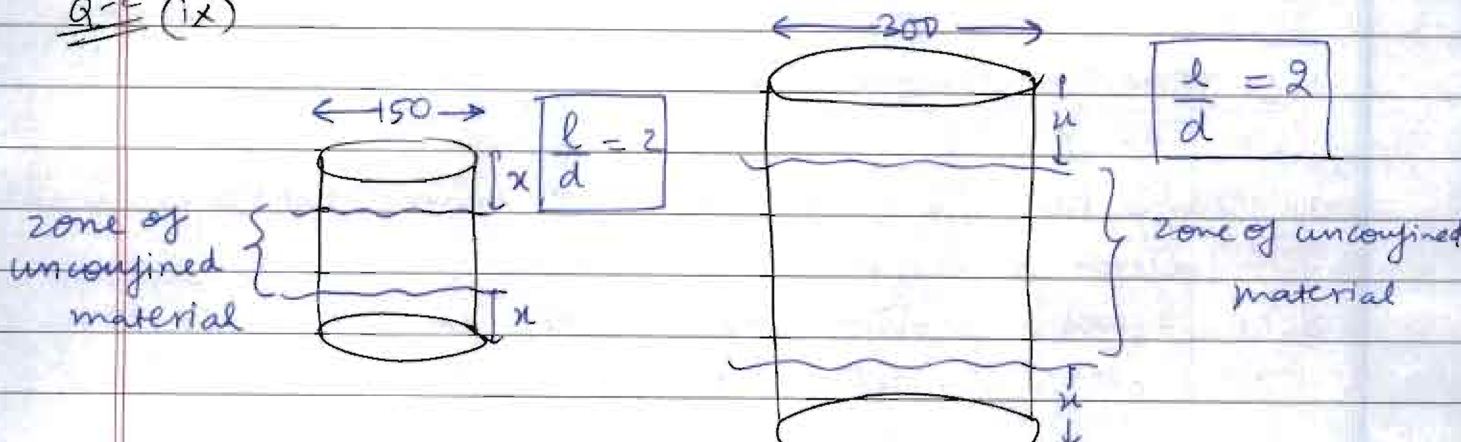
→ The restraining effect of the platens (because of friction) of the testing machine extends over the entire height of a cube. but ~~tests~~ leaves unaffected a part of test cylinder.

→ Due to restraining effect the strength differs and the cylinder fails at a early stress than the cube. and hence at the verge of failure, $\sigma_{Cube} > \sigma_{Cylinder}$

→ Cylinder strength is closer to the true uniaxial compressive strength of concrete and $f_{cylinder} = 0.8\, f_{cube}$.

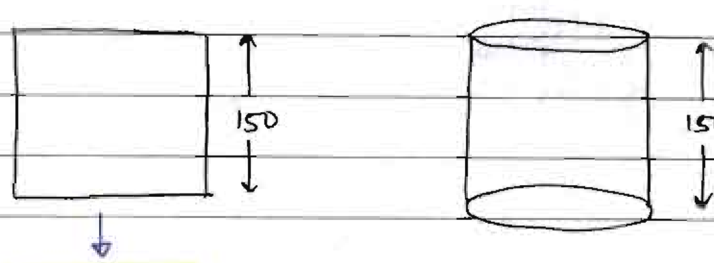
→ IS code uses cube compressive strength.

Q:- (ix)



Upto $h \cong 1.7D$ → friction effect is significant.

→



Cube will fail early due to stress concentrations.

→ **Grade of concrete**

As per IS code:

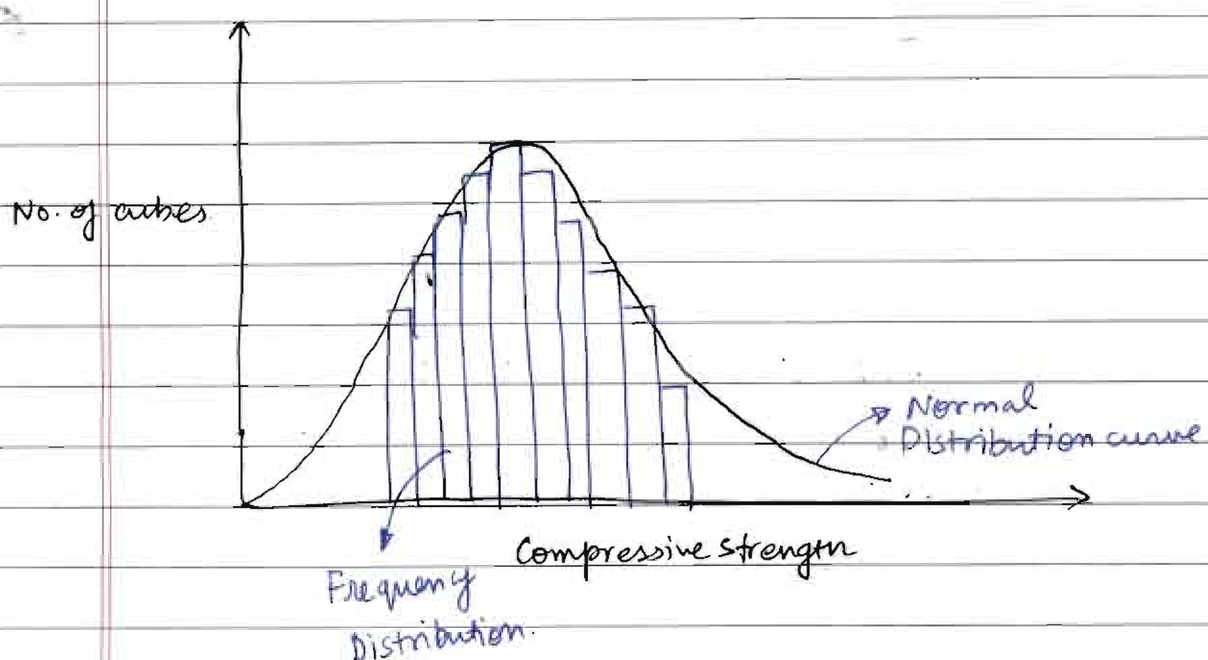
① Ordinary Concrete → M10, M15, M20
② Standard Concrete → M25 to M60 55
③ High-Strength concrete → M65 60 to M100

} IS code valid for these two

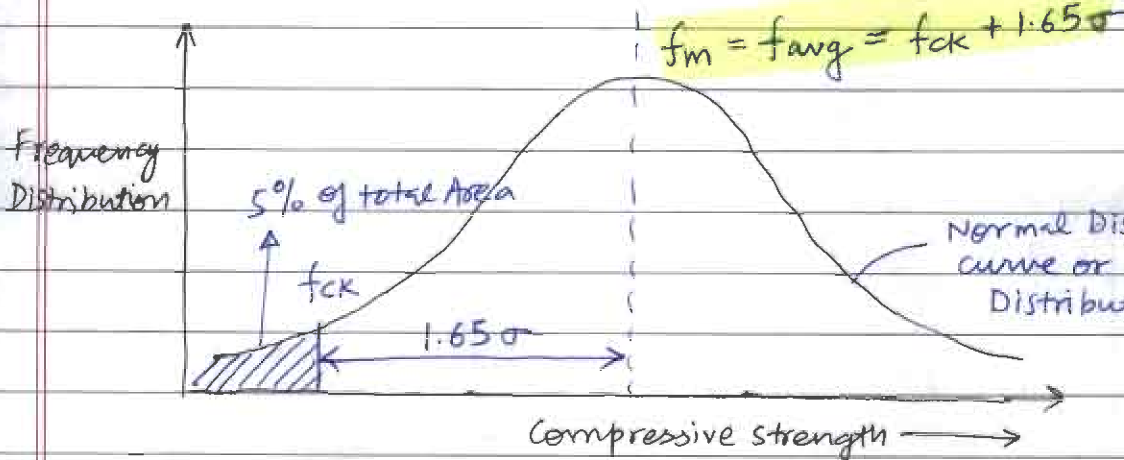
NOTE → M30 means characteristic compressive strength of 150 mm size cube at 28 days is 30 N/mm².
→ IS 456-2000 may not be applicable for concrete grade above M60.
→ M5, M7.5 is known as Lean concrete.

→ **Characteristic strength of concrete**

→ When a large no. of test result of concrete cube are plotted it follows a normal distribution curve.
→ Characteristic strength is the strength below which not more than 5% of the test result are expected to fall.



classmate
Date
Page



σ → Standard Deviation.

→ Minimum sample required for standard deviation calculation is 30 and no. of specimen req. = 30×3 = 90.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N} (f_i - f_m)^2}{N-1}} \qquad N \geq 30$$

→ Concrete is designated by characteristic cube strength at 28 days.

NOTE: Cement Hydrates and gains strength over a long period of time and hence strength of concrete increases with time.
→ However, this increase in strength is not considered as per IS 456 : 2000.

~~IS456 - 1978~~ → 7 days — $0.7 f_{ck}$
→ 28 days — f_{ck}
→ 6 months — $1.2 f_{ck}$

Q- The frequency distribution of the compressive strength of 100 samples is as follows. Calculate f_{ck}, f_m, σ and K where
$f_m = f_{ck} + K\sigma$

No. of samples	Compressive strength (N/mm^2)
2	10
3	14
9	16
11	18
14	20
15	22
21	24
11	26
9	28
3	30
2	32

→ Let us take $f_{ck} = 15 N/mm^2$.

$$f_m = \frac{\Sigma f_i n_i}{\Sigma n_i} = 22.1 N/mm^2$$

$$\sigma = \sqrt{\frac{\Sigma (f_i - f_m)^2 \cdot n_i}{N-1}} = 4.507$$

$$f_m = f_{ck} + k\sigma$$

$$k = \frac{f_m - f_{ck}}{\sigma} = 1.575$$

Date 11/07/19

⇒ Compressive strength of concrete in structure

→ It is not equal to the strength obtained from the compression test of cube due to many factors like duration of loading, size of member [size effect], multiaxial state of stress and strain gradient.

→ Strength decreases with increase in size however after a certain value, it is almost constant.

→ compressive strength of concrete in structure $= 0.85 f_{cylinder}$

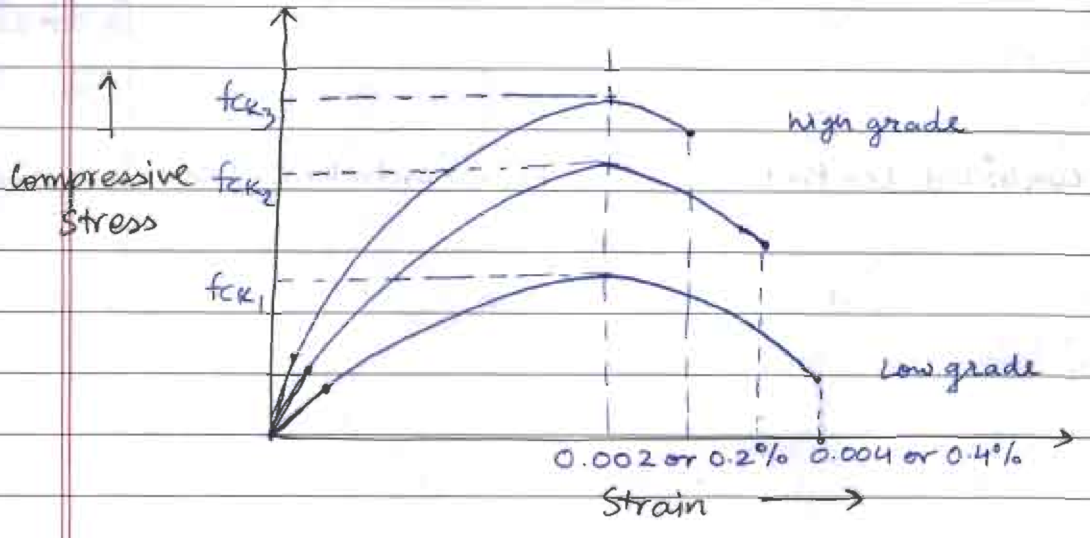
$$= 0.85 \times 0.8 f_{cube}$$

$$= 0.68 f_{cube}$$

$$\simeq 0.67 f_{ck} \text{ [IS code]}$$

→ Due to size effect, actual strength available of concrete in structure $= 0.67 f_{ck}$

⇒ Stress-Strain curve of concrete in compression



→ Curve is generally linear upto 1/3 to 1/2 of peak stress.

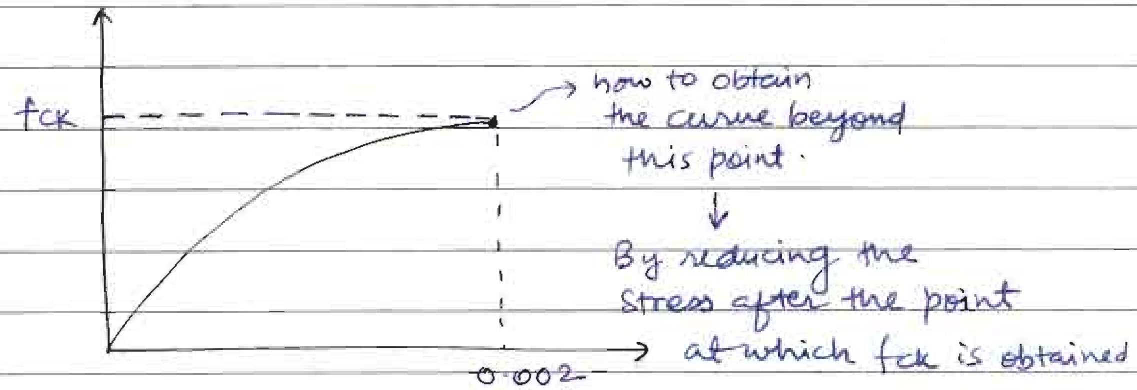
→ maximum compressive stress reaches at a strain of 0.002

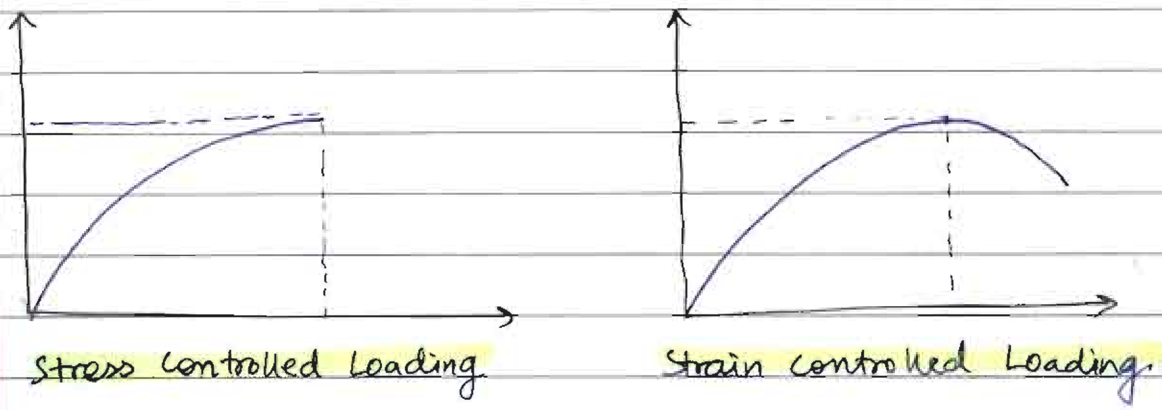
→ Stress at 0.002 (0.2%) strain is called compressive strength of concrete.

→ The strain at failure is in between 0.003 to 0.005 for usual grade of concrete.

→ The higher the concrete grade, steeper is the initial portion and sharper is the peak of the stress-strain curve i.e not flat at top.

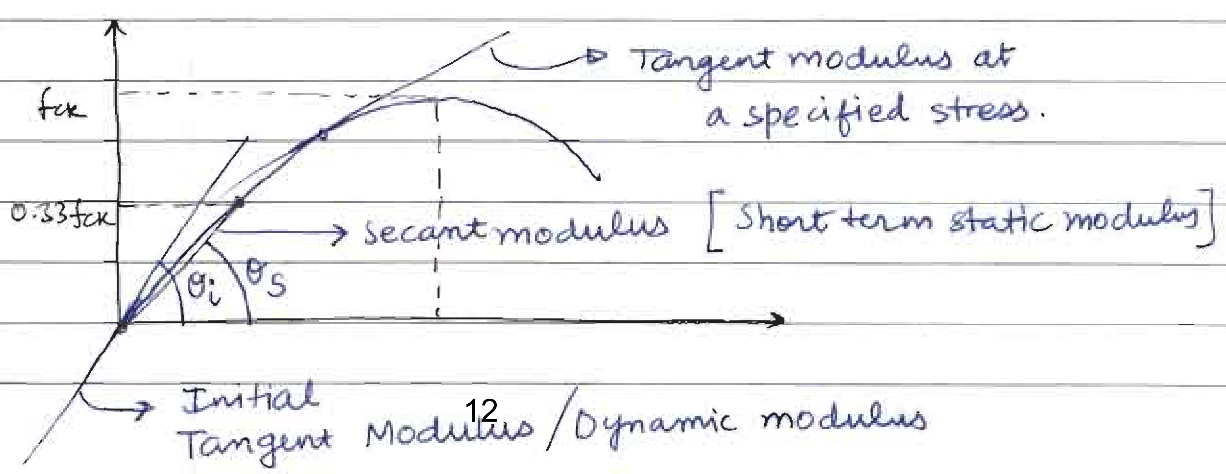
→ Low grade concrete is more ductile than high grade concrete. However, in RCC structure ductility of concrete is not considered.





→ To obtain the descending part of the curve, the applied load shall be strain controlled.

⇒ Modulus of Elasticity and poisson's ratio



⇒ 3 types of modulus:

1) Initial Tangent Modus / Dynamic modulus (E_{cd})

→ Slope of tangent at origin of stress-strain curve. (corresponds to a small instaneous strain).

→ Can be used for dynamic load cases (earthquake, wind) or very short period loading like (impact loading in which long term effect of creep and shrinkage can be neglected)

→ Can be obtained by NDT [Electrodynamic method, Resonance frequency method] (NDT → Non ~~Descriptive~~ Testing)
-Destructive

2) Secant modulus (E_c)

→ Slope of line drawn from origin to a specified stress level, here it is $0.33 f_{ck}$.

→ As per IS code, $E_c = 5000\sqrt{f_{ck}}$, where f_{ck} – characteristic compressive strength

E_c ↓ MPa. f_{ck} ↓ MPa

[±20% variation permissible]

→ E_c is used to calculate instantaneous elastic deformation for structure analysed using linear static analysis.

→ E_c does not take into account long term effect of creep and shrinkage and hence called as short term static modulus.

3) Tangent Modulus (E_t)

→ Slope at any particular point on the curve.

→ It applies to changes in load from a particular load level.

NOTE:

→ E_c increases with increase in grade of concrete.

→ IS code uses Secant modulus / short term static modulus.

→ Generally dynamic modulus ≥ short term static modulus.

→ Modulus of Elasticity is primarily influenced by the elastic properties of aggregate and to a lesser extent by the conditions of curing, ageing of concrete, the mix proportion

AIR-1 Notes

Pages: 151

Structural Analysis
Handwritten notes by

Kartikay Kaushik
AIR-1 ESE 2021
IES Master classroom Student

Date:
Page No:

Structural Analysis

→ Syllabus

Obj ① Determinacy and Indeterminacy ✓ → Test ②

② Force methods. ✓ → Test ②

③ Displacement methods < Slope Deflection method ✓ / Moment Distribution method. → Test ②

Obj ④ Trusses

Obj ⑤ Influence Line Diagram → Test ②

Obj ⑥ Matrix methods

Obj ⑦ Misc (Cables and Arches)

1) Determinacy & Indeterminacy

→ Why do we go for indeterminate structure?

- → Deflections are limited. (greater stiffness)
- → Max BM that develops is smaller as compared to determinate structure i.e. cross-sectional requirement is less → material economy & DL ↓
- → More load transfer paths, failure of 1 member will not lead to failure of the entire structure.

→ Disadvantages

- → Support settlement leads to stresses in the members.
- → Stresses induced to temperature changes.
- → Supports have to be more strong.

$\boxed{\text{NOTE: 50\% more saving when using indeterminate structures.}}$

→ In structural Analysis, we generally analyse indeterminate structures.

→ If all member forces and support reactions in a str. cannot be found out only by using the eq^ns of static equilibrium, the structure is said to be indeterminate.

→ In the analysis of indeterminate structures, 2 methods are adopted:

1) Force method

2) Displacemethod.

→ In Force methods, member forces or support reactions are taken as unknowns and compatibility eqⁿ is written to find out the unknown member forces and support reactions

→ No. of compatibility eqⁿs req = No. of unknown member force/support rxns
= Degree of Static indeterminacy of the structure.

→ In displacement method of analysis, joint displacements are taken as unknown.

NOTE: Joint is the location where 2 members meet and generally we take it as support location, beam column joint, location of discontinuity like internal hinge, sliders

→ We write the force displacement relationship and use equilibrium equations to find out the joint displacements (unknown). The joint displacements when put back into the force displacement relationship, we get the member forces.

→ The number of eqⁿ equations required
= Number of unknown joint displacements
= Degree of Freedom of the structure
= Degree of kinematic Indeterminacy

DATE
PAGE

⇒ Static Indeterminacy of a Structure (D_s)

D_s → degree of static indeterminacy = [Number of member forces and support reactions] − [No. of equations of static equilibrium]

$\Sigma F_x = 0$
$\Sigma F_y = 0$ **2D**
$\Sigma M_z = 0$

$\Sigma M_x = 0$ $\Sigma F_x = 0$
$\Sigma M_y = 0$ $\Sigma F_y = 0$ **3D**
$\Sigma M_z = 0$ $\Sigma F_z = 0$

$$D_s = D_{s_i} + D_{s_e}$$

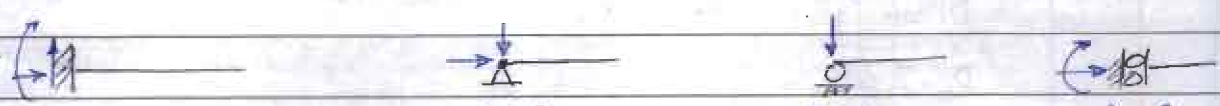
D_{s_i} → internal indeterminacy; D_{s_e} → external indeterminacy.

→ D_{s_e} = [Number of support reactions (R)] − [No. of equations of static equilibrium]

→ 2D ⇒ $D_{s_e} = R - 3$

→ 3D ⇒ $D_{s_e} = R - 6$

2D



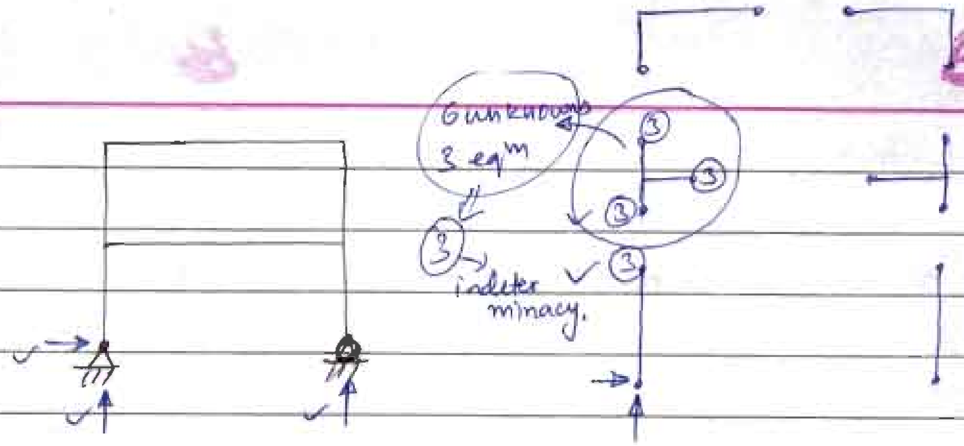
R=3 R=2 R=1 R=2

3D

R=6 R=3 R=1 R=5

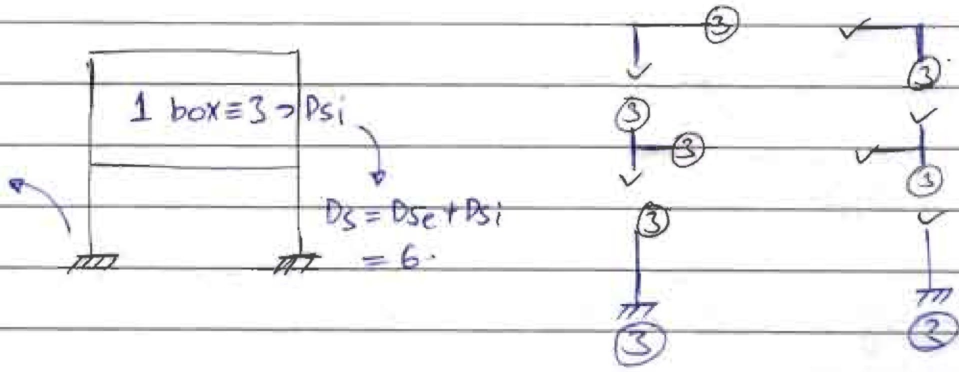
NOTE: No. of support reactions at any support = No. of restrained displacements.

$$\boxed{D_{s_i} = D_s - D_{s_e}}$$



→ Even by knowing all of the support rxns if all the member forces cannot be obtained using equilibrium equations then the str. is said to be internally indeterminate.

$D_{se} = R - 3$
$= 6 - 3$
$\boxed{D_{se} = 3}$



Total no. of support rxns = 6

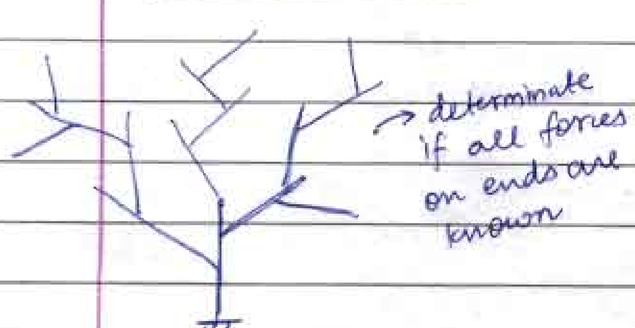
Total no. of member forces = 18

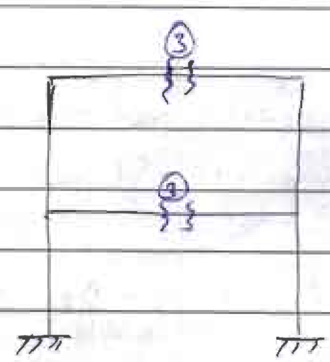
So, $D_S = (18 + 6) - (3 \times 6)$ → No of eq^ns of static eq^ns.

$\boxed{D_S = 6}$

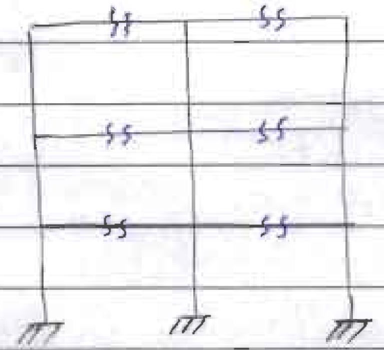
⇒ Static indeterminacy of frames

→ open tree concept





$D_S = 6$ → 3 x Number of cuts.



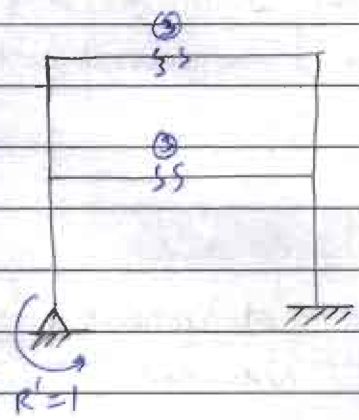
$D_s = 18 \quad \{3 \times 6\}$

→ Frames are rigid jointed structures. All the joints are made rigid by providing extra restraint R' and the structure is cut to make it open tree like structure. Hence $D_s = 3C - R' \quad \{2D\}$

$= 6C - R' \quad \{3D\}$

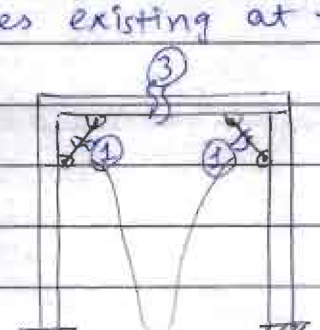
where C is the number of cuts required and

R' is the number of restraints required.

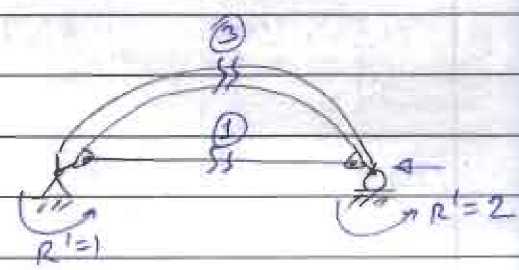


$D_s = 6 - 1 = 5.$

NOTE: If at the cut location unknown forces are less than 3 then in that case for every cut we cannot take 3 unknowns. The unknowns should be taken as per the no. of internal forces existing at the cut location.

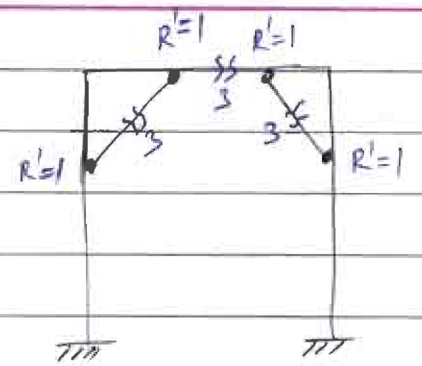


knee braces



$D_s = 3 + 1 + 1 = 5$

$D_s = 3 + 1 - 1 - 2 = 1.$



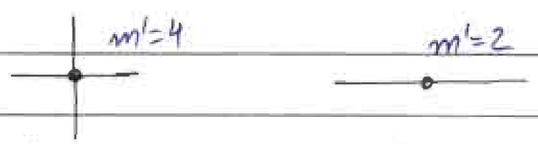
$D_S = 3C - R'$
$= 3 \times 3 - 4 = 5$

→ For open tree following conditions must be met:

1. Each tree should have only 1 root
2. There should not be any looped branches
3. None of the members should fall off

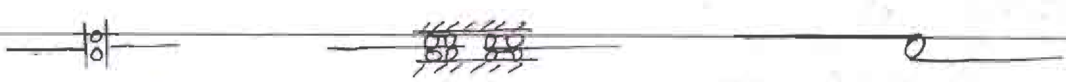
→ R' {No. of support restraint req.} = [No. of support rxn if fixed] − [No. of existing support reactions]

→ Restraining member or joint



No. of restraint required = { $m'-1$ (2D) ; $3[m'-1]$ (3D) }

→ m' → number of members meeting at the joint



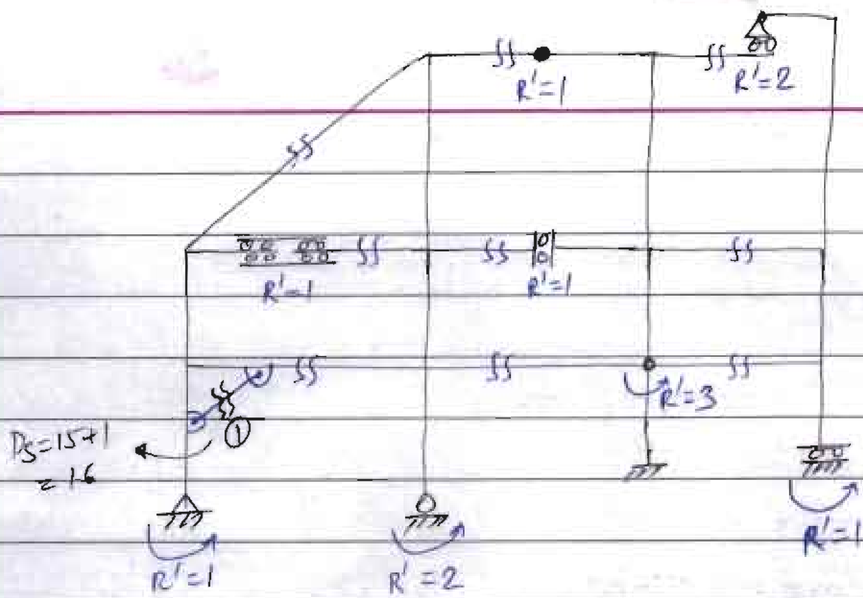
Shear release
$R'=1$

Axial force release
$R'=1$

Axial force & BM release
$R'=2$

$R'=2$

Q-



$D_s = 9 \times 3 - 12 = 15$

$D_{se} = 8 - 3 = 5$

$D_{si} = 10$

Box concept

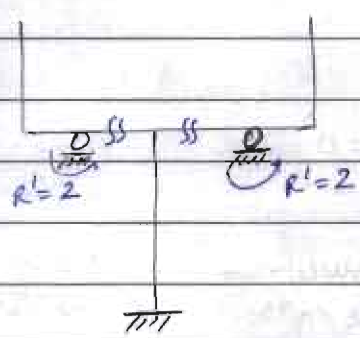
No. of boxes $= 6$

No. of releases $= 1+1+1+2+3 = 8$

So, $D_{si} = 6 \times 3 - 8 = 10$

$D_{se} = R - 3 = 8 - 3 = 5$ $\Big\}$ $D_s = D_{si} + D_{se} = 15$

Q-

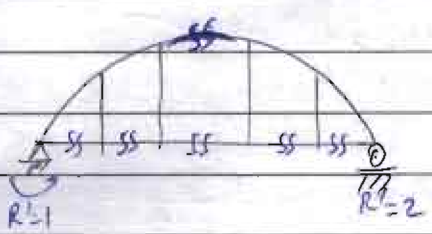


$D_s = 3 \times 2 - 4 = 2$

$D_{se} = 2$

$D_{si} = 0$

Q-

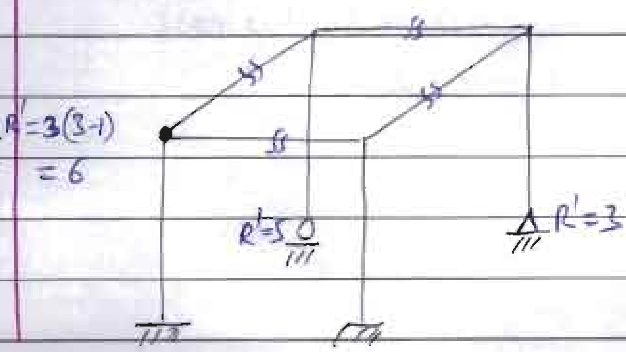


$D_s = 3 \times 6 - 3 = 18 - 3 = 15$

$D_{se} = 0$

$D_{si} = 3 \times 5 = 15$

Q-



$D_s = 6C - R' = 6 \times 4 - 14 = 10$

$D_{se} = (6+6+1+3) - 6 = 10$

$D_{si} = 0$

DATE ______
PAGE ______

2D

$D_s = 3m + r - 3J - \text{no. of releases}$.

eqn of equilibrium

3D

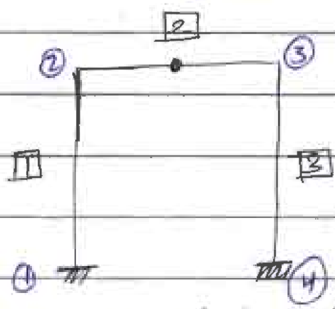
$D_s = 6m + r - 6J - \text{no. of releases}$.

$m \rightarrow$ no. of members.

$r \rightarrow$ no. of support reactions.

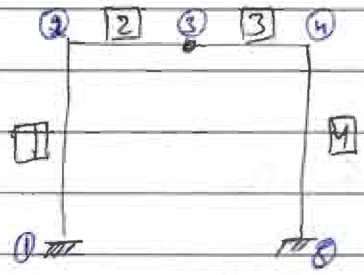
$J \rightarrow$ no. of joints.

$D_{si} = ??$



$D_s = 3\times3 + 6 - 3\times4 - 1$

$= 15 - 13 = 2$



$D_s = 3\times4 + 6 - 3\times5 - 1 = 2$

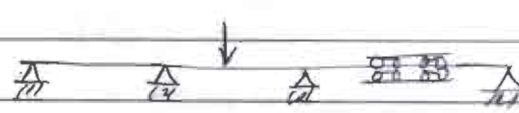
$\Rightarrow$ Static indeterminacy for beams ($D_{s_i} = 0$)

$$\boxed{D_s = \left(\text{No. of support rxns}\right) - \left(\text{No. of equilibrium } \cancel{\text{rxns}} \text{ eq}^n\text{s}\right) - \left(\text{No. of releases}\right)}$$

$\rightarrow$ in case of beams all indeterminacy is taken as external indeterminacy and D_s is calculated as

general loading case

$D_s = 8 - 3 - 1 = 4$



vertical loading case

$D_s = 4 - 2 - 0 = 2$

General Loading	Vertical loading with all supports at the same level
Reaction = 2	R = 1
R = 1	R = 1
R = 3	R = 2
R = 2	R = 1

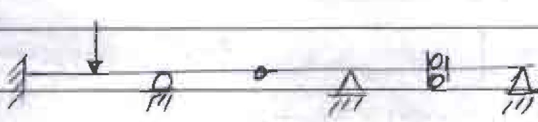
Reactions.

General Loading	Vertical loading with all supports at the same level
R′ = 1	R′ = 1
R′ = 1	R′ = 1
R′ = 2	R′ = 1
	R′ = 0

Releases

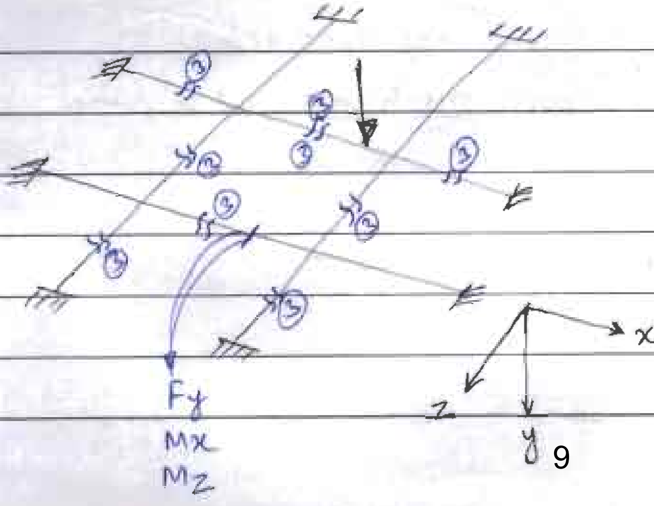
General Loading	Vertical loading with all supports at the same level
Static eq^m = 3	Static eq^m = 2

$D_S = (3+1+2+2) - 3 - 2 = 3$



$D_S = (2+1+1+1) - 2 - 2 = 1$

⇒ Static Indeterminacy for Horizontal grid member with vertical loading



$D_S = 3 \times 8 = 24$
↓
C

→ Since at any section we have only 3 internal forces we can treat it as a 2-D structure and hence, $D_S = 3C$, since $R' = 0$ generally.

DATE ______
PAGE ______

⇒ Stability of structure

→ Stability can be characterized as:

(a) External Stability

(b) Internal Stability

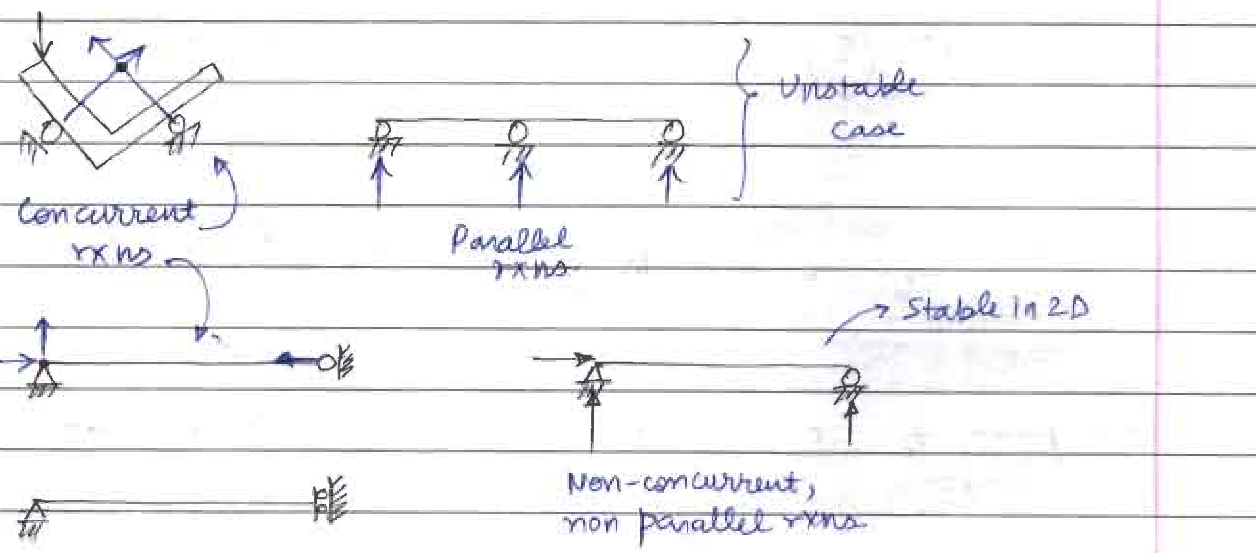
(A) External Stability

→ If the body is sufficiently constrained by external rxns such that rigid body motion of the structure does not take place then the structure is said to be externally stable.

→ The necessary conditions for external stability are:

1) There should be minimum of 3 rxns

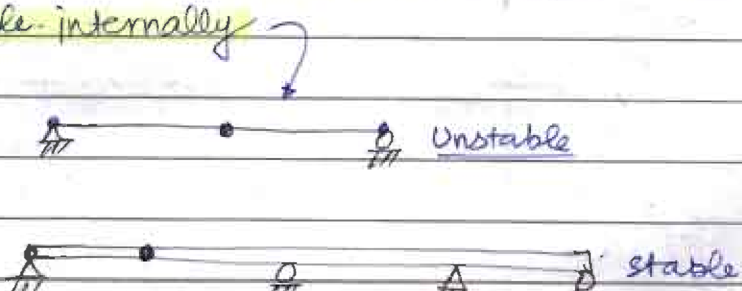
2) The reactions should be neither ||el, nor concurrent, nor-coplanar



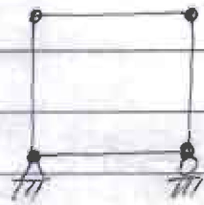
(B) Internal Stability

→ When a part of the structure moves appreciably w.r.t the other then the structure is said to be internally unstable.

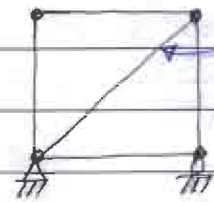
→ 3 hinges in continuation makes a mechanism and hence it is unstable internally



Unstable

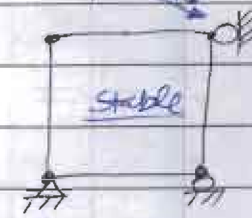


Unstable



external restraint compensates

Stable

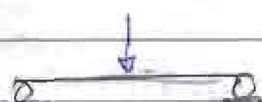


Stable

$D_{se} = 1$, $D_s =$

NOTE:

- Internal Instability could be due to lack of sufficient members or due to large number of internal releases.
- Negative value of D_{se} means structure is externally unstable.
- Negative value of D_s means structure is overall unstable.
- Negative value of D_{si} does not ensure that the structure is unstable internally, because lack of members and large no. of internal releases can be compensated by providing external restraints.
- In complicated structures it may not be visually possible to comment on the stability of the structure. In that case if the structure is analysed by various methods yield the similar results → then the structure is stable otherwise unstable.
- If a structure is stable under a particular loading but is unstable under general loading condition, then the case of special loading under which it is stable is said to be unstable equilibrium.



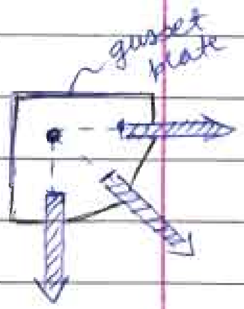
→ unstable equilibrium and statically unstable

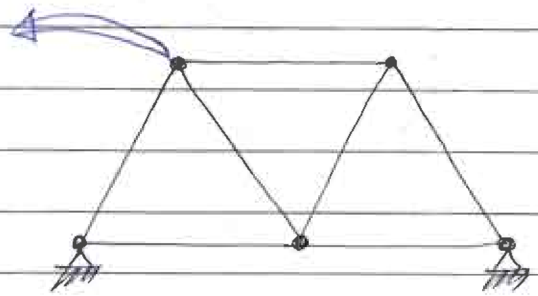
- If the no. of rxns is less than 3 then the structure is said to be statically unstable

DATE

PAGE

Static Indeterminacy of Truss





$D_s = m + r - 2J$ — (2D)

$D_s = m + r - 3J$ — (3D)

- In case of truss member, every joint is a pin joint and load is acting only on the joint
- Hence all members are links and thus can have only axial force.
- In 2D truss, every joint will have only 2 static equilibrium equations as all forces are passing through single point So $\Sigma M = 0$ is of no consequence.

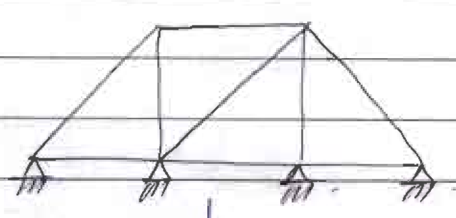
$D_{se} = r - 3 \} \rightarrow 2D$

$\qquad\; r - 6 \} \Rightarrow 3D$

$D_{si} = D_s - D_{se}$

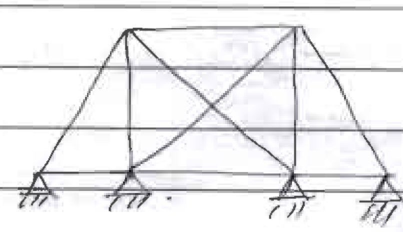
NOTE: Simple Truss

- If a truss can be completed by adding successively 2 members and 1 joint over a triangular framework then the truss is called Simple Truss
- Simple truss is always internally determinate and stable
- $D_s = D_{se}$ for a simple truss.



Simple Truss

$D_s = 4 \times 2 - 3 = 5$

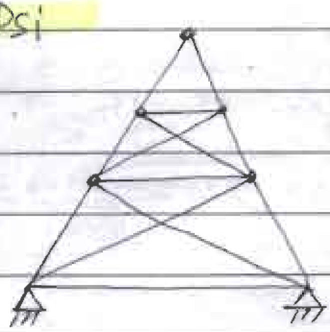


$D_{se} = 5$

$D_{si} = 1$

$D_s = 6$

→ In an otherwise simple truss, the no. of double diagonal panel is $= D_{Si}$

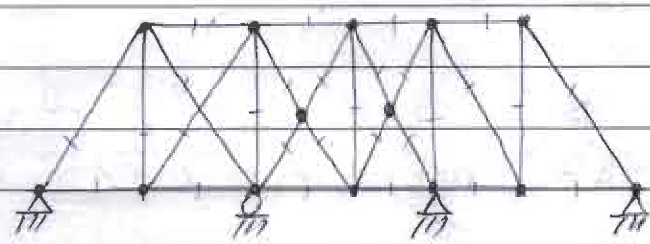


$$D_S = m + r - 2J$$
$$= 13 + 4 - 2\times 7 = 3$$

or $D_S = D_{Se} + D_{Si}$

$$\underbrace{4-3}_{D_{Se}} + \underbrace{2}_{D_{Si}} = 3$$

Q.



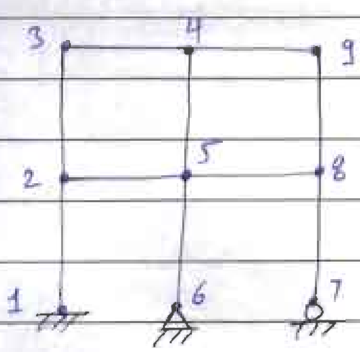
$$D_S = m + r - 2J$$
$$= 28 + 7 - 2\times 14$$
$$= 35 - 28 = 7$$

⇒ Kinematic Indeterminacy

$$D_K = \begin{bmatrix} \text{Total no. of possible} \\ \text{joint displacements} \end{bmatrix} - \begin{bmatrix} \text{Total no. of} \\ \text{reactions} \end{bmatrix}$$

Type of Joint	Total no. of possible joint Displacements	D_K
1) Rigid jointed plane frame	$\Delta x, \Delta y, \theta_z \Rightarrow 3$ nos.	$3J - r$
2) Rigid jointed space frame	$\Delta x, \Delta y, \Delta z, \theta_x, \theta_y, \theta_z \Rightarrow 6$ nos.	$6J - r$
3) Pin jointed plane frame	$\Delta x, \Delta y \Rightarrow 2$ nos.	$2J - r$
4) Pin jointed space frame	$\Delta x, \Delta y, \Delta z \Rightarrow 3$ nos.	$3J - r$

*



$$D_K = 3\times 9 - 6 = 21$$

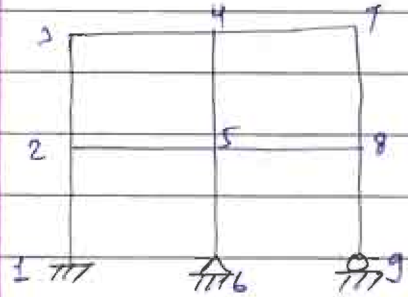
For $\underbrace{J_2, J_3, J_4, J_5, J_9, J_8}$, $\underbrace{\Delta x_i, \Delta y_i, \theta_i}_{18}$

$J_1 \to 0$
$J_6 \to 1$
$J_7 \to 2$ } 3

$18 + 3 = 21$

simply counting is better

If members are inextensible



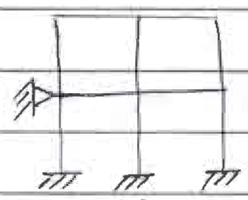
$$\left\{\begin{array}{l}\Delta y_2=0\\ \Delta y_3=0\\ \Delta y_5=0\\ \Delta y_4=0\\ \Delta y_8=0\\ \Delta y_7=0\end{array}\right\} + \begin{array}{l}\Delta x_2=\Delta x_5=\Delta x_8 \Rightarrow 1 \text{ cut } 2\\ \Delta x_3=\Delta x_4=\Delta x_7 \Rightarrow 1 \text{ cut } 2\end{array}$$

$D_K = 21-10 = 11.$

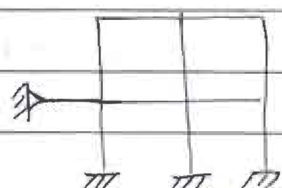
NOTE:

→ In case of inextensibility, D_K in the case of building frame can be taken as $(3J-r-m)$, where m is the no of inextensible members.

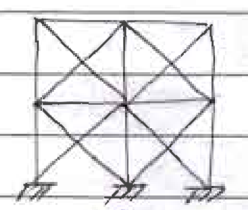
→ This formula is valid only for building frames without lateral bracing



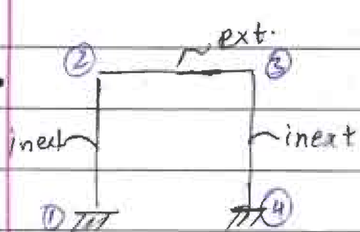
Not a building frame



Building frame.



Not a building frame



$D_K = 3J-r-m$

$= 3\times4-6-2 = 4$

↳ $\Delta x_2, \theta_2, \Delta x_3, \theta_3$.

AIR-1 Notes

Pages: 53

Structural Dynamics
Handwritten notes by

Kartikay Kaushik

AIR-1 ESE 2021

IES Master classroom Student

STRUCTURAL DYNAMICS

CONTENT

Structural Dynamics

Free and Forced vibrations of single and multi Degree of freedom

→ Vibration is the motion of a particle or a body, displaced from equilibrium position. Vibration in structural system may result from environmental forces like wind, earthquake, waves etc

→ Also rotating machines can create vibrations in a structure

→ Dynamic Loading

→ A load that varies in magnitude or point of application is called dynamic loading. Dynamic loading can be classified as:

(a) Deterministic (Prescribed) → Machine loading

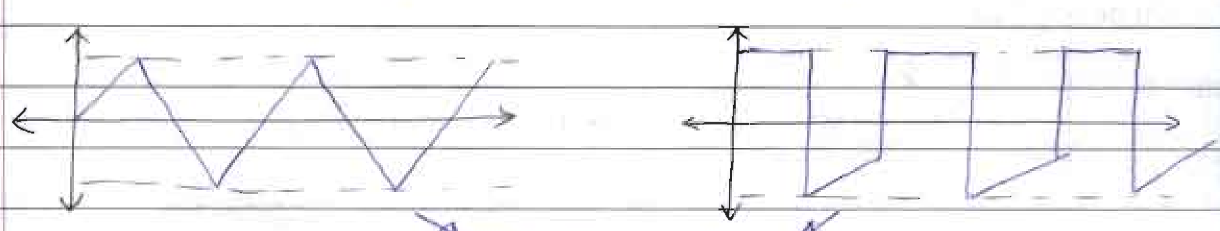
(b) Stochastic (Random) → Environmental loading

→ Deterministic loading is a known function of time. However, Stochastic loading is not completely known wrt time.

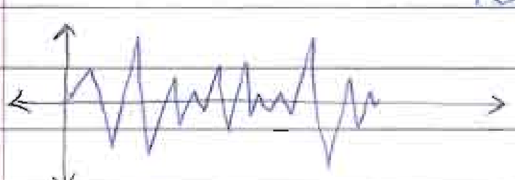
→ Also Dynamic Loading can be classified as:

(a) Periodic Loading (Machine Loading)

(b) Non-Periodic Loading (Environmental Loading)



Periodic Loading



→ Non-Periodic Loading

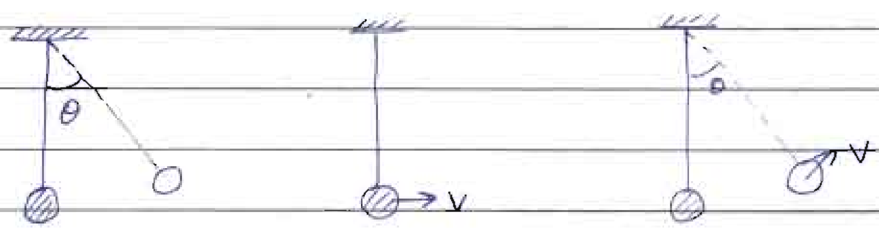
Earthquake

→ Difference b/w Static and Dynamic Analysis

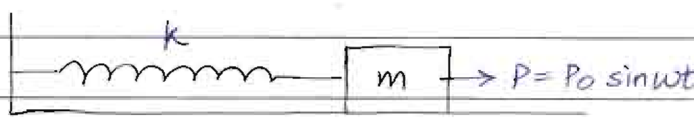
Static	Dynamic
1) Force is constant	1) Force changes wrt time
2) Only one response i.e. displacement	2) Three response i.e. displacement, velocity, acceleration.
3) Only one solution.	3) Infinite no. of solutions
4) Can be solved using static equilibrium	4) Can be solved using dynamic equilibrium or an inertial force + static equilibrium
5) Simple analysis	5) Complex analysis.

⇒ Causes of dynamic effects

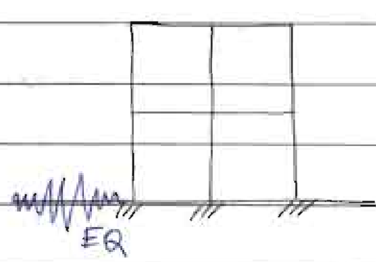
(i) Initial condition



(ii) Applied Force



(iii) Support movement



⇒ Type of vibrations

1) Free and Forced
2) Linear and Non-Linear
3) Undamped and Damped — Underdamped / Critical Damped / Over damped.

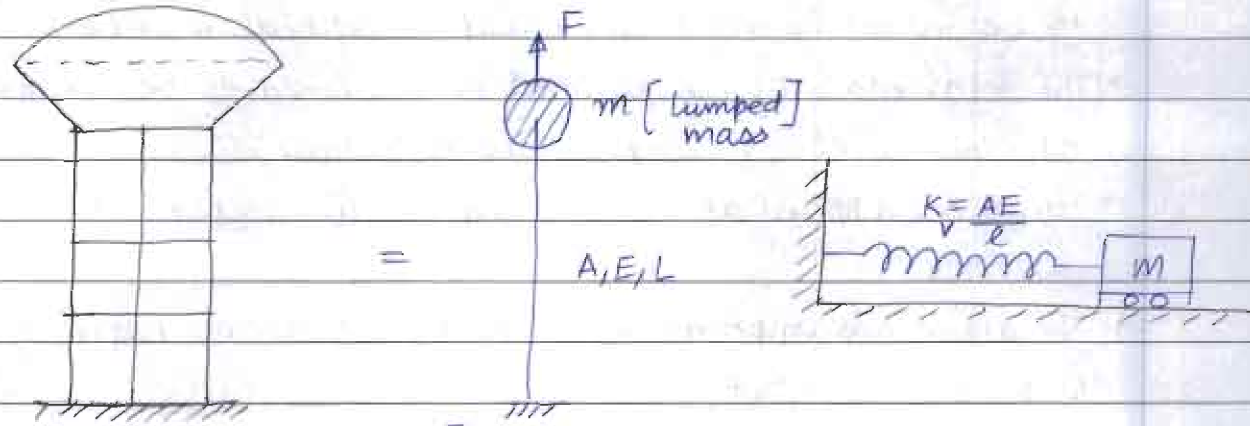
4) Longitudinal, transverse & rotational
5) Deterministic and Random.

> **NOTE:** We generally consider linear vibrations in structural analysis to take advantage of principal of superposition i.e system behaves linearly.

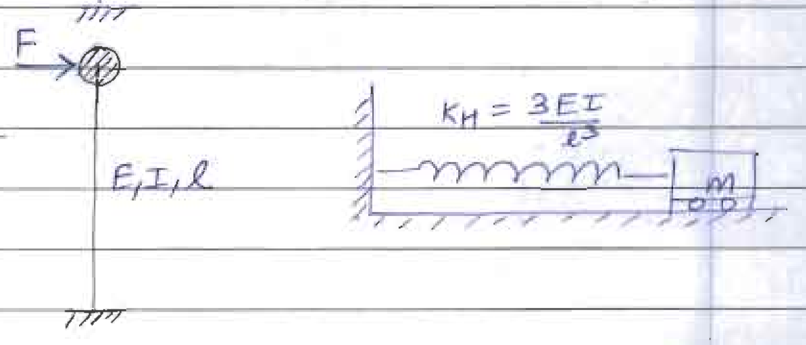
→ The motion that occurs due to initial condition is known as free vibration
→ The motion that occurs due to applied force is called forced vibration

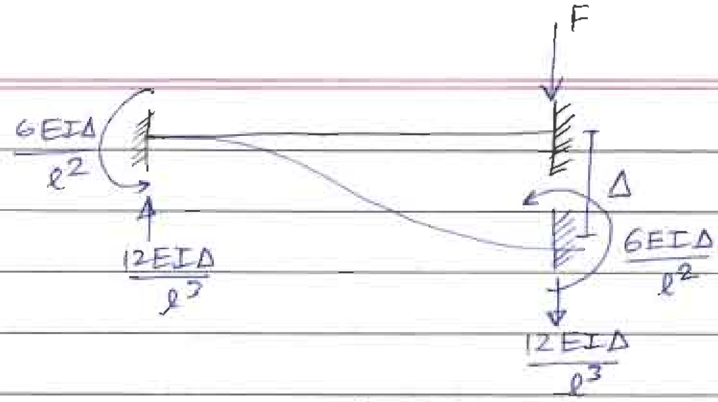
Vibration
- Free
  - Undamped
  - Damped
- Forced
  - Arbitrary Force.
  - Undamped SHM
  - Damped SHM

⇒ Analytical model of the dynamic system



Lumped Mass Technique





$F = \frac{12EI\Delta}{l^3} \Rightarrow \boxed{K = \frac{12EI}{l^3}}$

→ The mass represents inertial characteristic + kinetic energy

→ The spring represents stiffness (restoring force) and potential energy.

→ The damping represents energy dissipation mechanism.

⇒ Concept of shear building

① → It is assumed that no rotation of horizontal member at floor level and hence the structure behaves like a cantilever beam and is deflected by shear force only (earthquake force)

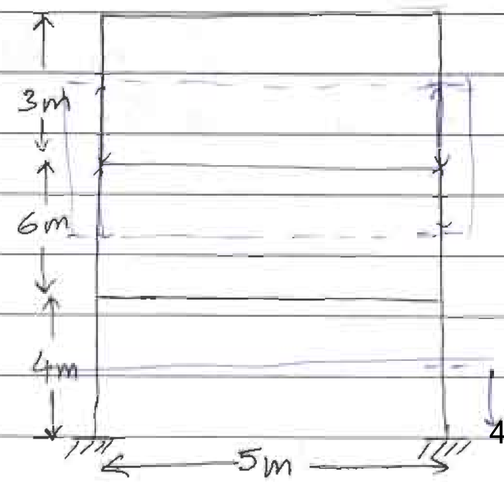
② → Horizontal members i.e. beams and slabs are considered to be infinitely rigid compared to vertical members.

③ → The total mass of the building is assumed to be concentrated at floor levels (Lumped mass technique)

④ → Forces are applied at nodes only i.e. @ lumped mass location.

→ The above assumptions ~~to~~ reduce the ∞ no. of degree of freedom to finite no. of DOF

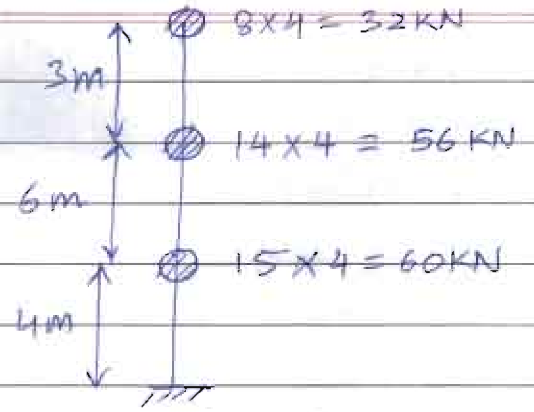
Q.



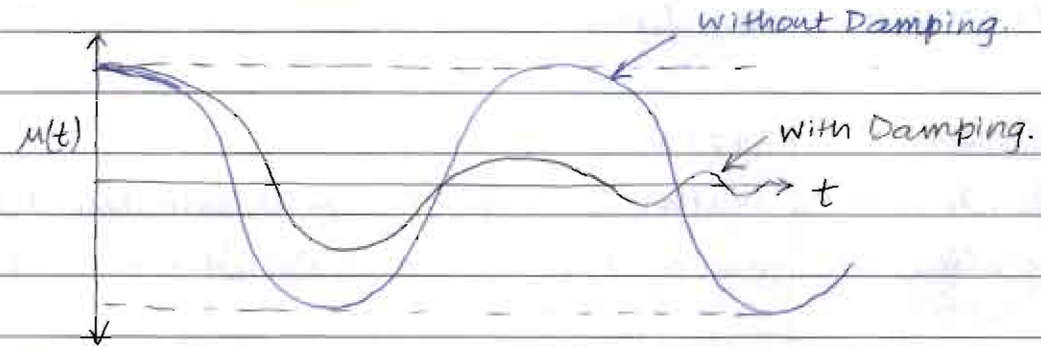
Size of beams and columns = 0.4m × 0.4m

Calculate the lumped masses in the beam column frame.

Weight per unit length = 25 × 0.4 × 0.4
= 4 kN/m



→ <u>Damping in dynamic system</u>



→ The amplitude of a vibrating system will not remain constant and it decays with time due to dissipation of vibrating energy and this is called damping.

→ Amplitude means maximum response. It can be amplitude of displacement, velocity or acceleration.

→ Damping in a structural system is due to various mechanisms such as :

① Internal friction of material
② friction at joints
③ Drag effect of medium.

→ It is very difficult to exactly quantify damping of a system based on geometry as it depends on various factors. However, stiffness can be calculated by using material and geometrical properties.

→ Damping is generally obtained from experiments. Following are the main types of damping:

① <u>Structural Damping</u> - Internal damping in the structure and is an inherent property of the structure. Includes damping at structural connections and damping due to alternate loading

② Viscous Damping – Due to viscous medium in which the structure is vibrating (eg – Shock absorber of a motorcycle)

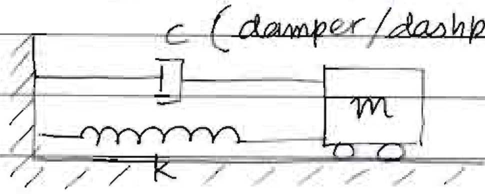
→ For this type of damping, the damping force is directly proportional to the velocity of motion.

→ Generally in structural modelling, we consider all types of damping as viscous damping.

③ Coulumb Damping / Friction Damping

→ Results from the friction b/w sliding surfaces and depend on coeff. of frictn

→ Generally, all types of damping are modelled into viscous damping



$u(t) \rightarrow$ displacement

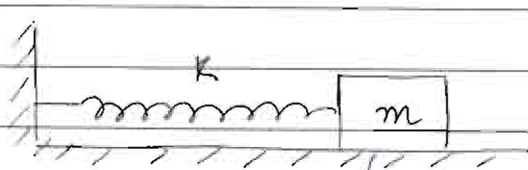
$\dot{u}(t) \rightarrow$ velocity

$\ddot{u}(t) \rightarrow$ acceleration.

$F_d = c\dot{u}$

$F_d \rightarrow$ viscous damping force, $c \rightarrow$ damping coefficient (viscous damping)

$\frac{N-s}{m}$ or $\frac{kg}{s}$



$\hookrightarrow F = \mu N$ – (Friction Damping)

⇒ Effects of vibration

①→ Overstressing and collapse of structure

②→ Cracking and other damages.

③→ Damages to sensitive equipments

④→ Adverse human response.

⑤→ Fatigue fracture.

⇒ Vibrational control in the design of structure

→ Identify, calculate and control the dynamic response

Chapter-2 ⇒ Undamped free vibration of SDOF system

→ Free vibration is initiated by disturbing an elastic system from the static equilibrium position by giving the mass some initial displacement, initial velocity or initial displacement + velocity.

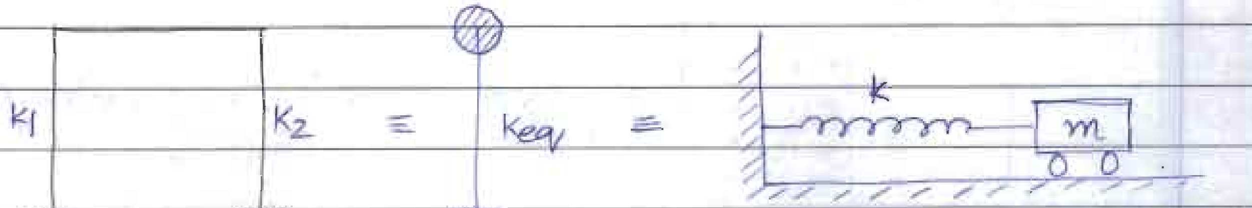
→ No Dynamic Excitation is present i.e. $P(t) = 0$

→ During the vibration, no loss of energy as there is no damping. ($c = 0$)

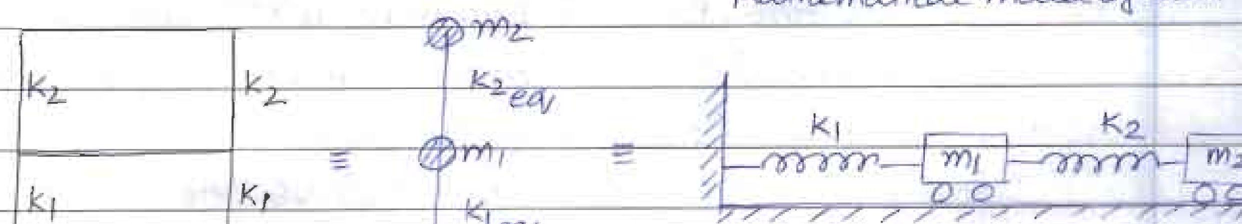
→ Vibration Analysis

① Mathematical Modelling
② Formation of eqⁿ of motion (DE)
③ Solution of eqⁿ of motion
④ Interpretation of resuets.

⇒ Mathematical Modelling



Mathematical model of SDOF



Mathematical model of MDOF

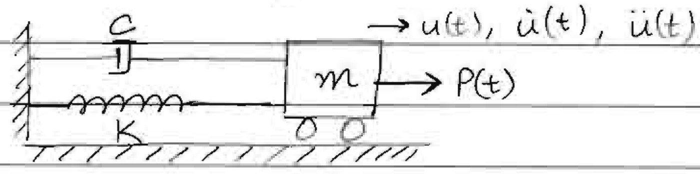
⇒ Formulation of eqⁿ of motion

The governing ~~ee~~ DE describing the motion is known as eqⁿ of motion.

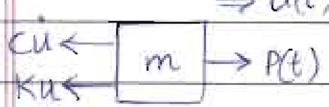
Few important methods are:

1. Newton's Second Law of motion
2. D-Alembert's Principle
3. SHM
4. Energy method.
5. Rayleigh method.

⇒ Newton's Second Law of motion



⇒ $\ddot{u}(t)$



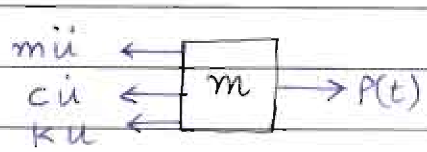
$$\Rightarrow P(t) - c\dot{u} - Ku = m\ddot{u}$$

$$\Rightarrow \boxed{m\ddot{u} + c\dot{u} + Ku = P(t)}$$

General eqⁿ of motion with viscous damping.

⇒ D-Alembert's Principle

→ This principle states that with the inertia force included, a system is in static equilibrium at each instant of time.



$$\Rightarrow \boxed{m\ddot{u} + c\dot{u} + Ku = P(t)}$$

NOTE: External force $P(t)$, displacement $u(t)$, velocity $\dot{u}(t)$ and acceleration $\ddot{u}(t)$ are taken to be positive in +ve x-dirⁿ.

→ Spring force, F_s is opposite to the displacement and Damping Force, F_d is opposite to the velocity.

→ The sign convention considered and eqⁿ of motion derived is independent of direction of motion.

⇒ Solution of eq^n of motion

$$m\ddot{u} + c\dot{u} + Ku = P(t)$$

→ For undamped free vibration,

$m\ddot{u} + Ku = 0$ → Second order LDE with Degree = 1

$\ddot{u} + \frac{K}{m}u = 0$

$D^2u + \frac{K}{m}u = 0 \Rightarrow \left(D^2 + \frac{K}{m}\right)u = 0$

$u \neq 0$ (because of Dynamic vibrations)

$\Rightarrow D^2 + \frac{K}{m} = 0$

$\Rightarrow D = \pm i\sqrt{\frac{K}{m}}$ → $u = c_1 e^{i\sqrt{\frac{K}{m}}t} + c_2 e^{-i\sqrt{\frac{K}{m}}t}$

$\Rightarrow u = c_1\left[\cos\left(\sqrt{\frac{K}{m}}t\right) + i\sin\left(\sqrt{\frac{K}{m}}t\right)\right]$
$+ c_2\left[\cos\left(-\sqrt{\frac{K}{m}}t\right) + i\sin\left(\sqrt{\frac{K}{m}}t\right)\right]$

$\Rightarrow u = (c_1+c_2)\cos\left(\sqrt{\frac{K}{m}}t\right) + i(c_1-c_2)\sin\left(\sqrt{\frac{K}{m}}t\right)$

$c_1+c_2 \rightarrow$ Real , $i(c_1-c_2) \rightarrow$ Real

Thus,

$$\boxed{u = A\cos\left(\sqrt{\frac{K}{m}}t\right) + B\sin\left(\sqrt{\frac{K}{m}}t\right)}$$

eq^n of motion for undamped free SDOF

→ Take $\boxed{\omega_n = \sqrt{\frac{K}{m}}}$ and thus, $\boxed{u = A\cos(\omega_n t) + B\sin(\omega_n t)}$

→ $\boxed{\text{Time Period, } T_n = \frac{2\pi}{\omega_n} = 2\pi\sqrt{\frac{m}{K}}}$

→ From the above eq^n it can be said that the state of mass i.e. displacement at 2 instances of time i.e. t_1 and $t_1 + \frac{2\pi}{\omega_n}$ is same. Here $\frac{2\pi}{\omega_n}$ is called as Time Period of function.

$\omega_n \rightarrow$ rad/s $\rightarrow$ circular frequency $\{ K \rightarrow N/m , m \rightarrow kg \}$

$T_n = \frac{2\pi}{\omega_n} \rightarrow$ Time Period

$\omega_n = 2\pi f_n$ $\{ f_n \rightarrow$ cyclic frequency [cycles per second] $\}$ Hertz (Hz)

$T_n = \frac{1}{f_n}$

$\Rightarrow$ at $t=0$, $u(t) = u(0)$

$\dot{u}(t) = \dot{u}(0)$

$u = A\cos(\omega_n t) + B\sin(\omega_n t)$

$\Rightarrow \boxed{A = u(0)}$

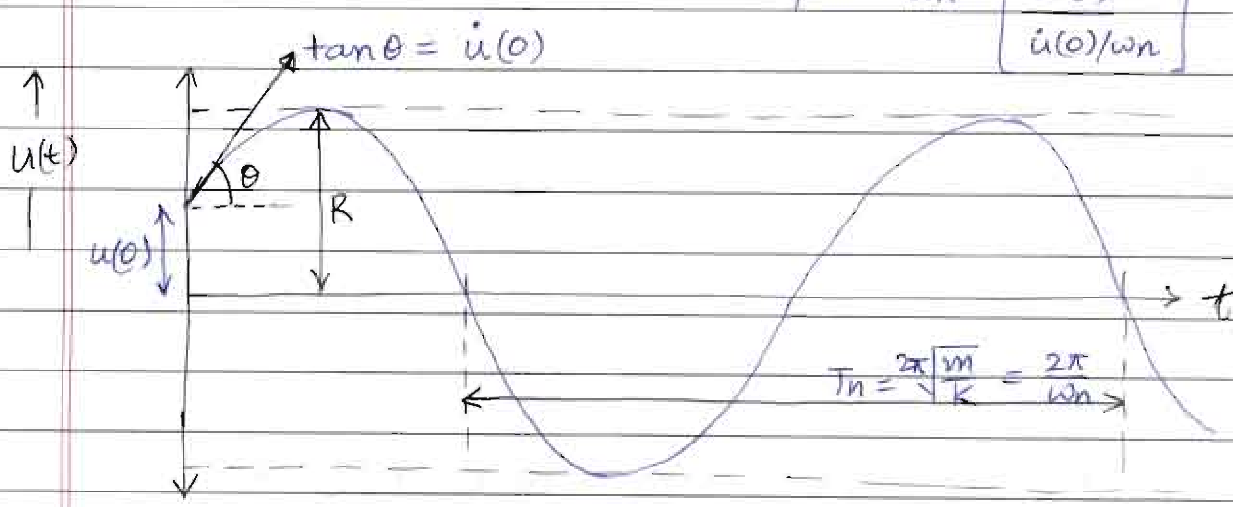
$\dot{u} = -A\omega_n \sin(\omega_n t) + B\omega_n \cos(\omega_n t)$

$\dot{u}(0) = B\omega_n \Rightarrow \boxed{B = \frac{\dot{u}(0)}{\omega_n}}$

$\Rightarrow \boxed{u(t) = u(0)\cos(\omega_n t) + \frac{\dot{u}(0)}{\omega_n}\sin(\omega_n t)}$

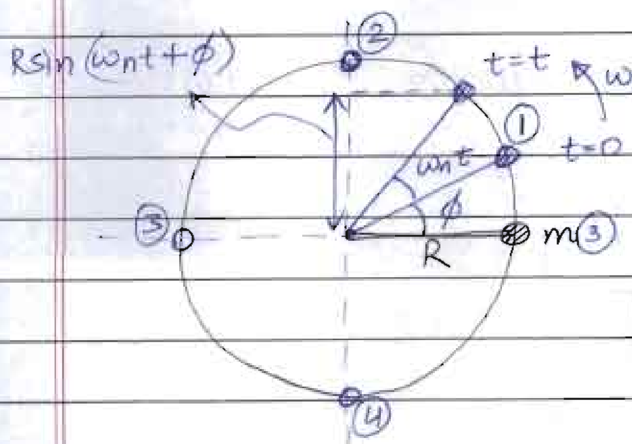
$\Rightarrow \boxed{u = R\sin(\omega_n t + \phi)}$ where, $R = \sqrt{[u(0)]^2 + \left[\frac{\dot{u}(0)}{\omega_n}\right]^2}$

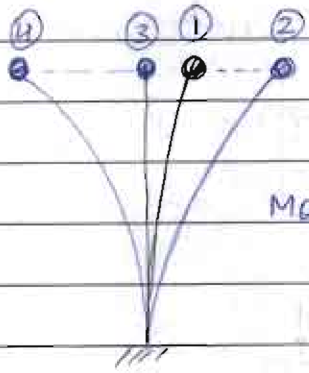
$\phi = \tan^{-1}\left[\frac{u(0)}{\dot{u}(0)/\omega_n}\right]$



$R = \sqrt{[u(0)]^2 + \left[\frac{\dot{u}(0)}{\omega_n}\right]^2}$

→ Comparison of uniform circular motion and SHM

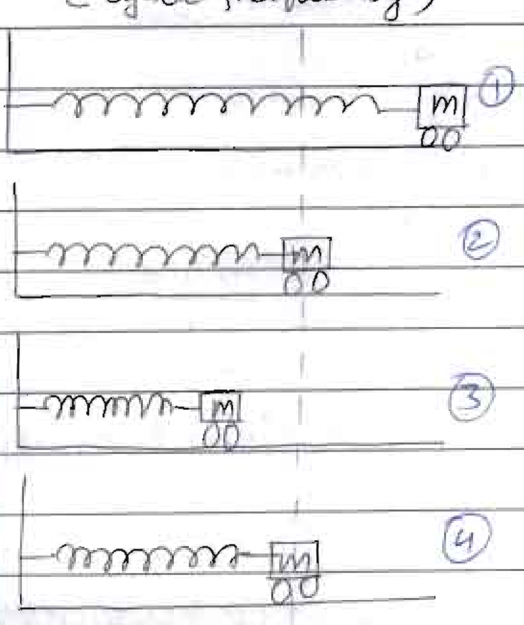


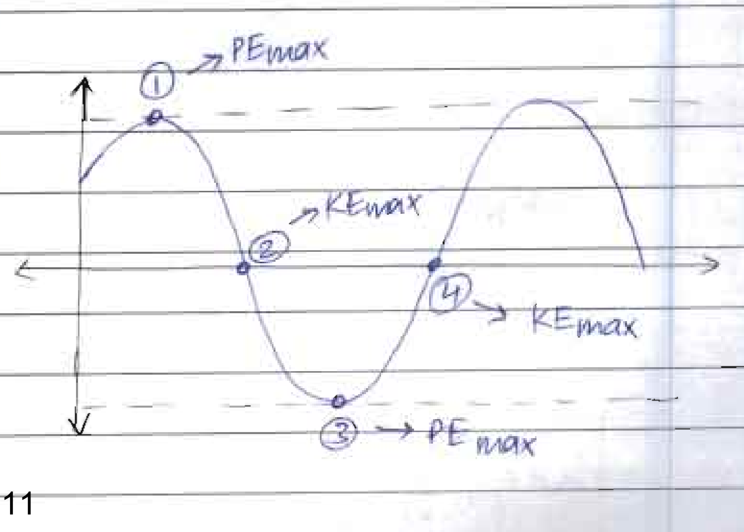


Motion of structure

NOTE: Characteristic of SHM
- → The motion shall be periodic
- → When disturbed from equilibrium position a restoring force acts on the body and is directly proportional to the displacement i.e. $F = -Kx$
- → ω_n, f_n, T_n are natural properties of the system. This means that irrespective of the initial displacement, velocity given to the system, the natural frequency and time period of the system will remain the same for linear elastic behaviour of the structure in a free vibration.

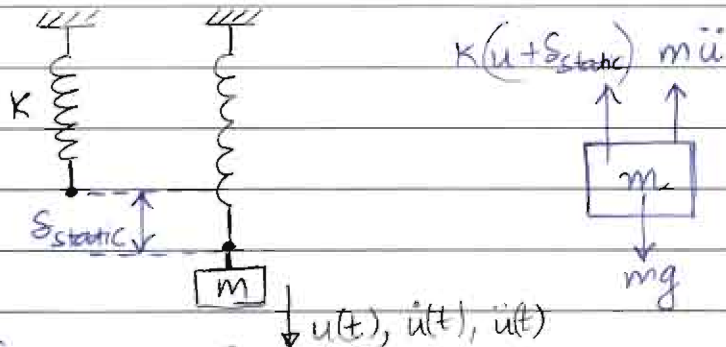
Q- The eq^n of free vibration of a system is $\frac{d^2x}{dt^2} + 64\pi^2 x = 0$,
it's natural frequency is 4 cps or 4 Hz
(cyclic frequency)





→ At any position of mass, $PE + KE = KE_{max} = PE_{max}$ [For no damping]

→ <u>Influence of gravitational force on equation of motion</u>



$$\delta_{static} = \frac{mg}{K}$$

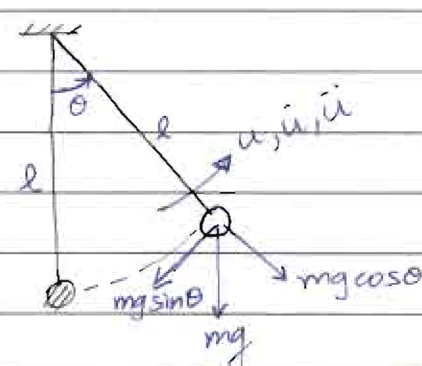
$$\Rightarrow \cancel{mg} = Ku + \cancel{K\delta_{static}} + m\ddot{u} \quad \Rightarrow \quad \boxed{m\ddot{u} + Ku = 0}$$

$u(t)$ → displacement from initial position (equilibrium position)

→ The above equation indicates that the equation of motion represented with respect to equilibrium position is not affected by gravitational force

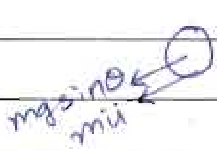
> NOTE: However when gravitational force acts as a destabilising or restoring force, we need to consider the effect of gravity

→ <u>Simple Pendulum</u>



$u = \theta \cdot l$

$\ddot{u} = \ddot{\theta}\, l$



$$\Rightarrow m\ddot{u} + mg\sin\theta = 0 \quad \equiv \quad \cancel{m\ddot{u} + K\theta = 0} \quad \boxed{\cancel{m\ddot{\theta} + \frac{g}{l}\theta = 0}}$$

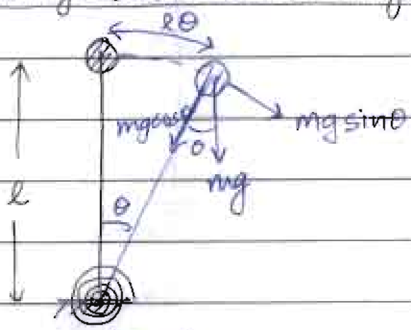
$$\Rightarrow l\ddot{\theta} + g\sin\theta = 0$$

$$\Rightarrow \boxed{l\ddot{\theta} + g\theta = 0} \quad \text{→ taking } \theta \text{ as very small}$$

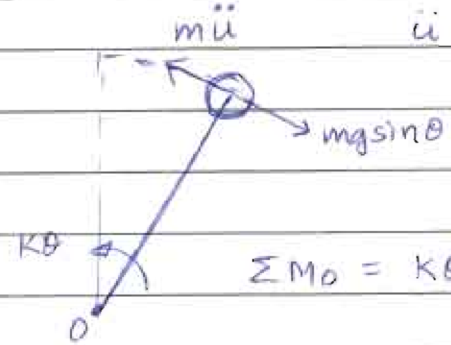
$$\boxed{\omega_n = \sqrt{\frac{g}{l}}}, \quad \boxed{T_n = \frac{2\pi}{\omega_n} = 2\pi\sqrt{\frac{l}{g}}}$$

→ example of gravity as a restoring force

→ Gravity as destabilizing force



Rotational Spring $K\left(\frac{Nm}{rad}\right)$



$\ddot{u} = \ddot{\theta}\, l$

$\Sigma M_O = K\theta + m\ddot{u}\, l - mg\sin\theta\, l$

So, $m\ddot{u}\, l + K\theta - mg\sin\theta\, l = 0$

$ml^2\ddot{\theta} + K\theta - mgl\theta = 0$

$$\boxed{m\ddot{\theta} + \left(\frac{K}{l^2} - \frac{mg}{l}\right)\theta = 0}$$

If $\frac{K}{l^2} - \frac{mg}{l} = 0$ → No vibration.

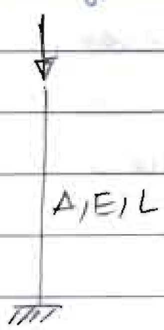
→ Stiffness of Dynamic system

→ The stiffness of structural system can be determined by using standard structural analysis.

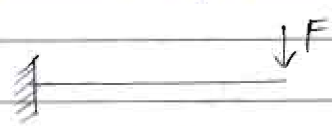
→ The stiffness will depend on material and geometrical property.

→ We need to calculate the equivalent stiffness of the structure in order to formulate the eq^n of motion.

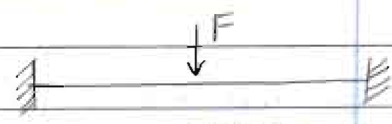
→ The stiffnesses of commonly used structural elements are:



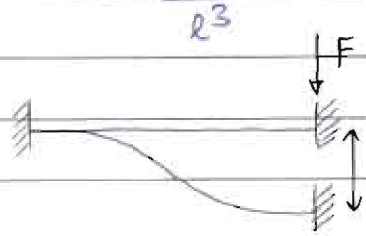
$K = \frac{AE}{L}$



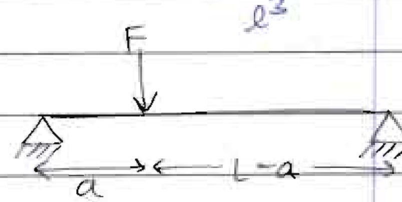
$K = \frac{3EI}{l^3}$



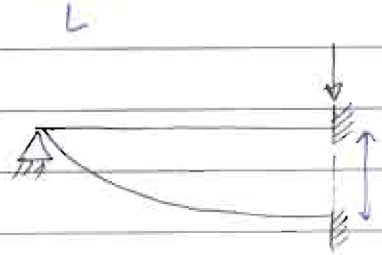
$K = \frac{192EI}{l^3}$



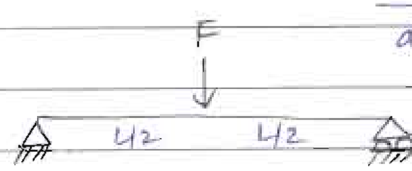
$K = \frac{12EI}{l^3}$



$K = \frac{3EIL}{a^2(L-a)^2}$



$K = \frac{3EI}{l^3}$



$K = \frac{48EI}{l^3}$

AIR-1 Notes

Pages: 283

SOIL MECHANICS & FOUNDATION ENGINEERING

Handwritten notes by

Kartikay Kaushik

AIR-1 ESE 2021

IES Master classroom Student

SOIL MECHANICS & FOUNDATION ENGINEERING

CONTENT

Soil Mechanics → Soil mechanics is the application of engineering mechanics in problems related to soil when used as a construction material & foundations on which we support our structures. It helps us to interpret the properties, behaviour & performance of various types of soil.

1. Origin of soil
2. Soil water relationship } Test (1)
3. Classification of soil
4. Clay mineral and Soil Structure
5. Compaction of soil → Test (1)
6. Permeability } GATE
7. Effective stress
8. Seepage
9. Compressibility and Consolidation → Test (1)
10. Shear strength of soil
11. Vertical Stress } Appⁿ
12. Earth pressure theory
13. Shallow foundation → Test (1) and Deep foundation → Test (2)
14. Exploration, expansive soil, stability of slope.

(1) Origin of Soil

→ Soil is an ~~unconsilat~~ unconsolidated material composed of soil particles produced by the disintegration of rock or decomposition of vegetative matter.
gravel / Sand / silt/clay   Organic silt / clay

→ Formation of soil is due to disintegration and transportation of igneous rock called parent rock or due to the decomposition of vegetative matter.

→ Disintegration of rock is due to weathering which are classified as:

(a) Physical weathering → Sand / gravel
(b) Chemical weathering → Silt / Clay

→ The physical weathering processes can be:

(a) Erosion of rock due to wind, water, glacier.

(b) Expansive force due to freezing water.

(c) Sudden change in temperature.

(d) Organic activity like growth of plant roots in existing cracks, rodents or worms etc.

(e) Unloading and resulting cracking.

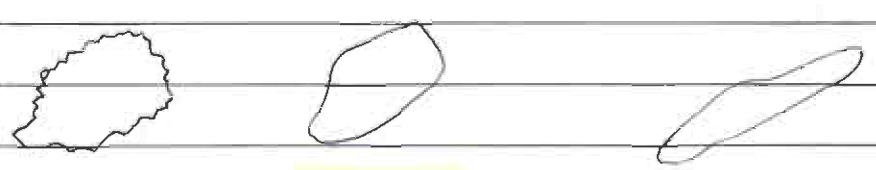
→ Soil formed by physical weathering has same mineralogical relationship and composition as that of parent rock.

→ Particles that are formed are bulky like sand and gravel.

→ The structural arrangement is called single grain structure

→ Single grain structure has no attraction or repulsion b/w the particles

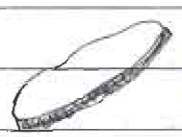
→ Shape of particle formed are angular, rounded, elongated and flat



Angular
→ Roughness more

Rounded
→ Roughness ~~more~~ less

elongated
(Low sphericity)



Flat

→ Quartz, Feldspar and Mica are primary soil minerals formed due to physical weathering.

(b) Chemical Weathering

→ The various chemical processes during chemical weathering are:

① Hydration – Reaction of minerals with H^+ and OH^- of water and these ions replace the existing cation.

② Oxidation – Acid produced during this process causes weathering

③ Carbonation – CO_2 in water dissolves minerals and they are carried away.

(4) Desilication – Leaching of silica.

NOTE: Leaching means when the water soluble parts are dissolved and washed out, the process is called Leaching.
In this process, mineral composition of the parent rock changes.

→ Chemical weathering process results in the formation of crystalline particles of colloidal size known as clay minerals like Kaolinite, Illite and Montmorillonite.

NOTE: If -2 micron sized particles have cohesion b/w them then it is called clay particle but if there is no cohesion then it is called clay-sized particle.

→ Most clay mineral particles have plate-like form. having high specific surface [high surface area per unit volume or mass) with a result that the behavior is affected significantly due to presence of surface forces and hence water can significantly affect the behavior of clay.

⇒ Residual and Transported Soil

→ If the soil is still located at the place of it's origin, it is called residual soil and if it has been transported by wind, water or glacier it is called transported soil.

→ Residual soils have better engineering property and they have angular soil particles.

→ Laterite is an example of Residual soil, Black Cotton Soil

→ The transported soil have smaller grain particles and larger amount of pores.

→ Depending on the transporting agency soils are classified as.

1. Alluvial soil → Transported by running water like rivers
2. Lacustrine soil → Deposited in still water like lake
3. Marine soil → Deposited in sea water
4. Aeolian soil → Deposited by air, wind.
5. Glacial deposits - Transported by ice, glaciers.

→ Names of various types of soils

1. Bentonite

It has high %age of clay mineral montmorillonite and it is highly plastic and results from the decomposition of volcanic ash. Highly water absorbent and great swelling and shrinkage tendency.

2. Black Cotton soil

It is a residual soil consisting of high %age of Montmorillonite. It has low Bearing capacity and high swelling /shrinkage. It is formed by chemical weathering of Basalt Rock. It is dark in color and is good for growing cotton.

> NOTE: Stabilisation of Black Cotton soil is done using lime stabilisation and reduces plasticity hence ~~increases~~ makes the soil friable.

3. Loess

It is a fine grained (silty sized), homogeneous, friable (easily crushable)

NOTE:
- < 2 μm → clay
- 2 μm - 75 μm → silt

} fine grained

- 75 μm - 4.75 mm → sand
- 4.75 mm - 80 mm → gravel

} coarse-grained

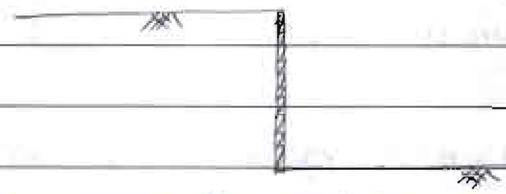
80 mm - 300 mm → Cobble

>300 mm - Boulder

Aeolian

air borne deposits having uniform grain size and high void ratio.

→ It can stand deep vertical cut because of slight cementation b/w particles due to $CaCO_3$ and Montmorillonite.



→ It has continuous root holes and hence permeability in vertical direction is much greater than that in the horizontal direction.

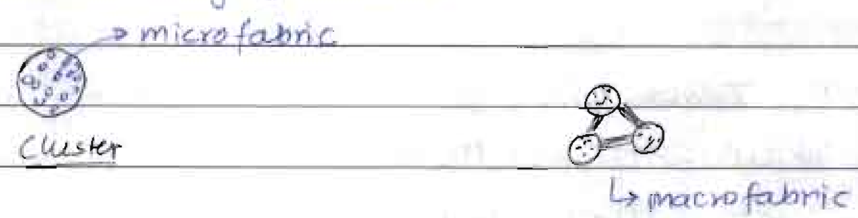
→ It is found in arid and semi-arid region and it is highly porous.

→ It is subjected to collapse when saturated.

→ It has loose meta-stable fabric [arrangement of particles], low density and high compressibility.

→ It has low Bearing Capacity.

→ It's macro-fabric is bulky granular.



④ Till

→ It is an unstratified soil made by melting of glaciers.

→ The deposit consists of particles of different sizes ranging from boulder to clay.

→ It can be easily densified by compaction and it is a well graded soil.

→ It has high shear strength. Also known as boulder clay.

⑤ Marl

→ It is a stiff marine calcareous clay of greenish color.

⑥ Varved Clay

→ These are sedimentary deposits consisting of alternate thin layers of clayey silt and silty clayey

NOTE: Clayey Silt
Adjective Noun
Noun represents main component.

→ These clays are results of deposition in glacial lakes due to periods of alternating

→ Shear resistance of varved clay is much smaller along horizontal plane and hydraulic conductivity is much greater in horizontal plane as compared to vertical plane.

7. Indurated Clay

→ Induration means clay has become more firm and it does not soften under prolonged wetting.

NOTE: Induration is a term used to describe degree of Lithification
→ Lithification is the conversion of unconsolidated sediments into sedimentary rocks by porosity destruction through compaction and cementation.

8. Diatomaceous Earth

→ Diatoms are minute unicellular marine organisms.

→ Diatomaceous earth is a fine light grey soft sedimentary deposit of silicious remains of skeletons of diatoms.

9. Lateritic soil

→ Lateritic soils are formed by decomposition of rocks, removal of silica and accumulation of Iron and aluminium Oxides.

→ It is a residual deposit formed from basalt.

→ Presence of Iron oxide imparts reddish color and high specific gravity.
→ Generally it hardens with passage of time.

⑩ Marine Deposit
→ It has low shearing strength, high compressibility and contains organic matter. It is soft and highly plastic.

⑪ Colluvial soil
→ Gravity deposited soil. Also named as Talus. It has irregular and coarse particle.

⑫ Peat
→ It is an organic soil having fibrous particles formed from vegetative matter under conditions of excessive moisture.
→ It is highly compressible and not suitable for foundations.

⑬ Muck
→ Mixture of fine soil particles in highly decomposed organic matter and black in color and extremely soft in consistency.

⑭ Loam
→ Mixture of sand, silt and clay.

⑮ Hard Pan
→ It does not disintegrate when submerged in water and offers great resistance to penetration.

⑯ Tuff
→ It is a fine grained soil composed of particles ejected from volcanoes and deposited by wind and water.

⑰ Dispersive clay (Easily Erodable)

→ It occurs in soil of low and medium plasticity that contains montmorillonite.

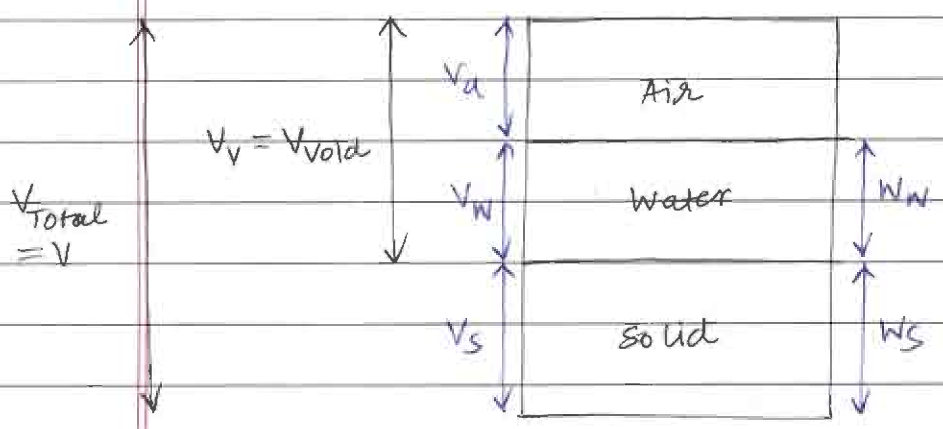
→ It is treated with lime to make it non dispersive.

⑱ Collapsing soil

→ Soil susceptible to large decrease in volume when saturated

② Soil-Water Relationship

⇒ Phase Diagram of soil



→ Soil is generally a 3-phase system but completely saturated soil and completely dry soil are called 2-phase system.

⇒ Basic Definitions

① Water content $\quad w = \dfrac{W_w}{W_s}$

> NOTE: In Environmental Engg,
> $$w = \frac{W_w}{W_w + W_s} = \frac{W_w}{W}$$

→ It has no upper limit and for dry soil it is zero.

→ Fine-grained soil have more moisture content than coarse grained soil.

② Void Ratio $e = \frac{V_v}{V_s}$

→ It has no upper limit

→ Void ratio of fine grained soil are generally higher than that of coarse grained soil although the size of void is large in case of coarse grained soil

NOTE: $e_{\cancel{clay}\ sand} \to 0.5$ to 0.7 } generally
$e_{clay} \to 0.8$ to 0.9

③ Porosity $n = \frac{V_v}{V}$

→ It's upper limit is 1.

→ If porosity is high density will be less.

④ Degree of Saturation $S = \frac{V_w}{V_v}$

→ For dry sole, $S=0$ and for saturated soil, $S=1$

⑤ %age air void $n_a = \frac{V_a}{V}$

⑥ Air content $a_c = \frac{V_a}{V_v} = 1 - S$

⑦ Bulk Unit weight $\gamma_t = \frac{W_{Total}}{V_{Total}}$

⑧ Unit weight of solid $\gamma_s = \frac{W_{solid}}{V_{solid}}$

⑨ Unit wt. of water, $\gamma_w = \dfrac{W_w}{V_w} = 9.81\ kN/m^3$

⑩ Dry unit weight, $\gamma_d = \dfrac{W_s}{V_{Total}}$

→ γ_d is used as a measure of denseness of soil i.e. higher value of γ_d indicated that more solids are packed in the unit volume of soil and hence soil is more compacted.

⑪ Saturated unit weight, $\gamma_{sat} = \dfrac{\text{Weight of sat. soil}}{\cancel{\text{Weight}}\ \text{Volume of sat. soil.}}$

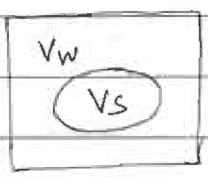
→ Saturated unit wt. will be a function of water content and as water content increases, γ_{sat} decreases.

⑫ Submerged unit weight, $\gamma_{sub} = \gamma_{sat} - \gamma_w$

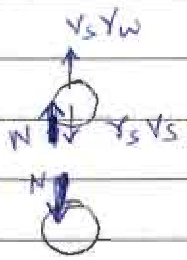
→ When the soil is submerged below ground water table, Buoyant force acts on the particle and hence,

$$\frac{\text{Buoyant weight}}{\text{volume of soil}} = \gamma_{sub}.$$

→ $\gamma_{sub} \times V =$ Weight (Buoyant) of soil



$$\gamma_{sub} \cdot V = (\gamma_{sat} - \gamma_w) V$$
$$= \gamma_{sat} V - \gamma_w V$$
$$= (\gamma_{sat} V_W + \gamma_{sat} V_S) - \gamma_w V_S - \gamma_w V_W$$
$$= \cancel{\gamma_w V_W} + \gamma_S V_S - \gamma_w V_S - \cancel{\gamma_w V_W}$$
$$= V_S(\gamma_S - \gamma_W)$$



So, $N + V_S \gamma_W = \gamma_S V_S$

$\Rightarrow \boxed{N = (\gamma_S - \gamma_W) V_S}$

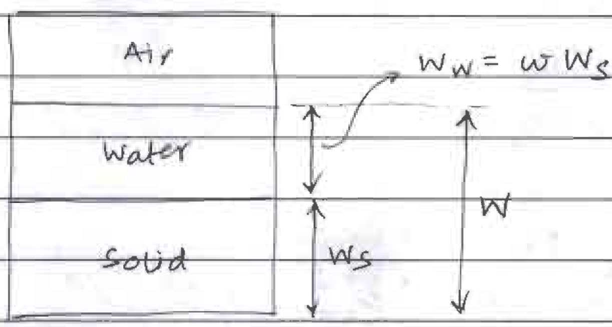
NOTE:
A saturated soil may not be submerged soil. like a soil saturated with capillary water is not submerged soil. Only soil below the water table is called submerged soil.

(13) Specific gravity of solids $G_s = \frac{\gamma_s}{\gamma_w}$

→ Generally for inorganic soils, $G_s \in (2.6, 2.7)$
and for organic soils, $G_s \in (1.5, 2)$
→ Specific gravity of solids is also called absolute specific gravity or grain specific gravity

(14) Mass specific gravity of soil, $G_m = \frac{\gamma_t}{\gamma_w}$ → bulk unit weight

⇒ Some important Relationship



(1) $W = W_s + W_w = W_s + w W_s$
$\Rightarrow \boxed{W_s = \frac{W}{1+w}}$

(2) $V_v = e V_s$
So, $V = V_v + V_s = (1+e) V_s \Rightarrow \boxed{V_s = \frac{V}{1+e}}$

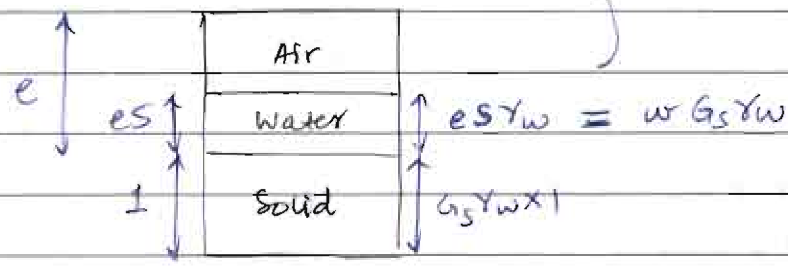
(3) $n = \frac{V_v}{V} = \frac{e V_s}{(1+e) V_s} = \boxed{\frac{e}{1+e} = n}$

(4) $e = \dfrac{V_v}{V_s}$ and $n = \dfrac{e}{1+e}$ $\Rightarrow$ $n + ne = e$

$\Rightarrow$ $\boxed{e = \dfrac{n}{1-n}}$

(5) $\boxed{eS = wG_s}$

(6)

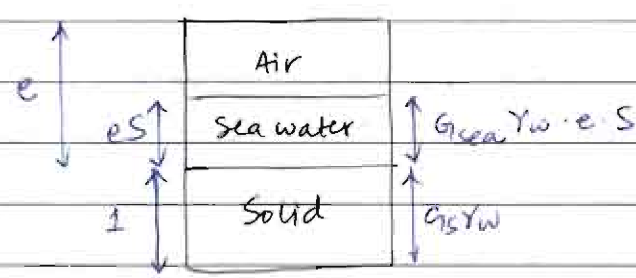


$$\boxed{\gamma_t = \frac{G_s\gamma_w(1+w)}{1+e}}$$

$$\gamma_t = \frac{G_s\gamma_w\left(1+\frac{eS}{G_s}\right)}{1+e}$$

$$\boxed{\gamma_t = \frac{\gamma_w(G_s+eS)}{1+e}}$$

(7)



So, $\boxed{\gamma_t = \dfrac{\gamma_w(G_s + G_{sea} \cdot eS)}{1+e}}$

(8) $\boxed{\gamma_{sat} = \dfrac{\gamma_w(G_s+e)}{1+e}}$

(9) $\gamma_{sub} = \gamma_{sat} - \gamma_w$
$$= \frac{\gamma_w (G_s + e)}{1+e} - \gamma_w$$

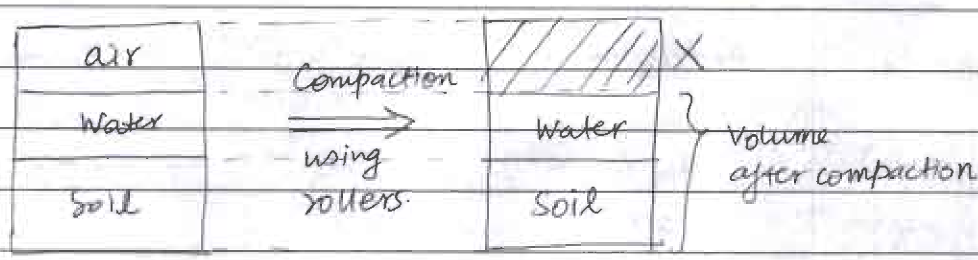
$$\boxed{\gamma_{sub} = \frac{(G_s - 1)\gamma_w}{(1+e)}}$$

(10) $$\boxed{\gamma_d = \frac{G_s \gamma_w}{1+e} = \frac{\gamma_t}{1+w}}$$

(11) $$1 - n_a = 1 - \frac{V_a}{V} = \frac{V - V_a}{V} = \frac{V_w + V_s}{V} = \frac{W_w}{\gamma_w V} + \frac{W_s}{V G_s \gamma_w}$$
$$= \frac{W_s}{\gamma_w V}\left[w + \frac{1}{G_s} \right] = \frac{\gamma_d}{\gamma_w}\left(\frac{1 + w G_s}{G_s}\right)$$

$$\Rightarrow \quad \boxed{\gamma_d = \frac{G_s \gamma_w (1 - n_a)}{1 + w G_s}}$$

(12)



$$\boxed{\gamma_d = \frac{G_s \gamma_w}{1 + w G_s}}$$ → Zero air void Dry density.

Zero air void dry density is the theoretical maximum dry density at a particular water content. It can never be achieved practically.

Q. The total unit weight of a soil is 16 KN/m^3. The specific gravity of solid particle of soil is 2.67. Water content of the soil is 17%. Assuming $\gamma_w = 9.81$ KN/m^3. Calculate.

AIR-1 Notes

Pages: 268

Strength of Material

Handwritten notes by

Kartikay Kaushik

AIR-1 ESE 2021

IES Master classroom Student

STRENGTH OF MATERIALS

CONTENT

Date 18/06/19

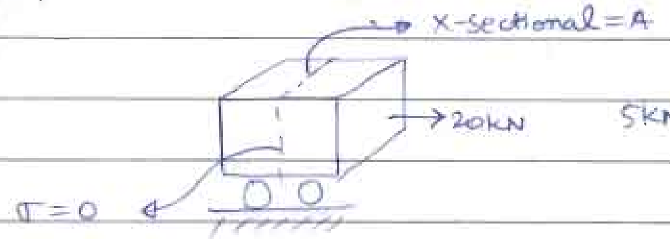
Strength of materials

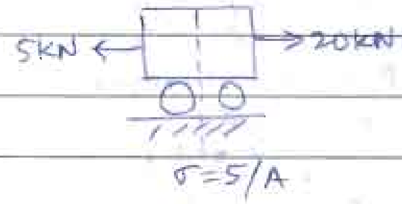
Syllabus:

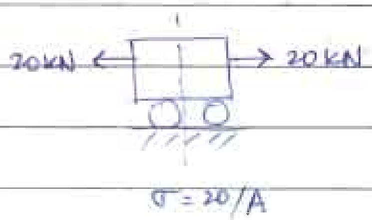
1) Properties of material and axial stress
2) Bending moment and shear force diagram
3) Bending stress
4) Transverse shear stress
5) Torsional shear stress
6) Transformation of stress and strain
7) Combined stress
8) Thick and Thin shell
9) Spring
10) Column
11) MOT
12) Deflection of Beams

Obj (8–11)

⇒ Properties of materials and axial stress







① Restraining Force

$\frac{RL}{AE} = L\alpha\Delta T \Rightarrow R = E\alpha\Delta T$

② Restrained Deformation

→ Stress develops on a body ~~on~~ in account of restraining force or restrained deformation.

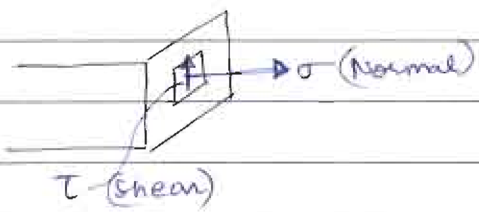
Stress

Normal Stress

→ $\dfrac{\text{Normal Force}}{\text{Area}}$

Shear Stress

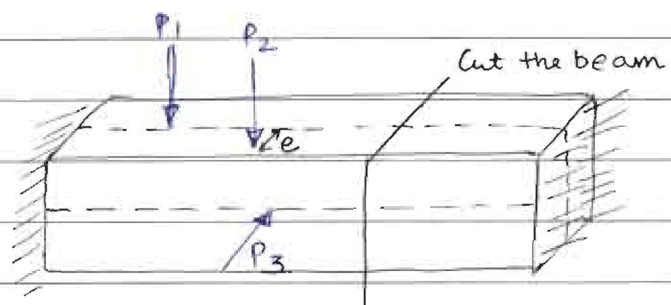
→ $\dfrac{\text{Force in the plane of section}}{\text{Area}}$

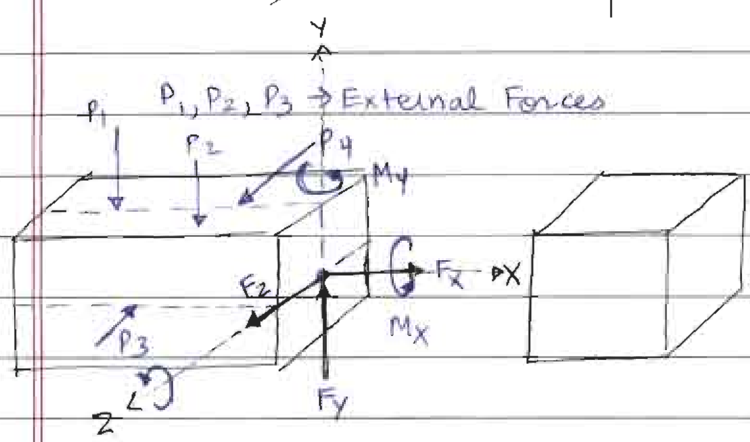


→ Stresses are of 2 types: Normal stress and shear stress.

→ Normal stress is ⊥ar to the section and shear stress is along the section

→ **Internal and External Forces**





$M_x, M_y, M_z, F_x, F_y, F_z$ are internal Forces $\Big\}$ at max there can be 6 I.F. in a plane.

> **NOTE:**
> Direction of Moment is given by Right Hand Thumb Rule

→ F_x → Axial Force (⊥ar to the section)

F_y →
F_z → } Shear Force (along the section)

M_x → Torsional Moment [points on section tend to move in the plane itself]

M_y →
M_z → } Bending Moment [points on the section tend to move out of plane]

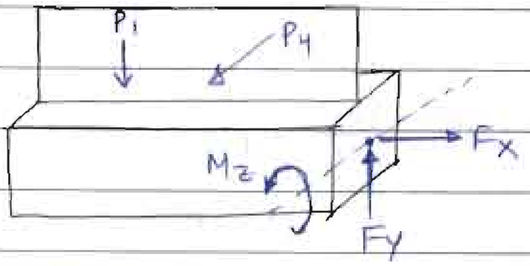
→ Axial Force → Axial stress → Normal stress

Shear Force → Transverse Shear Stress → Shear Stress

Torsional Moment → Torsional Shear Stress → Shear Stress

Bending Moment → Bending Stress → Normal Stress

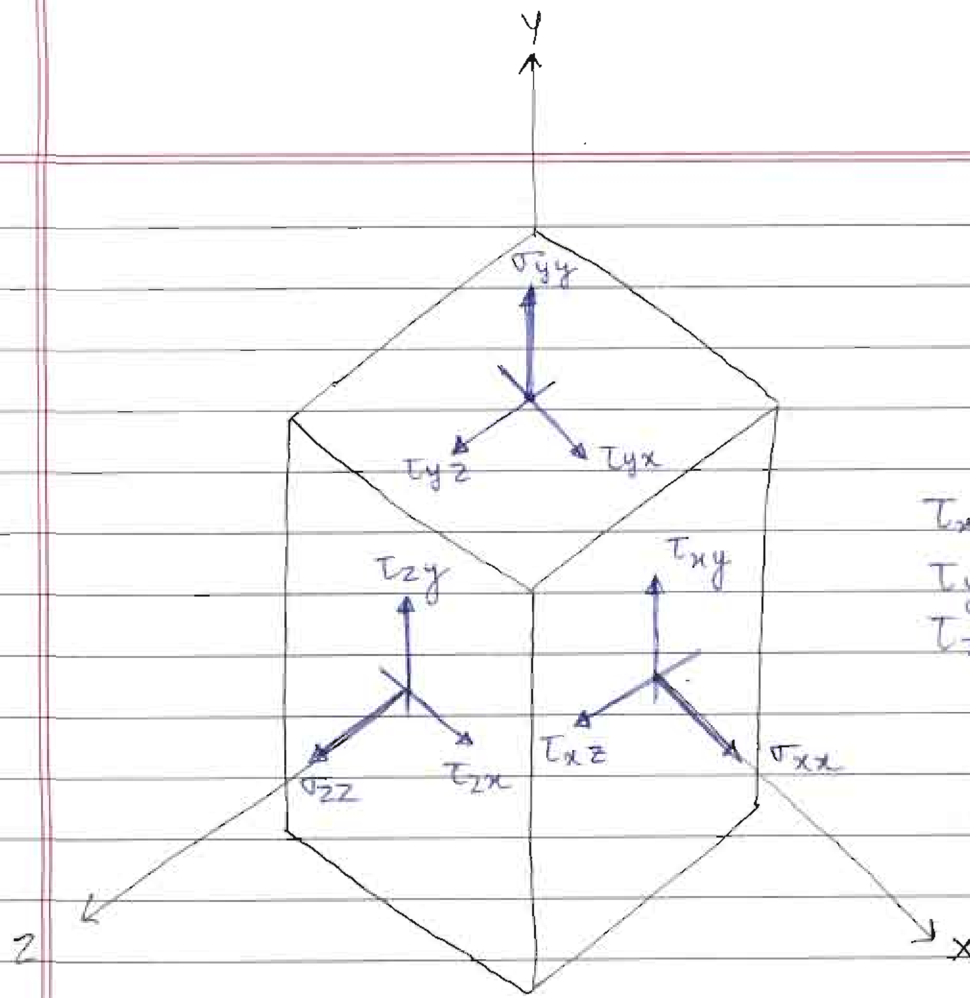
→ 2-D case → when loading and structure are in the same plane. [CG plane]



→ When structure and loading are in same plane, it is called a 2-D condition or a planar condition.

→ In 2-D condition, we have 3-internal Forces: Axial force, Shear force and Bending Moment

→ Stresses under general Loading condition



σ_{xx}

σ_{yy}

σ_{zz}

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

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

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

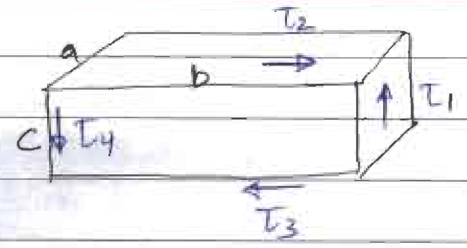
→ Convention → (Stress symbol)$\underset{\text{Plane}}{\square}\underset{\text{Direction}}{\square}$

⊕ x-plane → Outward normal to the plane is in ⊕x-direction.

→ At any point under general loading condition, number of stress components are 9. $\{\underbrace{\sigma_{xx}, \sigma_{yy}, \sigma_{zz}}_{\text{3-Normal Stress}}, \underbrace{\tau_{xy}, \tau_{xz}, \tau_{yx}, \tau_{yz}, \tau_{zx}, \tau_{zy}}_{\text{6-Shear Stress}}\}$

→ <u>Statement 1</u> Shear stresses on opposite faces are equal and opposite in direction. [Follows from Force equilibrium]

→ <u>Statement 2</u> Shear stresses on adjacent $\perp$ar faces are equal and are directed in such a way that either both of them point towards a junction or they point away from a junction. [Follows from moment equilibrium]



$\Sigma F_H = 0$

$\Rightarrow \tau_2(ab) - \tau_3(ab) = 0 \Rightarrow \boxed{\tau_2 = \tau_3}$

$\Sigma F_V = 0$

$\Rightarrow \tau_1(ac) - \tau_4(ac) = 0 \Rightarrow \boxed{\tau_1 = \tau_4}$

$\Sigma M = 0$

$\Rightarrow (\tau_1 ac)b - (\tau_2 ab)c \Rightarrow \boxed{\tau_1 = \tau_2}$

→ Thus at any point under general loading condition, number of distinct stress components is 6. $[\sigma_{xx}, \sigma_{yy}, \sigma_{zz}, \tau_{xy}, \tau_{yz}, \tau_{zx}]$

→ Stress Tensor

$$\begin{array}{c} \text{Direction} \\ \downarrow \end{array}$$

$$\begin{bmatrix} \sigma_{xx} & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & \sigma_{yy} & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & \sigma_{zz} \end{bmatrix}_{3\times 3} \longrightarrow \text{Plane}$$

→ Symmetry of stress tensor is on account of moment equilibrium.

NOTE:

No. of elements of tensor $= 3^n$

$n \rightarrow$ order of tensor

→ Stress is a second ~~of~~ order tensor [Stress, Strain, MOI]

→ Direction is a first order tenser

→ Magnitude is a zero order tensor

→ Transformation of any second order tensor can be done using Mohr's Circle

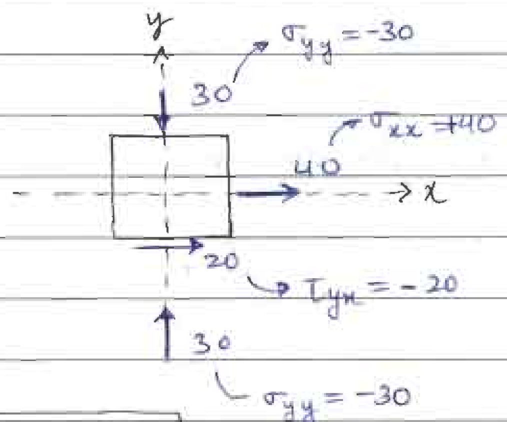
→ ~~Vector is~~

> **NOTE:**
>
> → Stress is not a vector quantity as it does not follow the Parallelogram law of vector addition, although it has some magnitude and direction.

→ Sign convention for Stresses

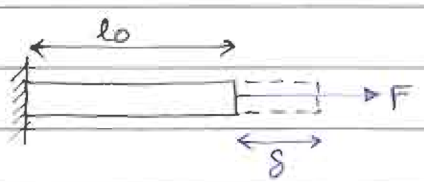
σ

Plane	Direction	Sign
+	+	+
+	−	−
−	−	+
−	+	−



> NOTE:
>
> For Normal Stress, we can have:
>
> (a) Tensile Stress → +ve
>
> (b) Compressive Stresses → −ve

→ Normal Strain

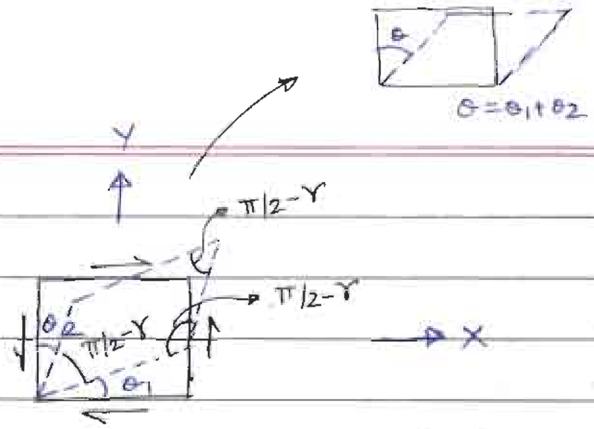


Normal Stress = F / A

Average Normal Strain ⇒ $\epsilon = \dfrac{\delta}{l_o} = \dfrac{\text{Change in length}}{\text{Original length}}$.

Elongation → +ve , Compression → −ve

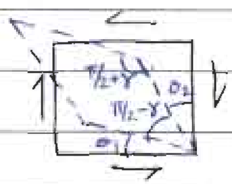
→ Shear strain



→ (Positive)

$\theta_1 + \theta_2 \rightarrow$ shear strain (γ)

→



→ (Negative)

→ If angle b/w positive faces decreases, shear strain strain will be taken positive.

→ If angle b/w positive faces increases, shear strain is taken as negative.

NOTE:
Positive and negative shear stress produce positive and negative shear strain respectively.

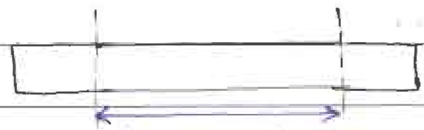
→ Normal strains can be measured using strain gauges or extensometer but stresses cannot be measured, they can only be derived.

→ Hence, Strain is a fundamental quantity not the stress.

→ Stress – Strain curve

→ Stress – Strain curve of a material represents the ~~static~~ characteristic property of a material. [Load deformation curve changes with dimension]

→ Stress-Strain curve for mild steel



{Universal Testing Machine exerts tensile Force}

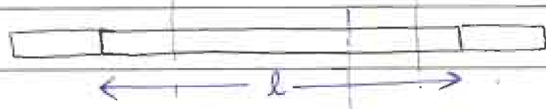
Engineering Strain $\varepsilon = \frac{\delta}{l_0}$

$l_0 \rightarrow$ gauge length

$A_0 \rightarrow$ X-sectional Area.

$\sigma = \frac{P}{A_0} \rightarrow$ engineering stress

$\boxed{l_0 = 5.65\sqrt{A_0}}$

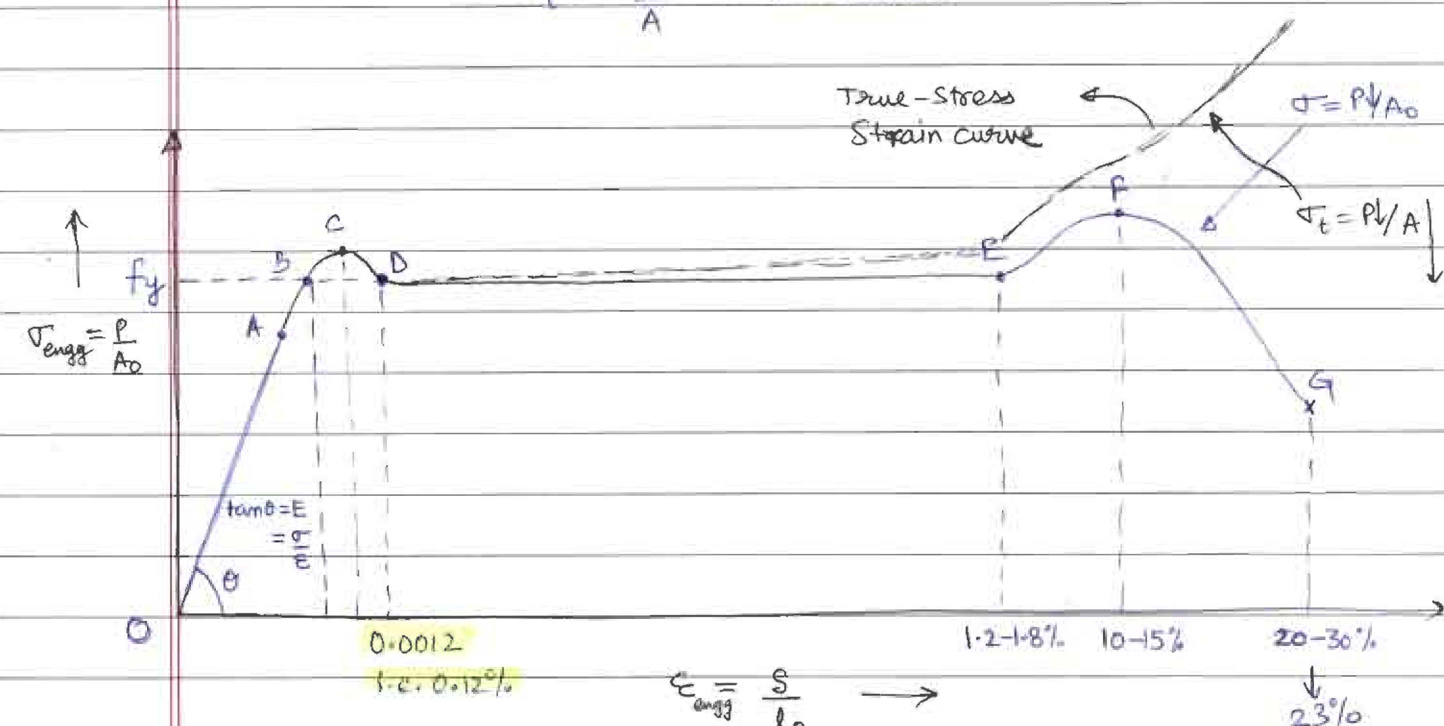


→ at any instant of time.

X sectional area = A

true strain $\leftarrow \varepsilon_t = \frac{\delta}{l}$

$\sigma_t = \frac{P}{A} \rightarrow$ true stress



A → Proportional limit

B → Elastic Limit

C → Upper Yield Point

D → Lower Yield Point

E → Beginning of strain hardening

F → Ultimate stress point

G → Fracture point.

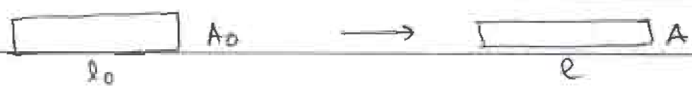
→ Region OA

→ Stress $\propto$ Strain

i.e. $\dfrac{\text{Stress}}{\text{Strain}}$ = constant = E [Modulus of Elasticity]

→ Strains are infinitesimal [very small]

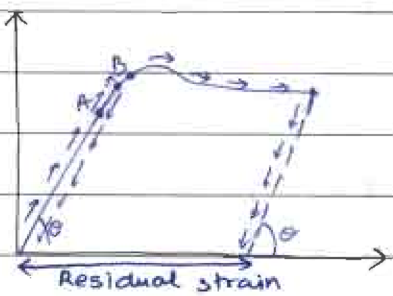
→ Volume of the specimen increases in tension.



$lA > l_0A_0$

→ Region AD

→ strain starts increasing at a greater rate.



→ If material is unloaded before elastic limit B, the original shape and dimension will be regained instantaneously i.e. there is no residual strain i.e. loading and unloading curve is same.

→ upper yield corresponds to a transient condition

→ Lower yield corresponds to load required to maintain yield.

→ Hence yield strength of material is taken corresponding to lower yield point.

→ Volume of the specimen increases due to tension.

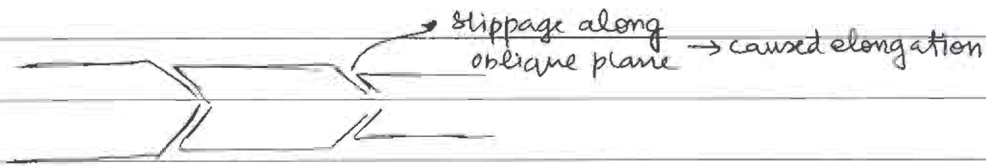
→ upto D normal stress is primarily responsible for deformation.

NOTE:

In case of solid mechanics, volume changes are thought to be only due to Normal stress

Shear stress creates distortion only [deformation without volume change]

→ **Region DE (Plastic Zone)**



→ Strain increases without significant increase in stress

→ Deformation is caused due to slippage of material on oblique plane, hence, deformation is primarily due to shear stresses, thus volume change is 0.

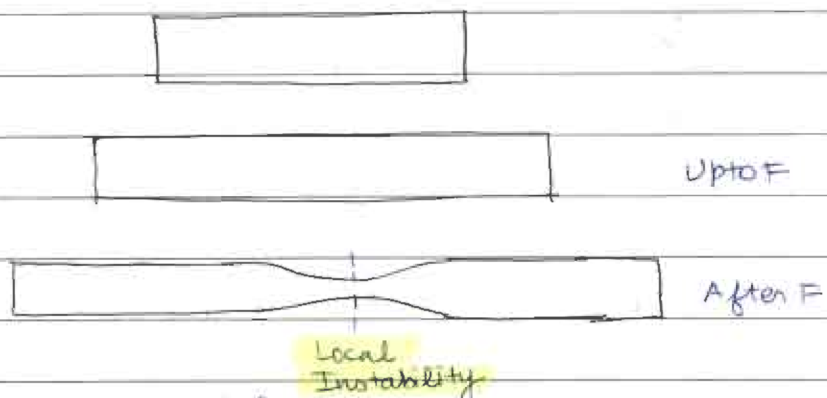
→ Strains are permanent

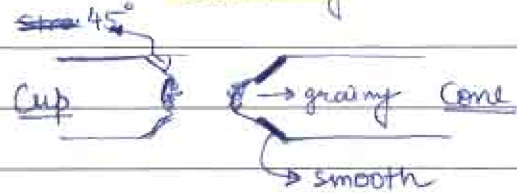
→ **Region EF (Strain Hardening Region)**

→ Beyond point E, material starts offering resistance against deformation

→ This is due to change in crystalline structure of the material

→ **Region FG (Necking Region)**





→ The X-section of the specimen begins to decrease at some localised location due to instability. This is called necking.

→ Ultimate rupture occurs along a cone shaped surface with angle from original surface $= 45^\circ$

→ This failure is called cup-cone failure and shear is responsible for failure

→ %age reduction in X-sectional area upto the time of fracture is about 50%.

NOTE:

→ In ductile materials, shear is responsible for fracture.

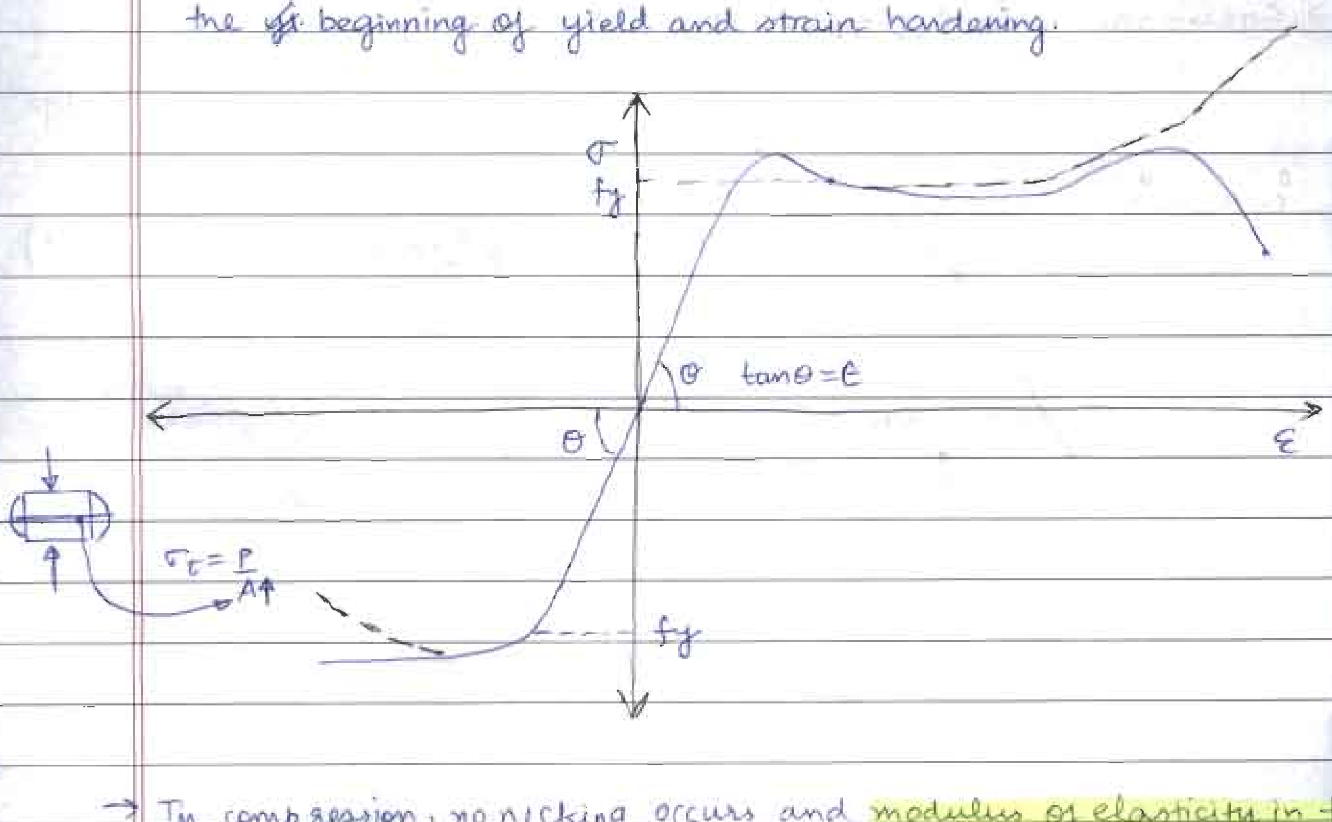
→ Ductile material → when material fails after high inelastic deformation [Rubber is a brittle material].

NOTE: → strain controlled loading.

Normal strain applied is ~~proportional~~ such that the rate of change of ~~shear~~ strain is constant. Near failure, Normal strain will be less to maintain this rate of change of strain.

→ Mild steel in compression

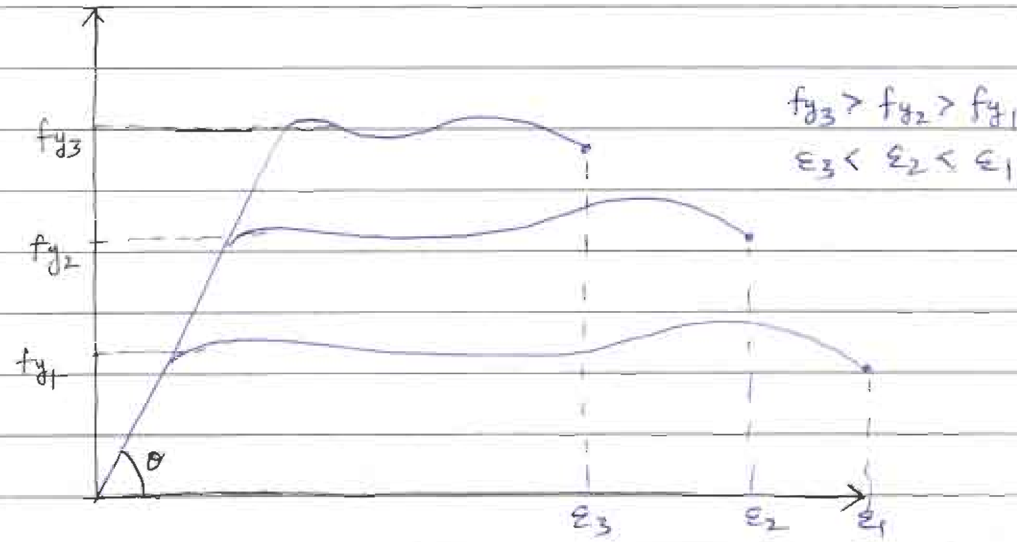
→ The stress strain curve in compression would be essentially same through its initial straight line portion and through the beginning of yield and strain hardening.



→ In compression, no necking occurs and modulus of elasticity in tension & compression are same.

→ True stress in compression would be smaller

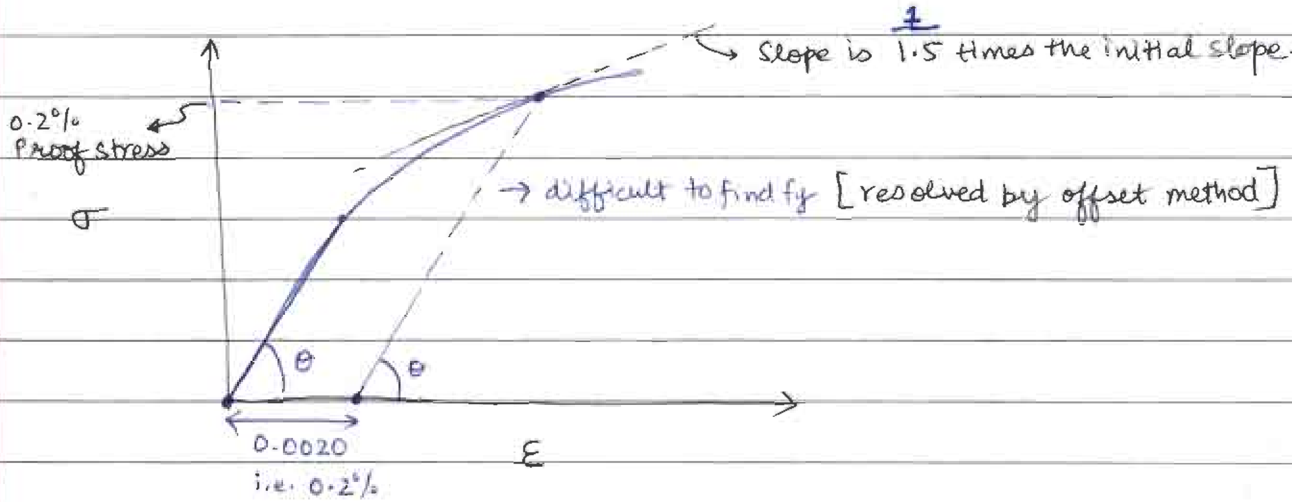
→ Stress–Strain curve for higher grades of steel



→ Strength, ductility and corrosion resistance can be altered by alloying, heat treatment and using various manufacturing processes.

→ But the modulus of elasticity for various grades are same and as the yield strength increases, ductility reduces.

→ Stress–Strain curve for aluminium and copper



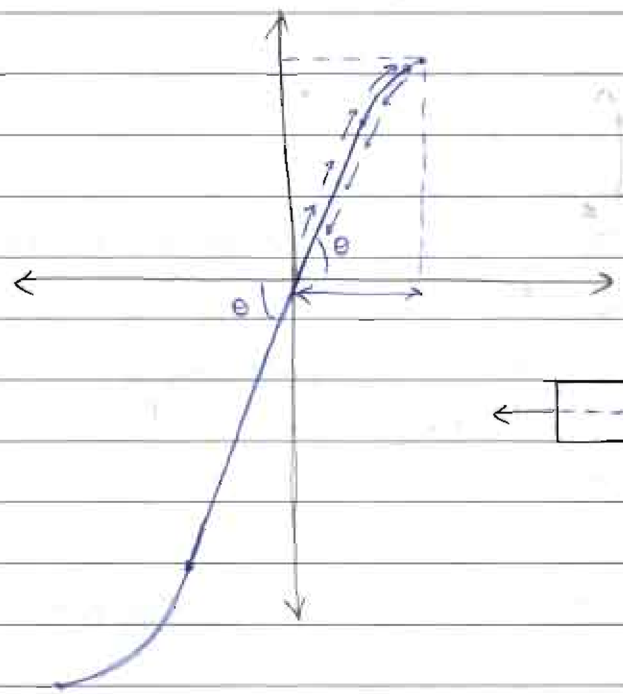
$$\sigma_{permissible} = \frac{f_y}{FOS} \quad \text{[ductile material]}$$

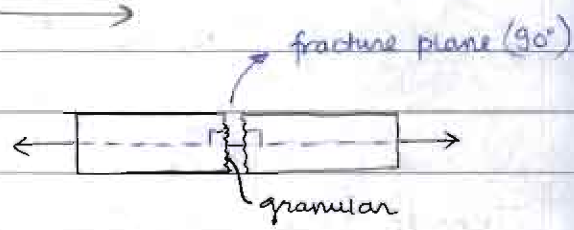
$$= \frac{f_u}{FOS} \quad \text{[Brittle material]}$$

→ In case of aluminium, copper and other materials having no well-defined yield pt, the yield stress for calculation purpose is calculated using offset method, in which we start with 0.0020 (0.2%) strain and move parallel to the initial straight line portion of the stress-strain curve.

→ The point where this line intersects the strain-strain curve corresponds to 0.2% proff stress which is taken as yield stress for calculation purpose.

→ Stress-Strain curve for brittle material {eg cast iron}





→ The linear elastic range in tension is smaller than in compression.

→ Strain at rupture is very small as compared to that in ductile material.

→ Rupture strain is elastic [fracture in elastic range]

→ There is no plastic zone, so ultimate stress = Rupture stress.

→ $\text{permissible stress} = \dfrac{\text{Rupture Stress}}{\text{FOS}}$

→ No necking occurs in this case.

→ Modulus of Elasticity in tension-compression are same

AIR-1 Notes

Pages: 164

Steel Structure

Handwritten notes by

Kartikay Kaushik

AIR-1 ESE 2021

IES Master classroom Student

DESIGN OF STEEL STRUCTURES

CONTENT

23/9/19

DATE
PAGE

Design of Steel Structures

[12-13 Ques in PTE
15-25% in Subjective]

1) Introduction
2) General Design consideration
3) Connection → Bolted / → welded
4) Tension Member
5) Compression Member
6) Beam Design
7) Gantry Girder
8) Plate Girder
9) Industrial building

Code : I.S 800-2007
IS 808 → Structural steel components.

1. Introduction

→ IS codes

(a) IS 800 : 2007 - General construction in steel. (with amendment no. 1, January 2012)
(b) IS 808 : 1989 - Dimensions for steel sections (Steel Table)

→ Steel

→ It is an alloy of iron having carbon content between 0.1 to ~~0.~~ 1.1%.

→ Based on carbon content, 3 types of steel are:

(a) Low Carbon steel (0.1 to 0.25% Carbon)
(b) Medium Carbon steel (0.2 to 0.60% Carbon)
(c) High Carbon steel (0.6 to 1.1% Carbon)

DATE ______

PAGE ______

→ Deoxidizers such as silicon or aluminium is used to control Dissolved Oxygen during the manufacturing process.

→ Lower %age of oxygen content is good for durability of steel and on the basis of oxygen content, we classify steel as

(a) ~~Field~~ Killed Steel [< 30 ppm Oxygen]

(b) Semi-Killed Steel [30 to 150 ppm Oxygen]

(c) Rimmed steel [> 150 ppm oxygen]

→ Structural steel are generally killed or semi-killed Carbon %age in structural steel is generally < 0.25% [Low carbon steel]

→ Mild Steel has a carbon content of nearly 0.1%

→ IS 800 : 2007 can be used for structural Mild steel or high tension structural steel

⇒ Various grades of Steel

Grade		Ultimate Stress (MPa)	Yield Stress (MPa)
E 250 (Fe 410)	A	410	250
	B	410	250
	C	410	250
E 300 (Fe 440)		440	300
E 350 (Fe 490)		490	350
E 410 (Fe 540)		540	410

E 250 (Fe 410) A → grade of steel

E 250 → Characteristic Yield Stress

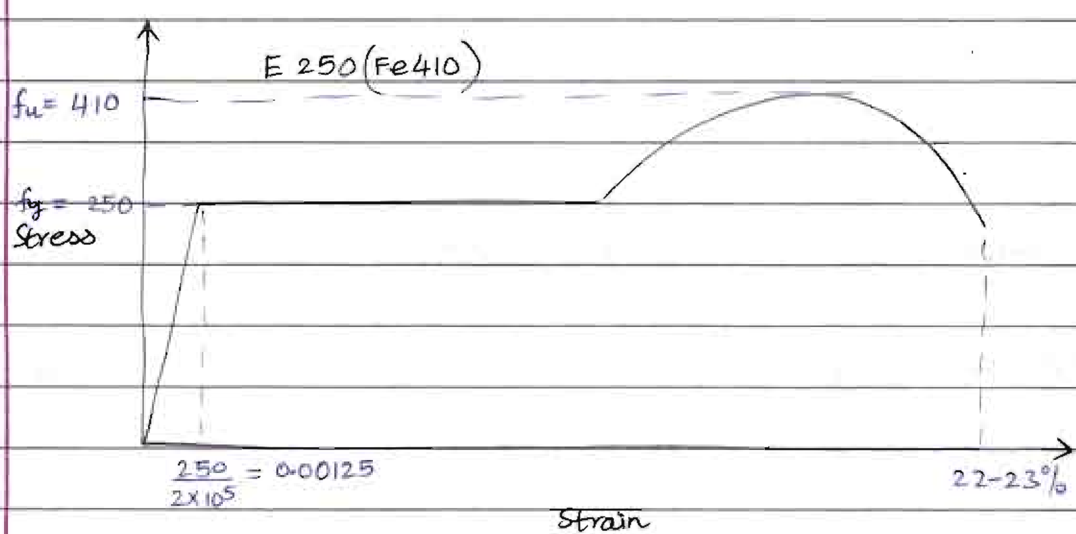
(Fe 410) → Characteristic Ultimate Stress

Fe 410 W → denotes higher weldability

NOTE:

1) Structural steel is specified according to characteristic ultimate tensile stress i.e. f_u. It is the ultimate stress below which not more than 5% of the materials are expected to fall

2) R/F bars in RCC are specified according to yield stress.



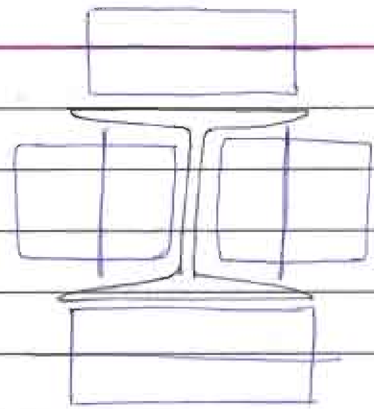
3) Thinner the section, higher is the strength due to higher amount of rolling, cold working, uniform rate of cooling.

Ex-

Residual Stress ⇑ →

	$t < 20$ mm	$20 < t < 40$ mm	$t > 40$ mm
E 250 (Fe 410)	$f_y = 250$ MPa	$f_y = 240$ MPa	$f_y = 230$ MPa

No. of Rollings ⇓ → Grain distribution poor



4) Brittle fracture due to higher tensile stress, lower temperature, thicker material, rapid change of stresses etc

5) Stainless steel is a low Carbon steel with around 10.5% chromium by weight.

⇒ Grade A is used for non-critical Application i.e. when members are not prone to brittle fracture.

⇒ Grade B is used for critical applications when temperature does not fall below 0°c and when parts are prone to brittle fracture or fluctuations of stresses as in case of bridges.

⇒ Grade C has a guaranteed low temperature upto -40°c and it shall be used for impact loading and higher chances of brittle fracture.

⇒ Physical properties of steel (for all grades)

(a) Density - 7850 kg/m^3

(b) Modulus of Elasticity - 2×10^5 MPa

(c) Poisson's Ratio - 0.3 (Elastic Range)
0.5 (Plastic Range)

(d) Shear Modulus - $G = \dfrac{E}{2(1+\nu)} = 0.769 \times 10^5$ MPa.

(e) Specific Gravity - 7.85

(f) Coefficient of thermal expansion - $12 \times 10^{-6} /°c$

DATE
PAGE

⇒ Advantages of Steel as a Structural material

1) High strength per unit weight
2) High ductility and toughness.
3) Uniformity i.e. very less quality control issues.
4) Environment friendly and high recyclability ($\simeq$ 100%)
5) Easy connections and faster construction.
6) Easy repair and modifications.
7) Longer life if properly maintained.

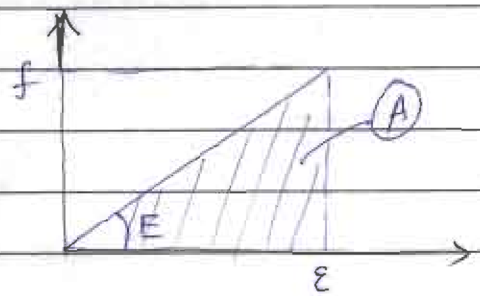
⇒ Disadvantage of steel as a structural material

1) Higher maintenance due to corrosion
2) Fire-proofing cost
3) Prone to buckling due to longer and slender member
4) Fatigue.

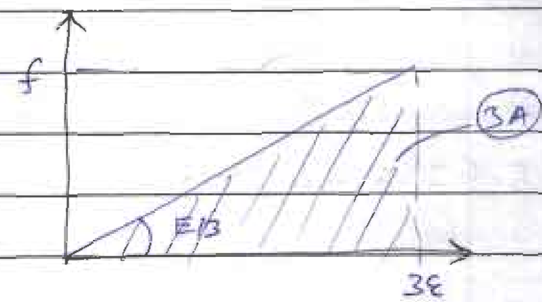
⇒ Aluminium

→ Higher strength to unit weight ratio as compared to steel.
→ However, due to lower modulus ($\simeq$ 1/3 of steel) bigger sections are required to avoid buckling.
→ greater resistance to corrosion and hence less maintenance.
→ Density is approx. 1/3 of steel [2700 to 2800 kg/m^3]
→ Coefficient of thermal expansion is nearly twice that of steel [23×10^{-6}]
→ less ductile than mild steel.
→ Does not have a well defined yield point and hence yield is assumed as 0.2% proof stress.
→ As it's modulus is 1/3 of steel, It can absorb 3 times the energy at same stress level as ~~a steel~~ compared to a steel member of same dimension

provided the stress does not exceed the proportionality limit. Hence it is also used for impact loading provided higher deflection is allowed.



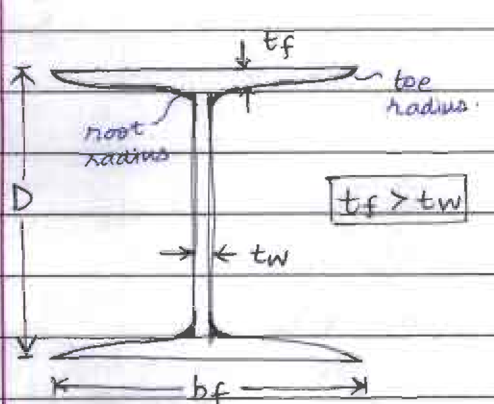
Steel



Aluminium.

→ Design concept is same as steel structure. (IS814)

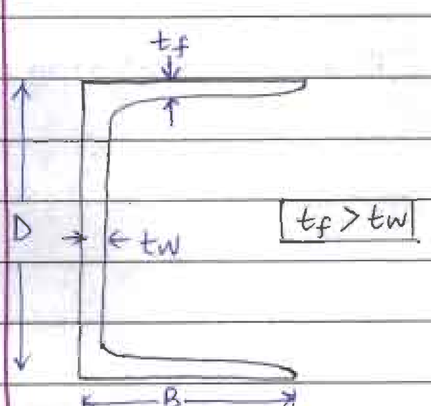
⇒ Standard structural steel sections



IS JB → Indian standard Junior Beam
IS LB → " " Light Beam
IS MB → " " Medium Beam
IS HB → " " Heavy Beam
IS SC → " " Column Section
↳ Type of I-section

Ex- ISMB 300

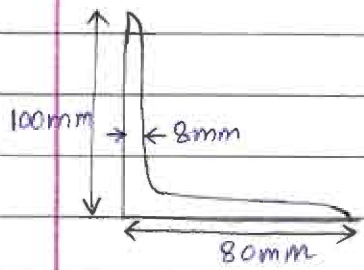
$D = 300$ mm, B or $b_f = 140$ mm, $t_f = 13.1$ mm, $t_w = 7.7$ mm



ISJC → Junior channel
ISLC → Light channel
IS MC → Medium channel.

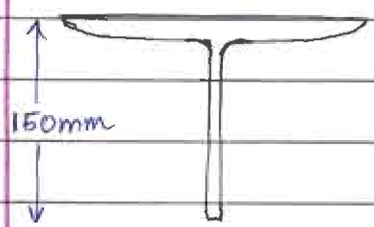
Ex- ISMC 100

$D = 100$ mm, $B = 50$ mm, $t_f = 7.7$ mm, $t_w = 5$ mm



ISA → Indian Standard equal/unequal angle.

Ex- ISA 100X80X8



ISNT → Indian Standard Normal T-section
ISMT → " " Medium T-section

Ex- ISNT 150@ 223·7 N/m

⇒ ISRO → Round Bars (ISRO 10)
i.e. 10 mm dia.

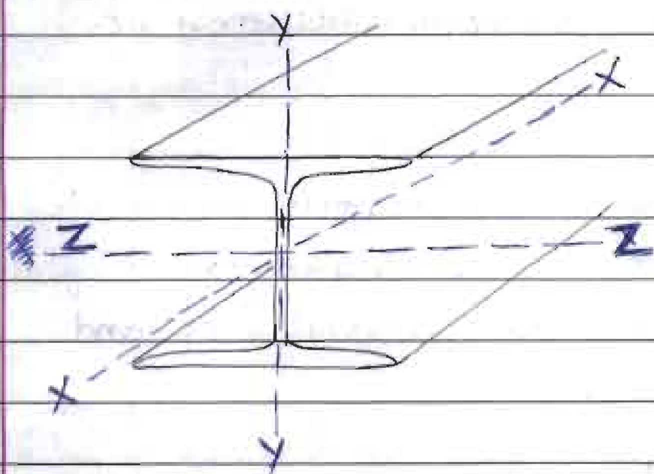
⇒ ISSQ → Square Bars (ISSQ 10 i.e. 10mm side)

⇒ ISPL → Plate (ISPL 2000 X 1000 X 8 → Length x width x thickness)

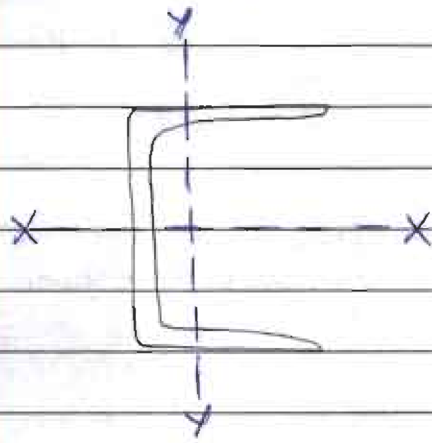
⇒ ISFL → Flat Section (30 ISF 10 → 30 mm width and 10mm thickness)

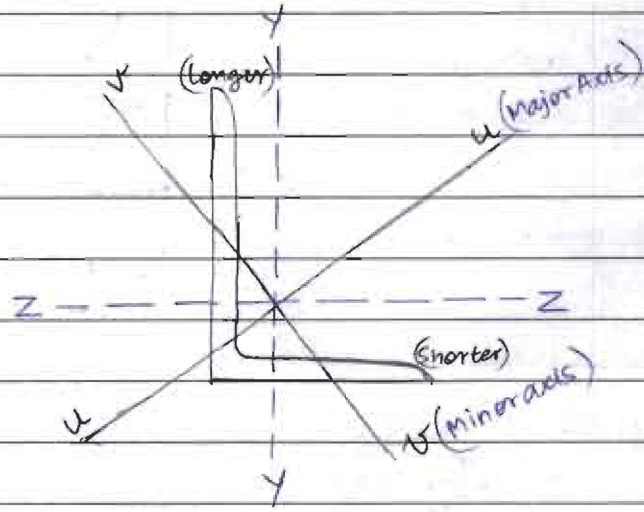
→ These sections can be used either alone (Rolled sections) or in combinations (Built up sections).

⇒ Convention for member axes



Along the member - X-X
Parallel to flange - Z-Z (Major axis)
Perpendicular to flange - Y-Y (Minor axis)





→ Parallel to smaller leg - ZZ
→ ⊥ar to smaller leg - YY

} for angle sections.

→ In earlier version of IS 800 : 1984, major axis was denoted as X-X

2) General Design Consideration

→ Structure shall fulfill safety, serviceability, economy, aesthetic and environmental criteria.

→ 3 design methods :

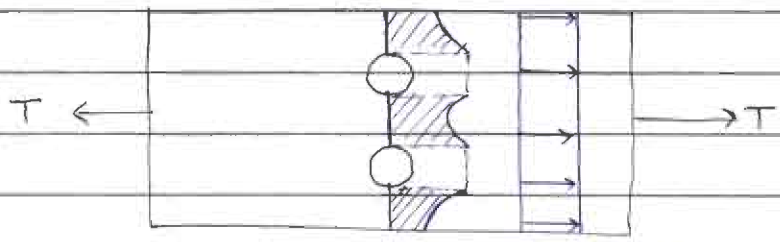
(a) Elastic or Working stress method
(b) Plastic / Ultimate Load method
(c) Limit State Method

⇒ WSM (Working Stress Method)

→ It assumes linear elastic response & safety is ensured by ensuring working stress will be less than permissible stress i.e.

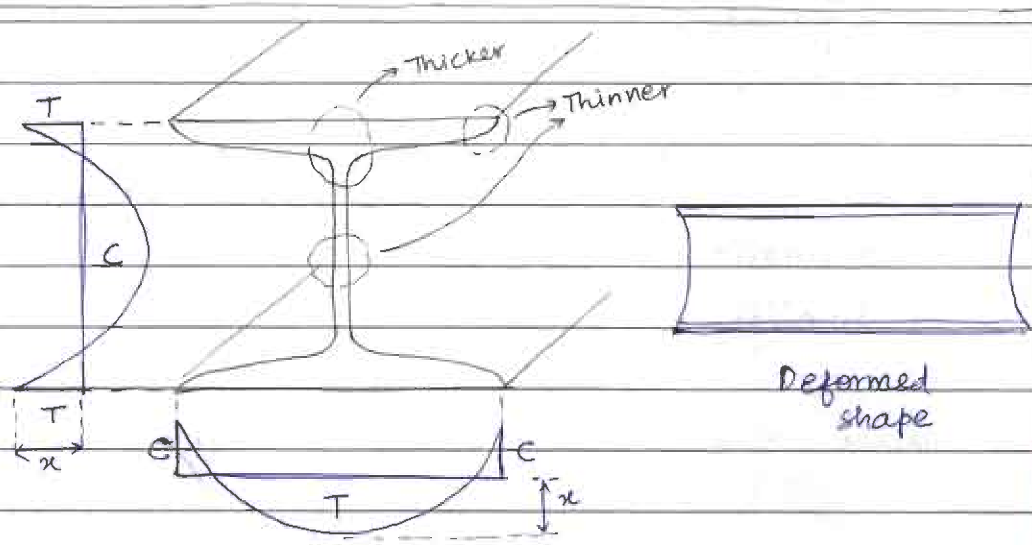
$$\frac{\text{Strength of material}}{\text{FOS}}$$

→ However, assumptions of stress being less than permissible stress is not realistic because of stress concentration, long term effect of creep and shrinkage, residual stress and other secondary stresses.



↳ stress concentration due to reduced area of X-section.

NOTE:



Residual stress along the length

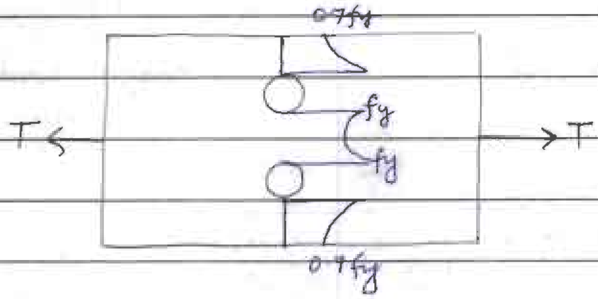
→ Unequal rate of cooling due to different thickness and exposed area and uneven compression by roller will lead to generation of residual stress. The part of section which cools first will have compression because it will resist the shortening of slower cooling part.

→ Also the slower cooling part will have tension.

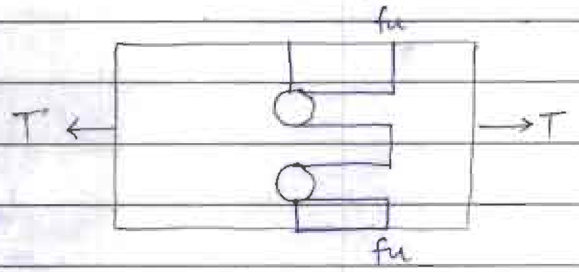
⇒ Does not utilise the reserved strength derived from ductility and redistribution of stress and hence FOS does not give a realistic figure or exact margin of safety.

→ FOS does not have a scientific basis and is based on experience.

→ It fails to discriminate b/w different types of loads that are simultaneously acting but having varying degrees of uncertainty.



When working load is acting, ~~momen~~ redistribution of stresses is not available.



At ultimate load, redistribution is significant.

Hence the material ~~to~~ strength is highly underutilized in WSM

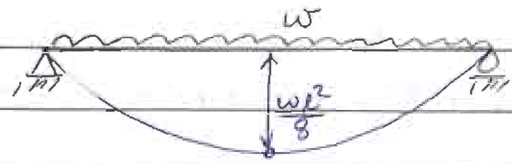
⇒ ULM (Ultimate Load Method)

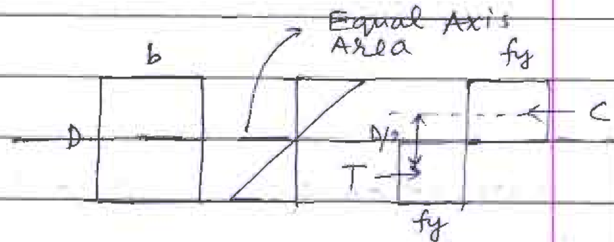
→ Design is done as in the case of plastic analysis in which working load multiplied by load factor is ensured to be less than the collapse load or ultimate load.

→ However, this method does not ensure serviceability criteria like deflection, vibration etc. Also, structure subjected to impact and fatigue loading shall not be designed with plastic theory. as it uses full material strength beyond elastic limit.

→ Also safety factor for material is not considered and hence it gives smaller section than WSM.

NOTE: Plastic Analysis





Only one mechanism required for failure

$$\frac{wl^2}{8} = M_p = f_y \frac{bD}{2} \cdot \frac{D}{2}$$

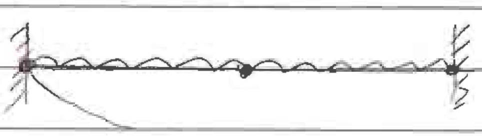
$$M_p = f_y \underbrace{\frac{bD^2}{4}}_{Z_p}$$

Z_p Plastic section modulus.

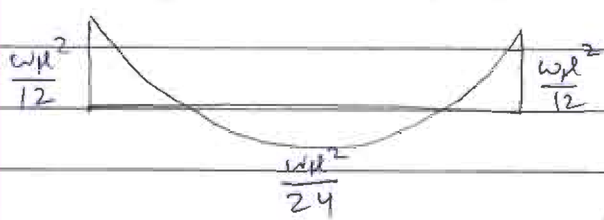
$Z_p = 1.5\ Z_e$

↳ elastic section modulus $= \frac{bd^2}{6}$

In case of SS steel beam ⇒ $\boxed{w_{max} = \frac{8M_p}{l^2}}$



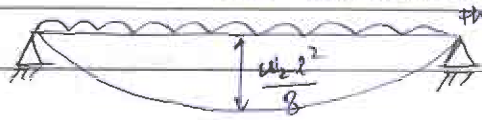
3 hinges required for failure



$\frac{wl^2}{12} = M_p$ → 2 plastic hinge at rigid joints occur.

converted to simply supported

W_2 (additional load that can be applied)



$\frac{w_2 l^2}{8} = \frac{M_p}{2}$ → because $\frac{M_p}{2}$ has been utilized before

So, total load that can be applied $= w_1 + w_2$

$$= \frac{12M_p}{l^2} + \frac{8M_p}{2l^2}$$

$$= \frac{16M_p}{l^2}$$

DATE

PAGE

⇒ LSM (Limit State Method)

→ To avoid all deficiencies of WSM and ULM, LSM was proposed.

→ Partial safety factors are used for both loads and material strength based on acceptable probability of failure derived using reliability analysis. (Level I)

→ Partial safety factors take into account possible overloads and under strength.

Design action (considering partial safety factor for loads) $\leq$ Design strength (considering partial safety factor for materials)

→ Factored Load / Design Load (F_d) = (Characteristic Load) X γ_f

γ_f → Partial safety factor for loads depending on load combination and limit state being considered.

→ Design strength (f_d) = $\dfrac{\text{Characteristic Strength}}{\gamma_m}$

γ_m → Partial safety factor for material strength.

→ Characteristic Load is the load which has 95% probability of not being exceeded during the life of the structure.

→ Characteristic strength is the strength below which not more than 5% of the test samples are expected to fall.

⇒ γ_f accounts for (Partial safety factor for loads)

1. Possibility of load exceeding characteristic load.
2. Possibility of inaccurate assessment of load.
3. Uncertainty in assessment of effect of load. (failure mechanism)

④ Uncertainty in the assessment of limit state being considered.

⇒ γ_m accounts for (partial safety factor for material strength)

① Possibility of strength falling below characteristic strength.
② Reduction in member size due to faulty construction.
③ Reduction in strength due to fabrication and tolerances.
④ Uncertainty in theoretical assumptions.
⑤ Uncertainty in the calculation of strength of member.

→ Limit states are the states beyond which the structure becomes unfit for use.

→ The limit states are classified as:

① Limit State of strength / Ultimate Limit strength.
② Limit State of serviceability.

⇒ Limit state considered by IS code

① Limit State of strength

(a) Strength including yielding, buckling and transformation into a mechanism (plastic hinge formation)
(b) Stability against overturning and sway
(c) failure due to excessive deformation or rupture
(d) fracture due to fatigue.
(e) Brittle fracture.

② Limit State of serviceability

(a) Deformation and deflection (can cause damage to non structural components and finishes but not to structural component)

AIR-1 Notes

Pages: 176

Surveying

Handwritten notes by

Kartikay Kaushik

AIR-1 ESE 2021

IES Master classroom Student

SURVEYING

CONTENT

classmate
Date 7/06/19
Page

Surveying [3-4 marks - 7-8 Q - 50-60M]
GATE — Objective — Conventional

Chapters

1. Fundamentals of Surveying
2. Linear Measurement
3. Compass Surveying
4. Theodolite
5. Traversing
6. Levelling
7. Tacheometry
8. Trigonometric Levelling
9. Measurement of Area Volume.
10. Photogrammetry
11. Curve
12. Field Astronomy
13. Theory of Errors.
14. Plane Table Surveying
15. Contour

1. Fundamental of Surveying

→ Surveying is the art of determining relative position of points on, above and below the earth surface, and presenting it graphically or numerically.

→ Objective of Surveying

1. To determine relative position of points
2. To layout or markout the proposed structure on the ground
3. To determine relative quantities like Area and Volume.

classmate
Date
Page

→ Methods of Presentation

$AB = 10\,km$ } Numerical representation

A —— 10km —— B } Graphical representation. { Plan or Map }

→ 1) Numerical Representation (AB = 10Km)

2) Graphical Representation (A —— 10km —— B)

→ Graphical representation is done in the form of Plan or map:

(i) Plan — Large Scale
(ii) Map — Small Scale.

NOTE:
→ vertical distance on a map can be presented with the help of contour or spot level.
→ Contour is an imaginary line joining the points of same elevation on the earth surface (Natural contour : Water surface)
→ Spot levels are height of individual points.
→ Contour is preferred over spot levels because it gives better visualisation over spot levels

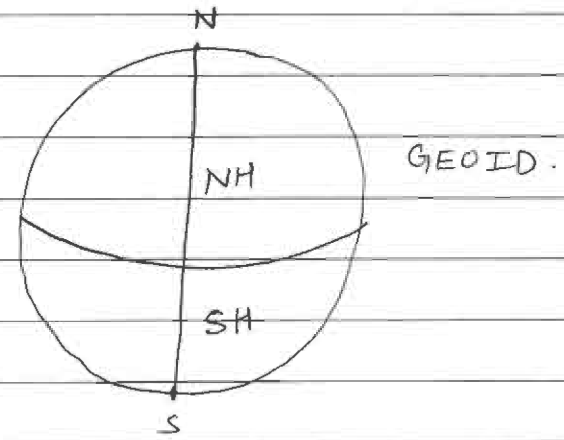
→ Basic definition

1) → Shape of Earth

(a) Oblate Spheroid : Slightly flat at poles.
Polar Axis is 43.5 km smaller than equatorial axis.

(b) Ellipsoid : Equatorial section is elliptical in nature

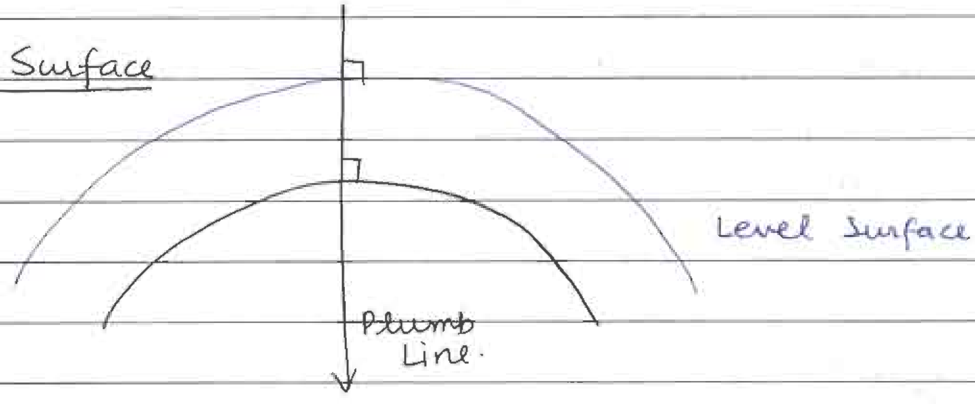
(c) Ovalloid : Southern Hemisphere is slightly larger than Northern Hemisphere.



→ We can observe that no geometrical figure completely defines the shape of earth, hence a new name is given to the shape of earth i.e. GEOID

> NOTE :
> For calculation purpose, we'll assume earth to be spherical in nature.

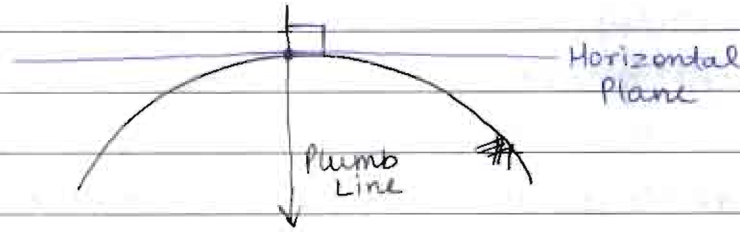
2) → Level Surface



→ Level Surface is a curved surface ||el to the spherical ~~Het~~ surface of earth and hence every point on it is equidistant from the centre of the earth.

→ Every element on level surface is perpendicular to plumb line.

3) - Horizontal Plane

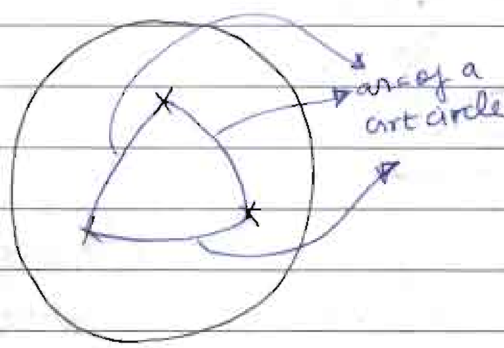


→ It is a tangential plane to the earth surface which is also perpendicular to plumb line.

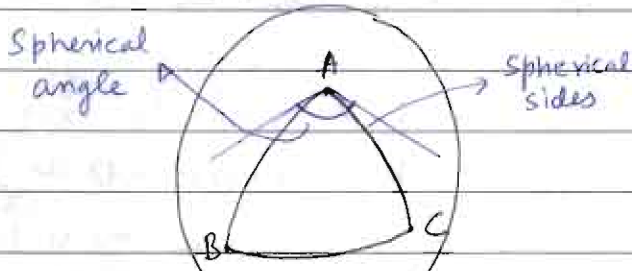
4) - Great circle

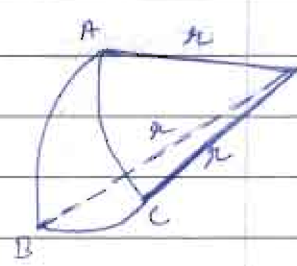
→ It is a imaginary circle passing through the centre of the earth.
→ A great circle divides earth surface into 2 equal parts.

5) Spherical Triangle



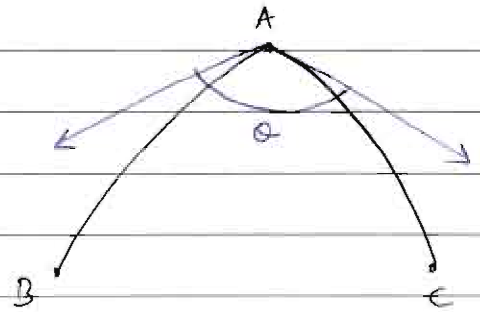
A spherical Δ is a Δ which is formed on the surface of a sphere by intersection of 3-arcs of different great circles.

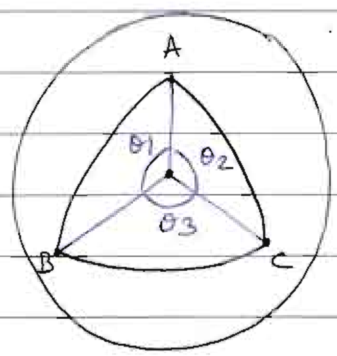




→ The arc enclosing spherical Δ are called as spherical sides and the angles in which these arc intersect are called as spherical angle.

→ Spherical angle is defined as angle between the tangent to the great circles at the point of intersection of 2 spherical sides





$\overset{\frown}{AB} = R\theta_1$
$\overset{\frown}{BC} = R\theta_3$
$\overset{\frown}{CA} = R\theta_2$

We can neglect R and compare on basis of θ.

→ Length of a side of a spherical Δ is defined as the angle subtended by that side at the centre of the sphere.

→ **Properties of Spherical Δ**

1. Each side of a spherical Δ must be less than equal to π.
2. Each angle of a spherical Δ must be less than π.
3. Sum of 3 sides must be between (0 to 2π).
4. Sum of 3 angles of a spherical Δ must be between [π to 3π).

NOTE:

$$\begin{array}{r} 182^\circ\ 57'\ 39'' \\ -\ 180^\circ\ 0'\ 0'' \\ \hline 2^\circ\ 57'\ 39'' \end{array}$$

$182^\circ\ 57'\ 39''$ → Sum of spherical Angles

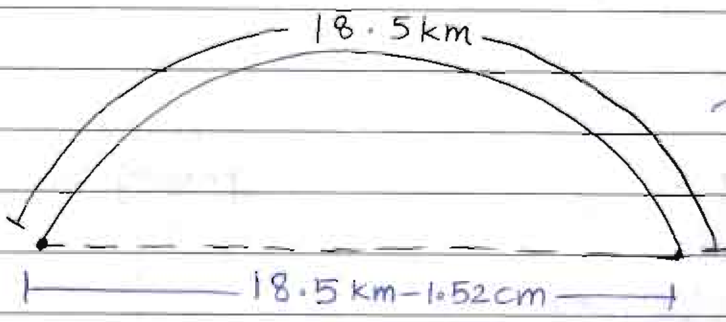
$2^\circ\ 57'\ 39''$ → Spherical Excess

Amount by which sum of angles of a spherical Δ exceed by 180° is called as Spherical Excess.

5. Surface Area of a spherical Δ must be less than $2\pi R^2$
6. Greater angle is opposite to greater side.

→ Classification of Surveying

→ Surveying can be classified into various means eg- instrument used, purpose, place of survey etc. But mainly is surveying is classified into 2 types:
1) Geodetic surveying
2) Plane Surveying.



→ curved area can be assumed to be plane as long as it is small.

Geodetic Survey $\geq$ 195.5 km^2 > Plane Survey

⇓

S.E. ⇒ 1″

Geodetic Survey	Plane survey
1. Geodetic survey is done for large area and we consider earth's surface as curved.	1. Plane Surveying is done for small area and earth surface is considered as flat surface i.e. curvature of earth is neglected.
2. Area greater than equal to 195.5 km^2	2. Area less than 195.5 km^2
3. It is done by SOI - Survey of India to establish control points throughout the Country.	3. It is done for local survey.
4. It uses spherical trigonometry	4. It uses plane trigonometry.

NOTE:

→ In Plane surveying plotted measurements are projected on a horizontal plane.

→ For Area = 195.5 km^2, spherical Excess = $1''$

→ Classification of surveying based on purpose of survey

1. Topographical Survey

These survey are used to obtain maps which show details of natural and man-made features on the earth surface including elevation information.

Scale: 1:25,000 to 1:10,00,000

2. Engineering survey

These surveys are used for engineering works, eg - dams, sewer, railway, roads etc.

Building work: 1:50 to 1:200

Bridges and other civil engg works: 1:500 to 1:2500

Highway: 1:1250 to 1:50000

3) Cadastral Survey

These are used to represent property boundaries.

1:1000 to 1:5000

4) Hydrographic Survey

These survey are done on or near the water body such as lake, river, bay etc.

5) Astronomic Survey

With the help of astronomic survey we can determine latitude, longitude and Local Mean time of any place

6) Geological Survey

It is used to obtain information about different strata of earth surface.

→ Classification based on Instrument

1) Chain Surveying

→ It is simplest type of surveying in which only linear measurements are done with the help of chain or tape.

→ No angular measurement is done.

2) Compass surveying

→ In compass surveying, directions and horizontal angles are measured with the help of compass and distances are measured with the help of chain or tape.

NOTE:

Trough compass is the only non-circular compass.

classmate
Date
Page

→ 1 Vernier division is slightly smaller than 1 division of main scale.

$$n v = (n-1) s$$

$$LC = s - v$$

$$= s - \left(\frac{n-1}{n}\right) s$$

$$\boxed{L.C. = \frac{s}{n}}$$

s → L.C. of main scale

n → no. of division on vernier scale.

→ **Retrograde Vernier**

→ n divisions on vernier scale are equal to (n+1) divisions on main scale

→ 1 vernier division is slightly larger than 1 division of main scale.

→ vernier division and main scale division increase in opposite direction, whereas in direct vernier both increase in same direction

$$n v = (n+1) s$$

$$L.C. = v - s$$

$$\boxed{L.C. = \frac{(n+1)}{n} s - s = \frac{s}{n}}$$

Q → The main plate of a Theodolite is divided into 1080 equal parts and 60th division of vernier scale coincides with 59th division of main scale. Determine L.C. of theodolite.

$$L.C. = s - v \qquad 60 v = 59 s$$

$$= \frac{360°}{1080} s - \frac{59}{60} s \qquad v = \frac{59}{60} s$$

$$= \frac{s}{60} = \frac{360°}{1080 \times 60} = \frac{6 \times 60 \times 60''}{1080} = 20''$$

→ Special Types of Vernier

1) Double Vernier

→ If graduations of main scale increases in one direction only we have a single vernier whereas when main scale is graduated in both the directions a double vernier is used. eg. - Theodolite.

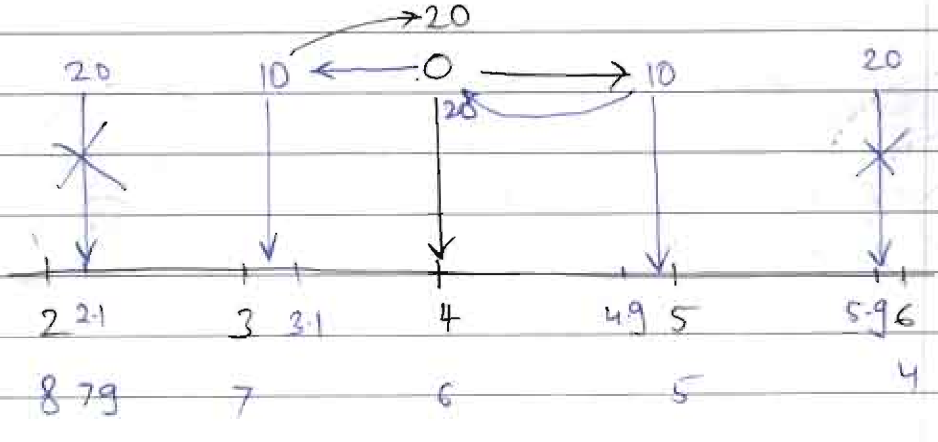
→ Double vernier consists of 2 direct verniers extending in both the direction with index mark in the centre.

2) Double Folded Vernier

→ A double folded vernier is a special type of double vernier whose total length is exactly half of combined length of corresponding double vernier

→ A double folded vernier is used when it is required to ~~to~~ reduce the length of vernier scale eg - sextant to measure vertical angles of elevation or depression.

→ In double folded vernier the vernier is read from index mark (0 mark) towards either of the extreme division and then from other extreme division towards centre in the same direction



→ **Extended Vernier**

→ When divisions of main scale are very close and it becomes very difficult to determine exact graduation where coincidence occurs, If vernier of normal length is used.

→ Hence, extended vernier is very useful when available length of vernier scale is small and it is required to have small least count without making vernier divisions very close.

→ In extended vernier, n divisions of vernier scale are equal to (2n−1) divisions of main scale.

$$n v = (2n-1) s$$

$$v = \frac{(2n-1)}{n} s.$$

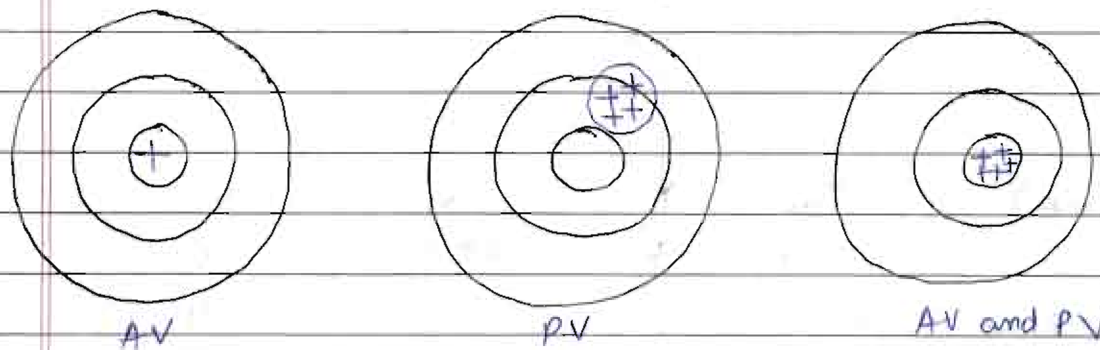
$$L.C. = 2s - v$$

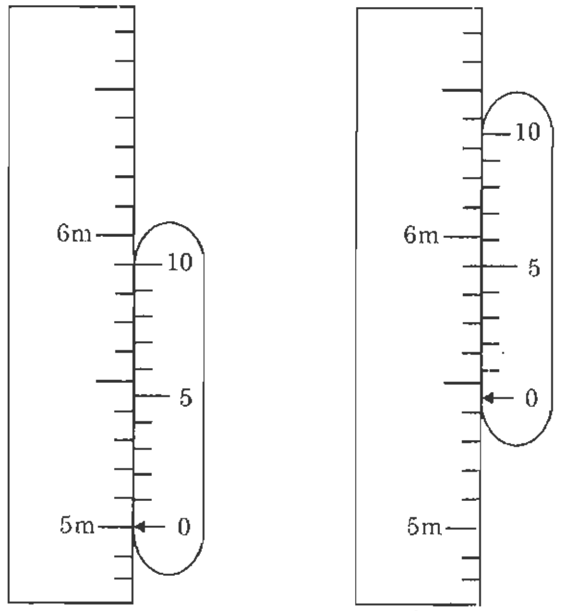
$$= 2s - \frac{(2n-1)s}{n} = \frac{s}{n}$$

**

> NOTE:
> Extended Vernier is used in an instrument called Abney Level used to find vertical angles

→ **Precision and Accuracy**

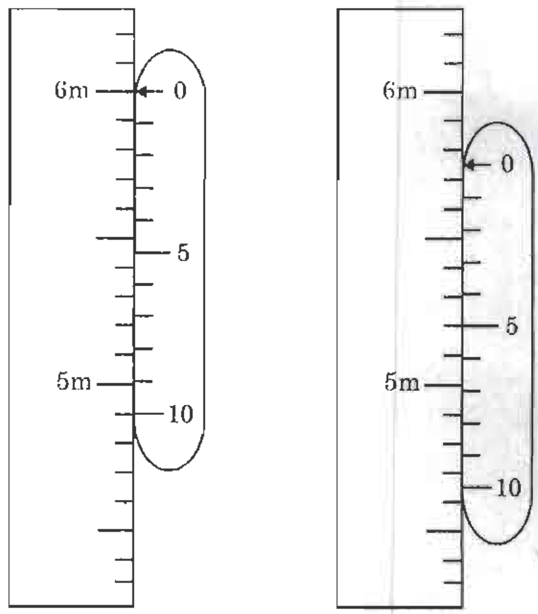




5.00m
(a)

5.~~3~~45m
(b)

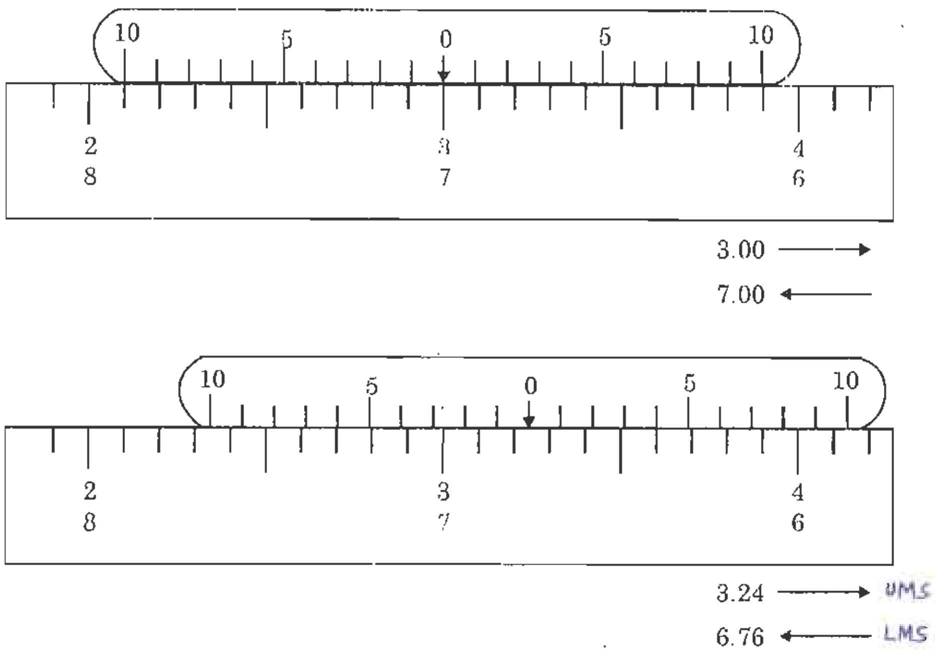
Direct Vernier



6.00m
(a)

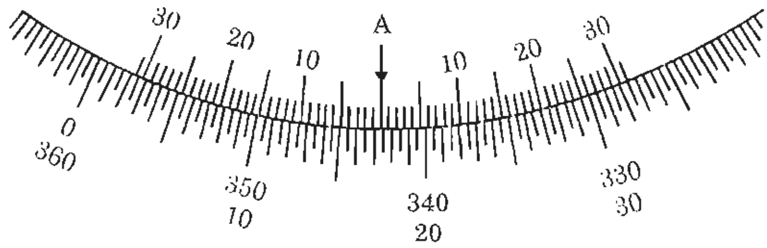
5.75m
(b)

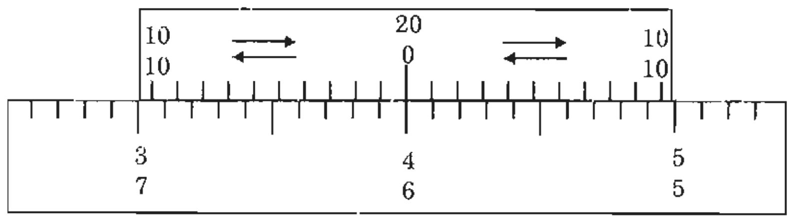
Retrograde Vernier



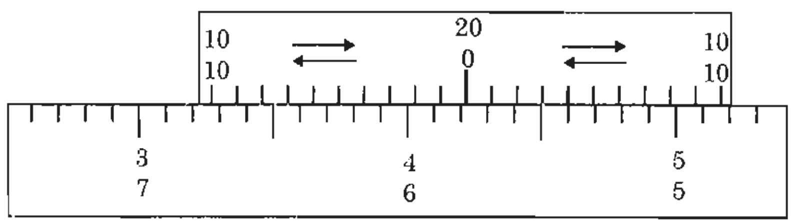
Double Vernier

1



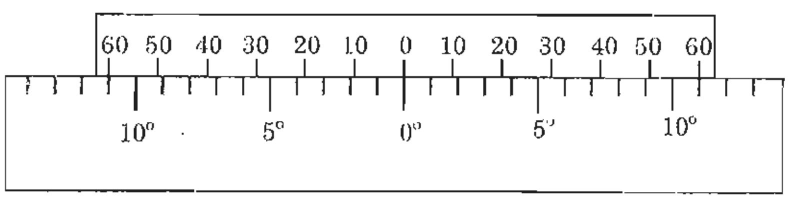


(a)

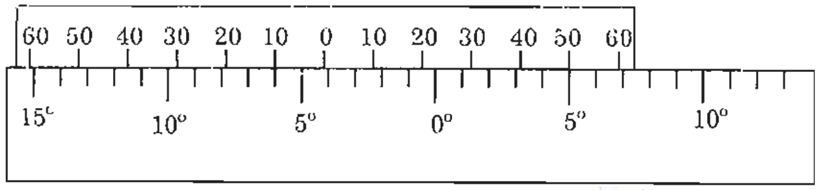


4.220 ⟶ (b) ⟵ 5.780

Double Folded Vernier



(a)



(b) 4°10′

Extended Vernier

2

AIR-1 Notes
Pages: 48

Handwritten notes by

Kartikay Kaushik
AIR-1 ESE 2021
IES Master classroom Student

Engineering Aptitude (15M – GATE, 10^+ – ES)

⇒ **Quantitative Aptitude and Reasoning**

- * → Number System ✓ → ratio ✓
- * → Work & Time ✓ → Average ✓
- → Percentage ✓ * → Alligation & mixture ✓
- * → Profit & Loss ✓ → Logarithms ✓
- → Partnership ✓ → Quadratic Eq^n
- → S I and C.I ✓ * → Series ✓
- * → Speed, Time, Distance ✓

- * → Clock ✓ → logical puzzles
- * → Calender ✓ → logical deduction
- * → Data Interpretation ✓ * → Blood Relations ✓
- * → Venn Diagram ✓ → Others.
- → Direction Sense ✓
- → Coding Decoding ✓

Number System

Number System → Positional No. Sys. | Non-Positional No. sys.

Positional No. Sys.
(Face value as well as place value)

Ex – $(abc)_{10} = a\times10^2 + b\times10^1 + c\times10^0$

Decimal Number Sys.

Non-Positional No. sys.
(Only Face value)

Ex – Roman Numerals

Decimal No. Sys. → A TC C TL L T.Th Th H T O

International No. Sys → 1B HM TM M H.Th T.Th Th H T O

⇒ **Concept of Addition**

$$
\begin{array}{r}
{}^{1\,3}\ \ {}^{2}\ {}^{3}\ {}^{2}\ \ \\
2^3\ 2^2\ 2^1\ 2^0 \\
(1\ 1\ 1\ 1)_2 \\
(1\ 0\ 1\ 1)_2 \\
(1\ 1\ 1\ 1)_2 \\
+\ (1\ 0\ 1\ 1)_2 \\
\hline
1\ 1\ 0\ 1\ 0\ 0
\end{array}
$$

classmate

Date ____

Page ____

$\rightarrow$

$$\begin{array}{r} (1\ 1\ 0\ 0\ 0)_2 \\ -(\ \ \ 1\ 1\ 1)_2 \\ \hline 1\ 0\ 0\ 0\ 1 \\ \hline \end{array}$$

Q $\rightarrow$ If $137 + 276 = 435$

then $731 + 672 = ?$

$(1\,3\,7)_8 \rightarrow$ octal

$(2\,7\,6)_8$

$(4\,3\,5)_8$

$$\begin{array}{r} 7\,3\,1 \\ +\ 6\,7\,2 \\ \hline (1\,6\,2\,3)_8 \end{array}$$

$\Rightarrow (111)_2 = (1\times2^2 + 1\times2^1 + 1\times2^0)_{10}$

$\Rightarrow (435)_8 = (4\times8^2 + 3\times8^1 + 5\times8^0)_{10}$

$\Rightarrow (abcd)_r = (a\times r^3 + b\times r^2 + c\times r^1 + d\times r^0)_{10}$

$\Rightarrow$ <u>Concept of Unit Digit</u>

$\Rightarrow 937 \times 873 \times 96 \Rightarrow 6$

$\rightarrow (abc\text{----}0)^n = (\text{---}0)$

$\rightarrow (abc\text{----}1)^n = (\text{---}1)$ } Cyclicity = 1

$\rightarrow (abc\text{----}5)^n = (\text{---}5)$

$\rightarrow (abc\text{----}6)^n = (\text{---}6)$

$\rightarrow (abc\text{---}4)^n$ $\rightarrow 2k \Rightarrow (\text{----}6)$; $\rightarrow 2k+1 \Rightarrow (\text{----}4)$ } cyclicity = 2

$\rightarrow (abc\text{---}9)^n$ $\rightarrow 2k \Rightarrow (\text{----}1)$; $\rightarrow 2k+1 \Rightarrow (\text{----}9)$ } Cyclicity = 2

$$(abc\text{-----}2)^n \begin{cases} \rightarrow 4k \Rightarrow (\text{---}6) \\ \rightarrow 4k+1 \Rightarrow (\text{---}2) \\ \rightarrow 4k+2 \Rightarrow (\text{---}4) \\ \rightarrow 4k+3 \Rightarrow (\text{---}8) \end{cases}$$

$$(abc\text{-----}3)^n \begin{cases} \rightarrow 4k \Rightarrow (\text{---}1) \\ \rightarrow 4k+1 \Rightarrow (\text{---}3) \\ \rightarrow 4k+2 \Rightarrow (\text{---}9) \\ \rightarrow 4k+3 \Rightarrow (\text{---}7) \end{cases}$$

$$(abc\text{-----}7)^n \begin{cases} \rightarrow 4k \Rightarrow (\text{---}1) \\ \rightarrow 4k+1 \Rightarrow (\text{---}7) \\ \rightarrow 4k+2 \Rightarrow (\text{---}9) \\ \rightarrow 4k+3 \Rightarrow (\text{---}3) \end{cases}$$

$\Rightarrow \left(155^{155} \times 166^{166}\right) - \left(167^{167}\right)$

$5 \cdot 6 \rightarrow 0 \quad - \quad 3 \quad \Rightarrow 7$

Q- Find the last digid of $1! + 2! + 3! + \text{----} + 100! \Rightarrow 3$

* $n!$ always ends with 0 if $n \geq 5$.

Q- Find the unit digit of $199^{1!+2!+3!+\text{----}+101!} \Rightarrow 9$.

Q- $(177)^{1024!} \Rightarrow 1$

DPP

Q1) $47 \times 10^{28} \leq X < 48 \times 10^{28}$

$47^3 \times 10^{84} \leq X^3 < 48^3 \times 10^{84}$

$6 \quad 84 \quad\quad 6 \quad 84$

⇒ Concept of tens digit

→ $973 \times 572 \times 471 = (\_\_\_\_ 76)$ } tens digit only
→ $73 \times 72 \times 71 = (\_\_\_\_ 76)$ } depends on the last 2 digit

Case I → Last 2 digits of the form a^b where a is ending with 1

→ $(141)^{39737} \rightarrow (\_\_\_\_ 81)$

→ $(161)^{98} \times (171)^{99} \rightarrow (\_\_\_ 81) \times (\_\_\_ 31) \rightarrow 11$

→ $(181)^{101!} \rightarrow (\ldots 01)$

Case II → Last 2 digit of the form a^b where a is ending with 3, 7 and 9

→ $(143)^{40} \rightarrow (43)^{40} \rightarrow (43^4)^{10} \rightarrow (43^2 \times 43^2)^{10}$

ends with 1 $\quad 43 \times 43$

$(40+3)43$

$1720 + 129 \rightarrow (49)$

$(01) \leftarrow (01)^{10} \quad (49 \times 49)^{10}$

$01 \leftarrow 2450 - 49 \leftarrow (50-1)\,49$

→ $(989)^{941} \rightarrow (89)^{941} \rightarrow 89 \times (89)^{940} \rightarrow 89 \times (89^2)^{470}$

89×89

$89 \leftarrow 89 \times 01 \quad 89 \times (21)^{470} \quad (21)$

Case III → Last 2 digits of the form a^b where a is ending with 5.

$(abc \ldots 25)^n \rightarrow (\_\_\_\_ 25)$

$(abc \ldots 15)^n \rightarrow (\_\_\_\_ 25)$ if n is even

$(\_\_\_\_ 75)$ if n is odd

classmate
Date
Page

$\Rightarrow$ General $\Rightarrow$ $(abc \text{---} (\text{even})5)^{n} \rightarrow (\text{---}25)$

$(abc \text{---} (\text{odd})5)^{\text{even}} \rightarrow (\text{---}25)$

$\star (abc \text{---} (\text{odd})5)^{\text{odd}} \rightarrow (\text{---}75)$

$\rightarrow (3855)^{1!+2!+3!+\cdots+100!} \rightarrow (\text{---}75)$

$\rightarrow (9875)^{1024!} \rightarrow (\text{---}25)$

Case IV $\Rightarrow$ Last 2 digit of the form a^b where a is ending with 2, 4, 6, 8

$25 \times 25 \rightarrow 6\boxed{25}$

$76 \times 76 \rightarrow 57\boxed{76}$

$(abc \text{---} 76)^{n} \rightarrow (\text{---}76)$

$(abc \text{---} 24)^{\text{even}} \rightarrow (\text{---}76)$

$(abc \text{---} 24)^{\text{odd}} \rightarrow (\text{---}24)$

$2^{10} \rightarrow (\text{---}24)$

$\rightarrow$ Find Last 2 digit of 22^{140}

$2^{140} \times 11^{140}$

$\underbrace{(24)^{14}}_{76} \quad 01 = \underline{76}$

$\Rightarrow (944)^{944} \rightarrow (44)^{944} \rightarrow 4^{944} \; \underbrace{(11)^{944}}$

$2^{1888} \times 41$

$2^{188 \times 10 + 8} \times 41$

$(2^{10})^{188} \times 2^{8} \times 41$

$(24)^{188} \times 56 \times 41$

$76 \times 56 \times 41 = 96$

→ First digit of 2^{72}

$$N = 2^{72}$$
$$\log N = 72 \log 2$$
$$\log N = 72 \times 0.30103$$
$$\log N = 21.6741$$
$$N = 10^{21.6741} = 10^{21} \times 10^{0.6741} = 4.72 \times 10^{21} \Rightarrow 4$$

⇒ Concept of Remainders

→ $\text{Rem}\left(\frac{x_1 + x_2 + x_3 + \_\_\_ + x_n}{x}\right) = \text{Rem}\left(\frac{r_1 + r_2 + r_3 + --- + r_n}{x}\right)$

$r_1 = \text{Rem}\left(\frac{x_1}{x}\right)$, $r_2 = \text{Rem}\left(\frac{x_2}{x}\right)$, - - - - -, $r_n = \text{Rem}\left(\frac{x_n}{x}\right)$

→ $\text{Rem}\left(\frac{7 + 11 + 14}{3}\right) = \text{Rem}\left(\frac{1 + 2 + 2}{3}\right) = 2$

→ $\text{Rem}\left(\frac{x_1 * x_2 * x_3 * --- * x_n}{x}\right) = \text{Rem}\left(\frac{r_1 * r_2 * r_3 * --- * r_n}{x}\right)$

→ $\text{Rem}\left(\frac{7 * 11 * 14}{3}\right) = \text{Rem}\left(\frac{1 * 2 * 2}{3}\right) = 1$

→ 5) 17 (3
15
2

Positive Rem = 2

Negative Rem = −3.

$\boxed{\text{Positive Rem} - \text{Negative Rem} = \text{Divisor}}$

→ $\text{Rem}\left(\frac{2^{100}}{3}\right) = \text{Rem}\left(\frac{-1 * -1 * -1 * - - \cdot 100\text{times}}{3}\right)$

$= \text{Rem}\left(\frac{1}{3}\right) = 1$

$\rightarrow$ $\text{Rem}\left(\dfrac{55^{56^{57^{58^{59^{60}}}}}}{7}\right) = \text{Rem}\left[\dfrac{(-1)^{\text{even}}}{7}\right] = \text{Rem}\left(\dfrac{1}{7}\right) = 1$

$\rightarrow$ $\text{Rem}\left(\dfrac{55^{57^{58^{59^{60}}}}}{7}\right) = \text{Rem}\left(\dfrac{(-1)^{\text{odd}}}{7}\right) = \text{Rem}\left(\dfrac{-1}{7}\right) = 6$

$\rightarrow$ $\text{Rem}\left(\dfrac{7^{2009} + 11^{2011} + 7^{2013} + 11^{2015}}{12}\right)$

$\rightarrow$ $\text{Rem}\left(\dfrac{(-5)^{2009} + (-1)^{2011} + (-5)^{2013} + (-1)^{2015}}{12}\right)$

$\rightarrow$ $\text{Rem}\left(\dfrac{(-5)(25)^{1004}}{12} + 11 + \dfrac{(-5)(25)^{1006}}{12} + 11\right)$

$\rightarrow$ $\text{Rem}\left(\dfrac{-5+11-5+11}{12}\right)$ $\text{Rem}\left(\dfrac{12}{12}\right) = 0$

$\Rightarrow$ $x^n - y^n$ is always divisible by $x-y$ $\forall\, n \in N$

$\Rightarrow$ $x^n - y^n$ is divisible by $x+y$ $\forall\, n \in$ even.

$\Rightarrow$ $x^n + y^n$ is divisible by $x+y$ $\forall\, n \in$ odd.

$\Rightarrow$ $\text{Rem}\left(\dfrac{2^{96}-1}{2^{32}-1}\right) = 0$

Q- $\text{HCF}\{2^{24}-1,\ 2^{64}-1\} \Rightarrow (2^8 - 1)$

$\star$ $\text{HCF}\{a^m - 1,\ a^n - 1\} = a^{\text{HCF}\{m,n\}} - 1$

$\star$ $\text{HCF}\{a^m + 1,\ a^n + 1\} = a^{\text{HCF}\{m,n\}} + 1$

only when m, n are odd.

classmate

Date

Page

⇒ Divisibility Rules

(1) Divisibility by 0 → undefined.

(2) Divisibility by 1 → always defined.

(3) Divisibility by 2 → $Rem\left(\frac{abc----U}{2}\right) = Rem\left(\frac{U}{2}\right)$

(4) Divisibility by 3 → $Rem\left(\frac{abc----U}{3}\right) = Rem\left(\frac{a+b+c+----+U}{3}\right)$

(5) Divisibility by 4 → $Rem\left(\frac{abc----TU}{4}\right) = Rem\left(\frac{TU}{4}\right)$

(6) Divisibility by 5 → $Rem\left(\frac{abc----TU}{5}\right) = Rem\left(\frac{U}{5}\right)$

(7) Divisibility by 6 → Check by 2 and 3 → co-primes.

(8) Divisibility by 8 → $Rem\left(\frac{abc----HTU}{8}\right) = Rem\left(\frac{HTU}{8}\right)$

(9) Divisibility by 9 → $Rem\left(\frac{abc----TU}{9}\right) = Rem\left(\frac{a+b+c+----+T+U}{9}\right)$

(10) Divisibility by 11

$$Rem\left(\frac{77777}{11}\right) = Rem\left(\frac{7\times10^4+7\times10^3+7\times10^2+7\times10+7}{11}\right)$$

$$= Rem\left(\frac{7(-1)^4+7(-1)^3+7(-1)^2+7(-1)+7}{11}\right)$$

$$= Rem\left(\frac{7-7+7-7+7}{11}\right) = Rem\left(\frac{7}{11}\right)$$

→ if the (sum of odd placed digit) − (sum of even placed digit) = 0 or 11 K

classmate
Date
Page

(11) Divisibility by prime Number, p

→ Common Process

1) Find magic no. and key (addition / subtraction)
2) Let N is a given number for which divisibility to be found by p.
3) Take the last digit of N, disappear the last digit of N and multipy the last digit by magic number.
4) Perform key in the rest of number.
5) If the final result is divisible by p, then N is divisible by p.
6) Repeat the same process for larger numbers.

→ Divisiblility by 7

$7 \times 1 = 7$

$7 \times 2 = 14$

$7 \times 3 = 21 \Rightarrow 10^1 \times 2 + 1$

key - subtraction

Magic no. = 2

$$
\begin{array}{r}
1983\cancel{7}\cancel{2} \\
-\ 4 \\
\hline
198\cancel{3} \\
-\ 6 \\
\hline
197\cancel{7} \\
-14 \\
\hline
183
\end{array}
$$

183 → check with 7

→ Divisibility by 13

$13 \times 1 = 13$

$13 \times 2 = 26$

$13 \times 3 = 39 \Rightarrow 10^1 \times 4 - 1$ → magic No. = 4

key → addition

→ Divisiblility by 17

$17 \times 3 = 51$ → $10 \times 5 + 1$ → magic no. = 5

key - subtraction

⇒ Number of factors

Natural Number → Exactly one factor (1 → neither prime nor composite)

Natural Number → Exactly two factor (prime number)

Natural Number → More than 2 factors (composite Number)

⇒ Check for Prime ⇒ 1007

⇒ Check nos less than $\sqrt{1007} \rightarrow 31.xx$

(2, 3, 5, 7, 11, 13, 17, 23, 29)

→ In natural nos from $1 \rightarrow 100$ → there are 25 prime nos.

→ Any prime no. can be expressed as $6k+1$ or $6k+5$ $(6k-1)$

↳ necessary not sufficient.

$$N = \underset{\text{Not Prime}}{6k},\ \underset{\text{may be prime}}{6k+1},\ \underset{\text{Not Prime}}{6k+2},\ \underset{NP}{6k+3},\ \underset{N.P}{6k+4},\ \underset{\text{may be prime}}{6k+5}$$

⇒ $N = P_1^a \times P_2^b \times P_3^c \times P_4^d \times ---- \times P_n^\delta$

Total No. of Factors = $(a+1)(b+1)(c+1) ---- (\delta+1)$

Total No. of Even factors = $a(b+1)(c+1) ---- (\delta+1)$

where a is power of 2.

Total No. of odd factors = $(b+1)(c+1)(d+1) ---- (\delta+1)$

where $b, c, d, ----$ are powers of odd primes

No. of distinct prime factors of $N = n$.

classmate

Date
Page

⇒ Sum of all the factors of N

$$= \frac{(P_1^{a+1}-1)}{(P_1-1)} \times \left(\frac{P_2^{b+1}-1}{P_2-1}\right) \times \left(\frac{P_3^{c+1}-1}{P_3-1}\right) \times \text{---} \times \left(\frac{P_n^{\delta+1}-1}{P_n-1}\right)$$

NOTE: Total No. of Factors of any perfect square is always odd
Total No. of Factors of composite No. other than perfect square is always $\boxed{\text{even}}$.

⇒ No of ways of expressing N as a product of 2 nos.

$$= \begin{cases} \frac{1}{2}\left[(a+1)(b+1)(c+1) \text{ --- } (\delta+1)\right] \rightarrow \text{if } N \text{ is not a perfect sq. number.} \\ \frac{1}{2}\left[(a+1)(b+1)(c+1) \text{ --- } (\delta+1)+1\right] \rightarrow \text{if } N \text{ is a perfect Square number.} \end{cases}$$

⇒ No of ways of expressing N as a product of 2 co-prime numbers

$= 2^{n-1}$ where n is the no. of distinct prime factors.

⇒ No of co-primes of a number $N = P_1^a P_2^b P_3^c \text{ --- } P_n^\delta$, less than N

$$= N\left(1-\frac{1}{P_1}\right)\left(1-\frac{1}{P_2}\right)\left(1-\frac{1}{P_3}\right) \text{ --- } \left(1-\frac{1}{P_n}\right)$$

⇒ Highest power of a prime p in N!

$$= \left[\frac{n}{p}\right] + \left[\frac{n}{p^2}\right] + \left[\frac{n}{p^3}\right] + \text{ --- } + \left[\frac{n}{p^a}\right]$$

till $\boxed{p^a > n}$

⇒ Product of all factor $= N^{\left(\frac{\text{Total no. of factors}}{2}\right)}$

H.P. of 2 in 100! = 50+25+12+6+3+1 = 97

HP of 10 in 100! = HP of 5 in 100! = 20+4 = 24

NOTE:

HP of 10 in n! = HP of 5 in n!

⇒ Find the highest power of 10 in $1^1 \times 2^2 \times 3^3 \times 4^4 \times --- 25^{25}$

5 → 5+10+15+20+50 = 100

⇒ Find the higuest power of 10 in $1^1 \times 2^2 \times 3^3 \times 4^4 \times ----- \times 100^{100}$

5 → (5+10+15+20+ ------ +100) + 25+50+75+100

5×210 + 250 = 1300

Work and Time

RTW Approach

R → Resources

T → Time (in days/weeks/hour/min/sec)

W → Work (complete work assumed as unity)

$$\text{Time} = \frac{\text{Total Work}}{\text{Work done in unit time}}$$

R	T	W
100 C	100D	100M
49 C	100 Days	49M

M_1	D_1	W_1
M_1	1	$\frac{W_1}{D_1}$
1	1	$\frac{W_1}{D_1 M_1}$
M_2	1	$\frac{M_2 W_1}{D_1 M_1}$

So Time taken by M_2 resources to complete work = $\dfrac{W_2}{\frac{M_2 W_1}{D_1 M_1}}$

$$\boxed{\frac{M_1 D_1}{W_1} = \frac{M_2 D_2}{W_2}}$$

R	T	Shift	W
100 C	100 D	4 hrs	100 M
49 C	?	6 hrs	49 M

$$\frac{M_1 D_1 H_1}{W_1} = \frac{M_2 D_2 H_2}{W_2}$$

$$\frac{\cancel{100} \times 100 \times 4}{\cancel{100}} = \frac{\cancel{49} \times D_2 \times 6}{\cancel{49}}$$

$$\boxed{D_2 = \frac{200}{3}}$$

NOTE:

$$\boxed{\frac{M_1 D_1 H_1 E_1}{W_1} = \frac{M_2 D_2 H_2 E_2}{W_2}} \Rightarrow \text{where } E_i \text{ is the efficiency.}$$

→ more men can do more work, less men can do less work
→ more efficient can do more work, less efficient will do less work
→ More work takes more time, Less work takes less time.
→ more men takes less time, Less men take more time.

⇒ Approach

	R		T		W
	A	→	x	→	1
	B	→	y	→	1

R		T		W
A	→	1	→	$1/x$
B	→	1	→	$1/y$
A+B	→	1	→	$\frac{1}{x}+\frac{1}{y}$

$$T_{A+B} = \frac{1}{\frac{1}{x}+\frac{1}{y}} = \frac{xy}{x+y}$$

*	R	T	W
	A+B	x	1
	B	y	1
	A	1	$\frac{1}{x}-\frac{1}{y}$

$$T_A = \frac{1}{\frac{1}{x}-\frac{1}{y}}$$

*	R	T	W
	A+B	x	1
	B+C	y	1
	C+A	z	1
	A+B+C	1	$\frac{1}{2}\left(\frac{1}{x}+\frac{1}{y}+\frac{1}{z}\right)$
	A	1	$\frac{1}{2}\left(\frac{1}{x}+\frac{1}{y}+\frac{1}{z}\right)-\frac{1}{y} = \frac{1}{2x}-\frac{1}{2y}+\frac{1}{2z}$
	B	1	$\frac{1}{2}\left(\frac{1}{x}+\frac{1}{y}+\frac{1}{z}\right)-\frac{1}{z} = \frac{1}{2x}+\frac{1}{2y}-\frac{1}{2z}$
	C	1	$\frac{1}{2}\left(\frac{1}{x}+\frac{1}{y}+\frac{1}{z}\right)-\frac{1}{x} = \frac{-1}{2x}+\frac{1}{2y}+\frac{1}{2z}$

$T_{A+B+C} = \frac{1}{\frac{1}{2}\left[\frac{1}{x}+\frac{1}{y}+\frac{1}{z}\right)}$, $T_A = \frac{1}{\frac{1}{2}\left[\frac{1}{x}-\frac{1}{y}+\frac{1}{z}\right)}$, $T_B = \frac{1}{\frac{1}{2}\left[\frac{1}{x}+\frac{1}{y}-\frac{1}{z}\right]}$, $T_C = \frac{1}{\frac{1}{2}\left[\frac{-1}{x}+\frac{1}{y}+\frac{1}{z}\right]}$

AIR-1 Notes

Pages: 81

Handwritten notes by

Kartikay Kaushik

AIR-1 ESE 2021

IES Master classroom Student

Engg. Drawing

Syllabus

*** 1) Engg. Curves	Mathematical	
2) Theory of projection	common sense and aptitude	
3) Projection of point		
4) Projection of line		
5) Projection of surface		
6) Projection of Solid		
** 7) Development of surfaces.	Aptitude.	

Ch-1 Engineering Curves

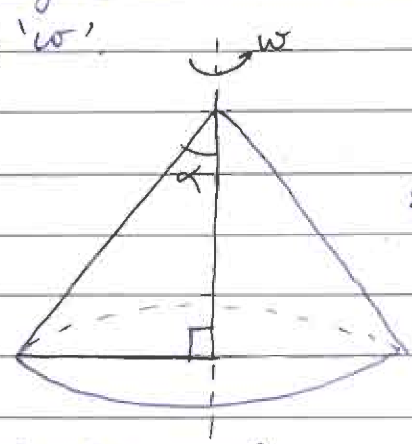
1) Conic Sections

2) Special curves.

1) Conic Sections

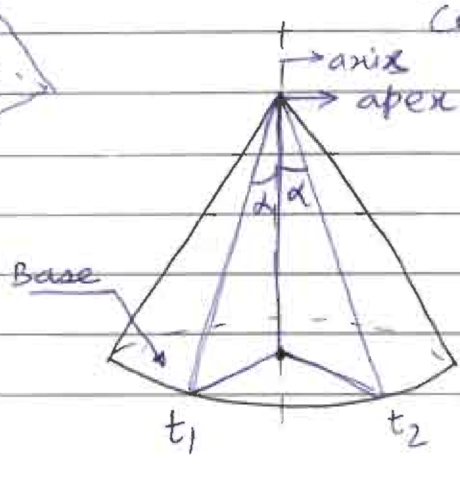
(a) Conic section defined as section of cone

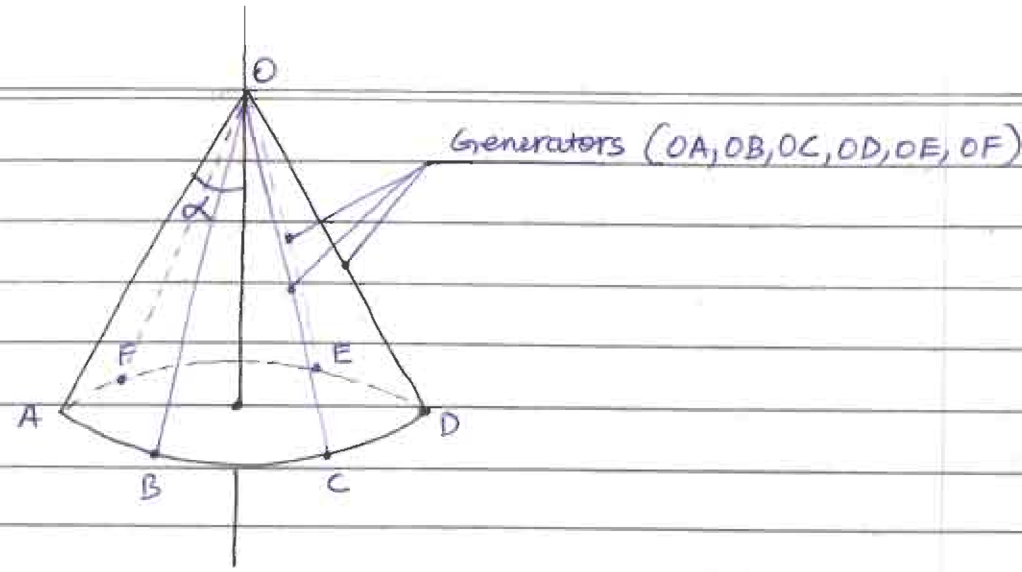
⇒ Consider a right angled Δ rotated about its altitude at a certain angular velocity 'ω'.



α → semi-apex angle.

Solid of Revolution → Right circular Cone

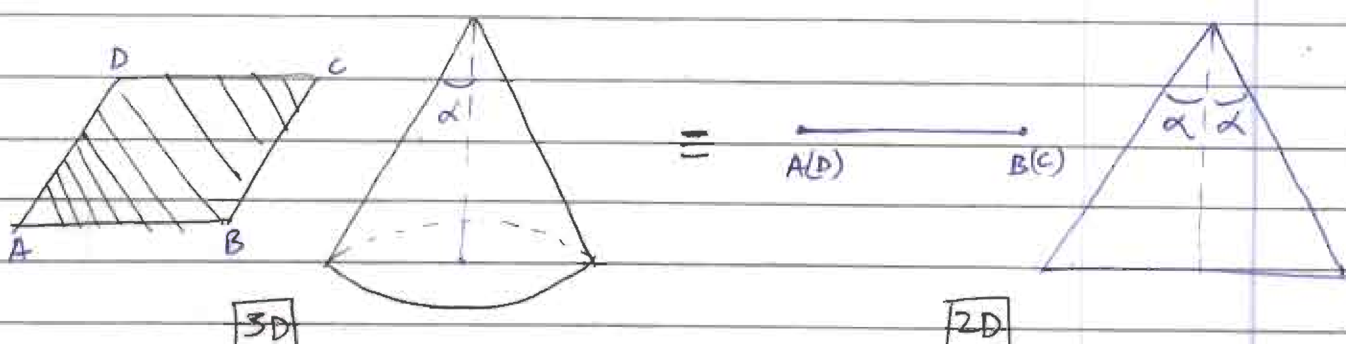


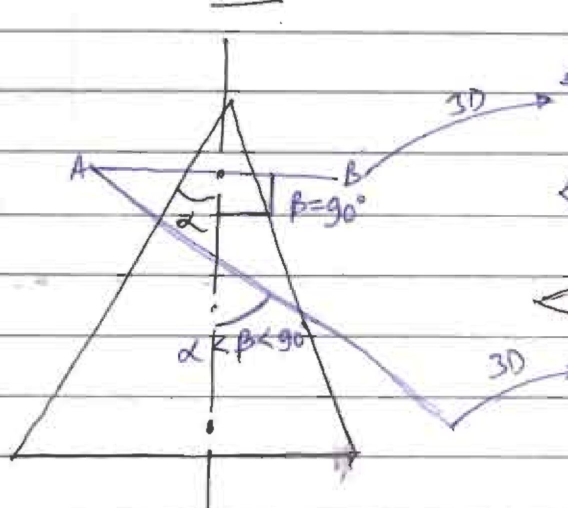


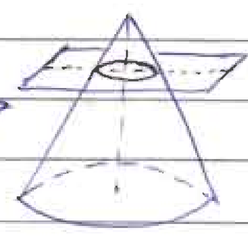
⇒ Any imaginary line joining the apex to the circumference of base of the circle is known a generator.

⇒ Cone is a solid of revolution i.e. it appears as a solid cone only when a triangular plane is rotated about it's altitude.
eg – Cylinder and sphere. → Single curved surface

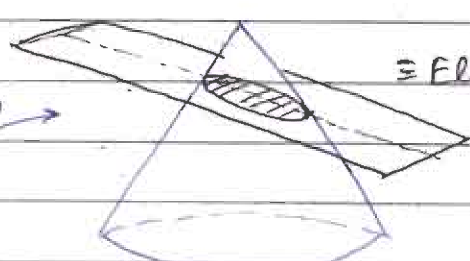
⇒ A conic section is the section of a right circular cone obtained by cutting the cone in different ways by a straight plane known as cutting plane



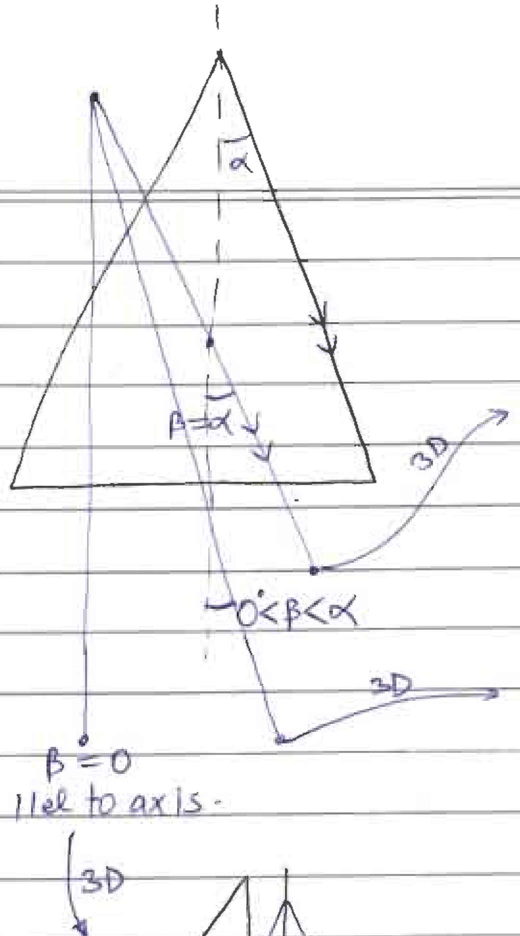


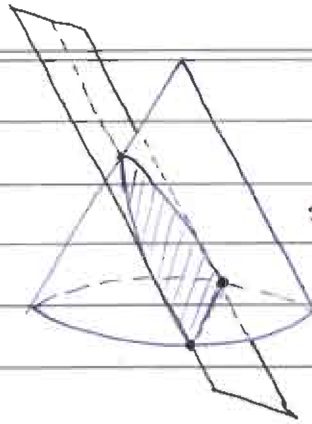


≡ Circle [Plane is ||el to the base or $\beta = 90°$]



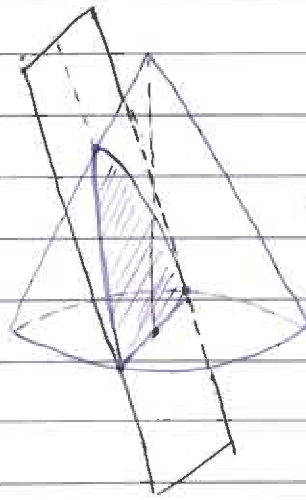
≡ Ellipse → $\alpha < \beta < 90°$





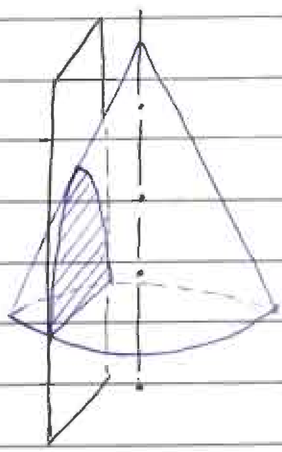
≡ Parabola [Cutting plane is ||el to one of the generators]

i.e. $\beta = \alpha$



≡ Hyperbola

$0^\circ < \beta < \alpha$



≡ Rectangular Hyperbola

$\beta = 0^\circ$

Plane of cutting is ||el to the axis of cone.

NOTE: → $\beta = 90^\circ$ → circle

→ $\alpha < \beta < 90^\circ$ → ellipse

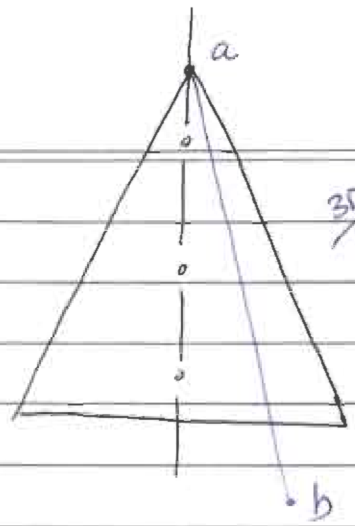
→ $\beta = \alpha$ → Parabola

→ $0^\circ < \beta < \alpha$ → Hyperbola

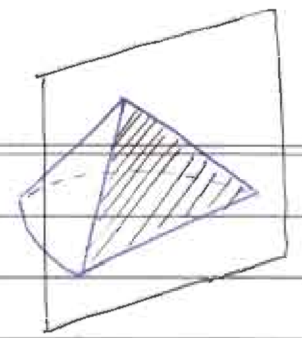
→ $\beta = 0^\circ$ → Rectangular Hyperbola.

→ Circle and ellipse cuts all the generators of a cone whereas parabola, hyperbola and rectangular hyperbola does not cut all the generators.

→ If the cutting plane cuts the right circular cone in such a way such that one end of the cutting plane passes through apex, then an isosceles Δ is formed.

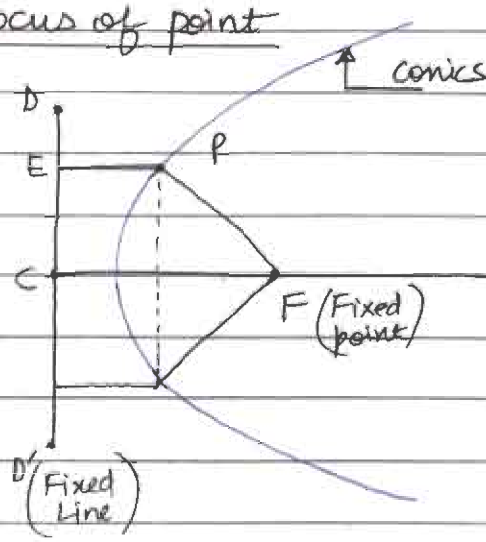


3D →



≡ isosceles Δ.

⇒ Conic sections as locus of point



$CC' \rightarrow$ axis of cone

$DD' \rightarrow$ Directrix

$F \rightarrow$ Focus.

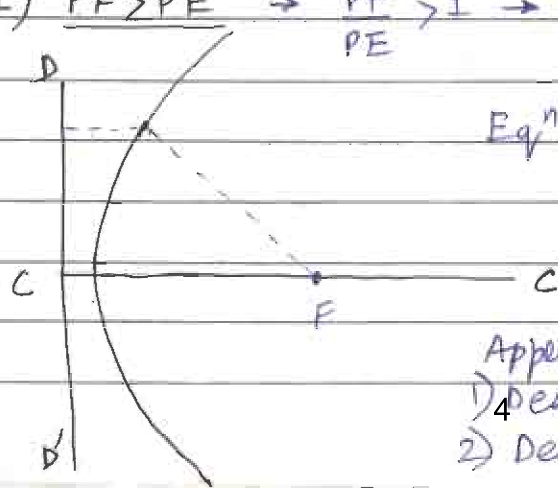
$e = \dfrac{PF}{PE} = \text{constt.}$

↳ eccentricity.

→ A conic is defined as the locus of a point moving in a plane such that the ratio of it's distance from fixed pt called focus to a fixed line called directrix is always a constant known as eccentricity.

Eccentricity, $e = \dfrac{\text{Distance of point from focus}}{\text{Distance of point from directrix.}}$

Case 1) $PF > PE \rightarrow \dfrac{PF}{PE} > 1 \rightarrow e > 1 \rightarrow$ Hyperbola



Eqⁿ → $\dfrac{x^2}{a^2} - \dfrac{y^2}{b^2} = 1$

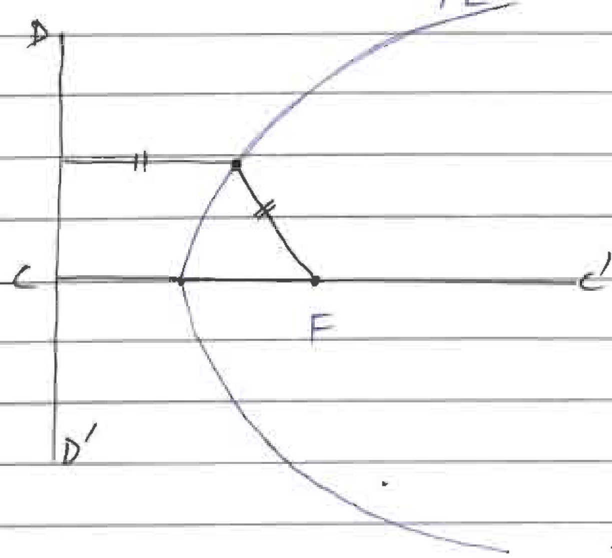
$b^2 = (e^2 - 1)a^2$

Application:

1) Designing of cooling towers

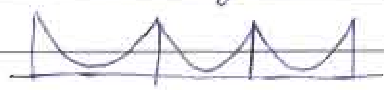
2) Designing of flower vases.

Case 2) $PF = PE \rightarrow \frac{PF}{PE} = 1 \rightarrow e = 1 \rightarrow$ Parabola

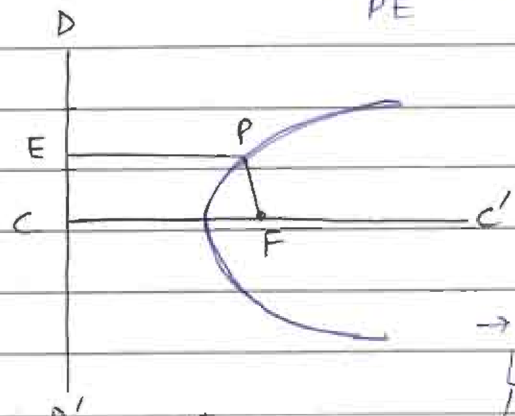


Eq^n $\rightarrow y^2 = 4ax$

→ Application:
- → Path of trajectory
- → Solar concentrator
- → Parabolic reflectors.
- → Headlights.



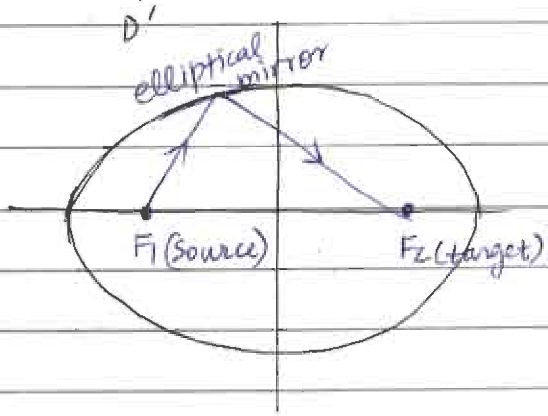
Case 3) $PF < PE \rightarrow \frac{PF}{PE} < 1 \rightarrow e < 1 \rightarrow$ ellipse



Eq^n $\rightarrow \frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$

$b^2 = (1 - e^2)a^2$

→ Application:
- → Designing of bridges, arches
- → Use of lithotripsy



Laproscopic Surgery to treat kidney stones.

NOTE: As $e<1$,

as $e \to 0$

Eqⁿ for $e<1 \Rightarrow \frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$ where $b^2 = (1-e^2)a^2$

$$\boxed{x^2 + y^2 = a^2} \leftarrow b^2 = a^2$$

↳ circle → $\boxed{e=0}$

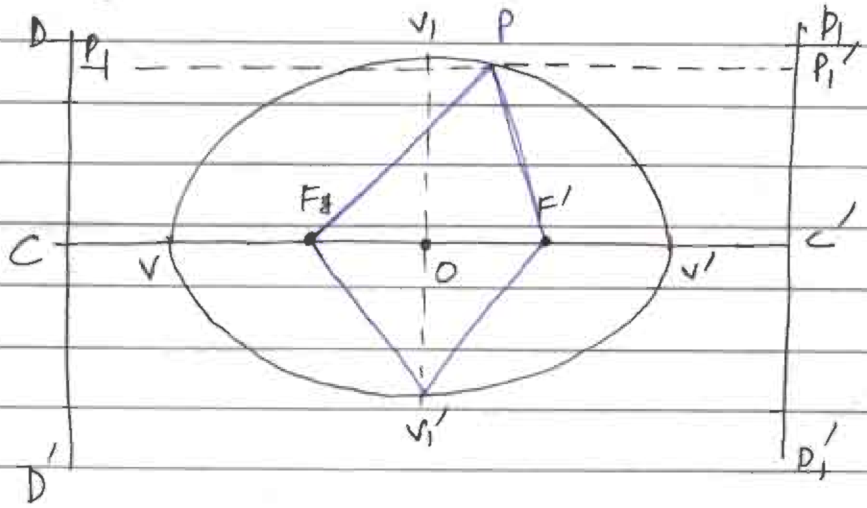
⇒ 3 conic sections:

1) Hyperbola
2) Parabola
3) Ellipse.

→ Circle is the 4th type of conic section and it is a special case of ellipse having eccentricity $=0$.

→ Isosceles Δ is not a conic section as it does not form second order equation.

⇒ Properties of conics



DD', $D_1D_1' \to$ Directrix

$VV' \to$ major axis

$V_1V_1' \to$ minor axis

$O \to$ Centre of ellipse

⇒ ~~$PF + PF' = ePP_1 + ePP_1' = e(CC')$~~

$\Rightarrow PF + PF' = FV' + F'V = FV' + VF = VV' =$ major axis

$\Rightarrow \underbrace{FV_1' + F'V_1'}_{\text{equal}} = VV' \Rightarrow FV_1' = F'V_1' = FV_1 = F'V_1 = \frac{VV'}{2}$

→ Ellipse is also defined as the locus of point which moves in a plane such that the sum of its distance from 2 fixed points is always constant and it is equal to major axis

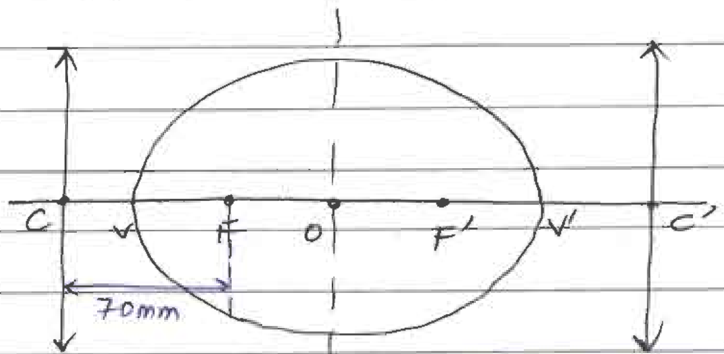
→ The distance of any end of the minor axis from focus is half of major axis.

Q- In the figure shown if distance of focus (F) from the directrix is 70 mm. , e = 3/4

(a) Find V'F

(b) Find FF', VV', CC'

(c) Find Relation b/w (ii)



(a) $e = \frac{V'F}{V'C} = \frac{3}{4} \Rightarrow \frac{V'F}{V'F+70} = \frac{3}{4} \Rightarrow \boxed{V'F = 210\,mm}$

(b) $e = \frac{VF}{VC} = \frac{3}{4} \Rightarrow VF = 30\,mm$

$VC = 40\,mm$

$FF' = VV' - 2(VF) \Rightarrow FF' = V'F + VF - 2VF = V'F - VF$

$\Rightarrow FF' = 210 - 30 = 180\,mm$

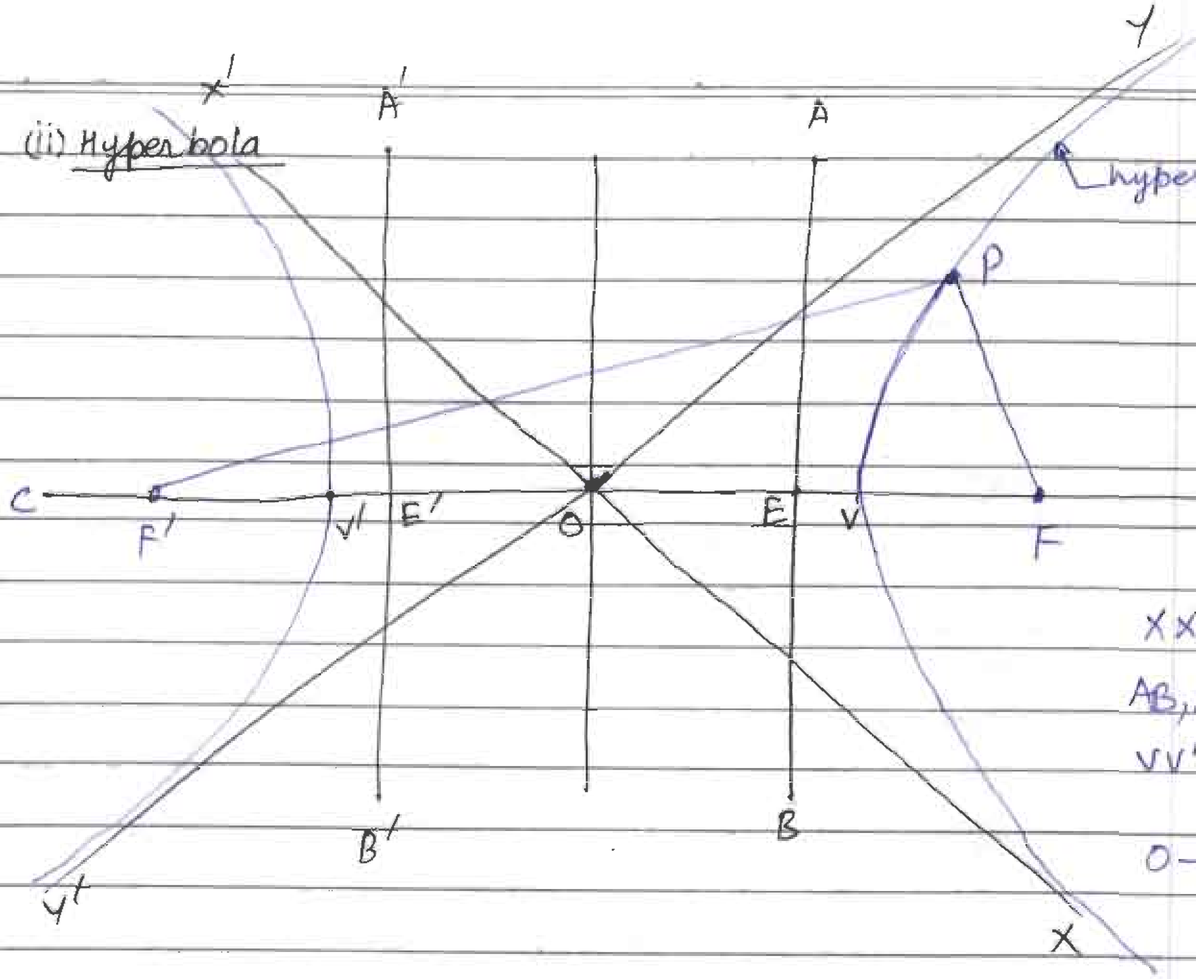
$VV' = V'F + VF = 210 + 30 = 240\,mm$

$CC' = VV' + 2VC = 240 + 2 \times 40 = 320\,mm.$

$$\frac{FF'}{VV'} = \frac{VV'}{CC'}$$

$VV' = \sqrt{FF' \times CC'}$ geometric mean

(ii) Hyperbola



$XX', YY' \to$ asymptotes

$AB, A'B' \to$ Directrix

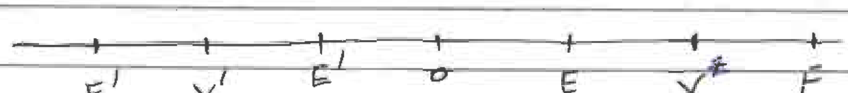
$VV' \to$ Transverse axis

$O \to$ Centre of hyperbola.

→ A hyperbola is locus of point which moves in a plane so that the difference between the point and the 2 focus is always constant and it is equal to transverse axis.

$$PF' - PF = VF' - VF$$
$$= VV' + \cancel{V'F'} - \cancel{VF} = VV'$$

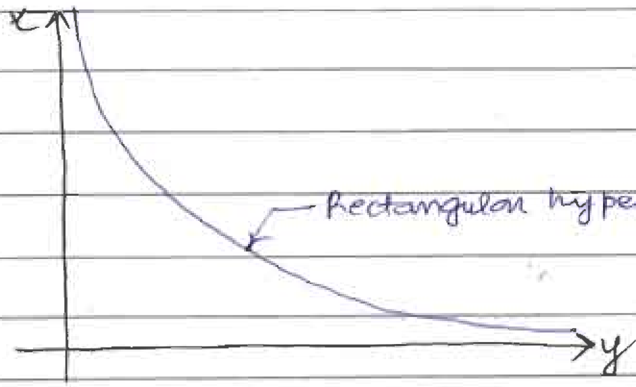
NOTE :



① $\Rightarrow \dfrac{FF'}{VV'} = \dfrac{VV'}{EE'} = e \Rightarrow \boxed{VV' = \sqrt{FF' \times EE'}}$

2) If angle between asymptotes is 90° then hyperbola is known as rectangular hyperbola or equilateral hyperbola, having eccentricity $= \sqrt{2}$

Ex: $xy = \text{constant} \Rightarrow y = \frac{k}{x} \Rightarrow y \propto \frac{1}{x}$



→ Boyle's Law ⇒ $PV = \text{constant}$.

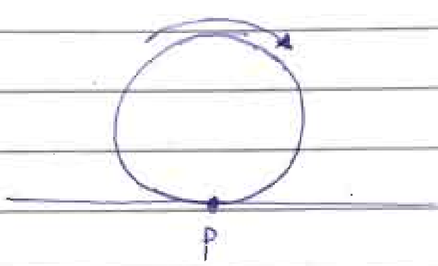
** II) Special Curves

- (I) Plane curves
  - (A) Cycloidal curves
    - → ~~cycloid and trochoid~~
    - → Epicycloid and Epitrochoid
    - → Hypocycloid and Hypotrochoid
  - Involutes
  - Spirals
    - → Archimedian Spiral
    - → Golden spiral
    - → Logarithmic Spiral
- II) Space Curves
  - Helices
    - → cylindrical Helix
    - → Conical Helix.

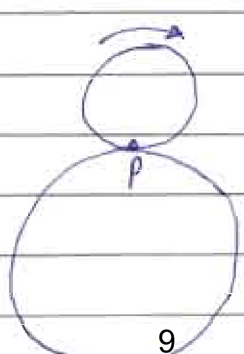
⇒ Plane curves:

→ Curve that is drawn on a 2D plane.

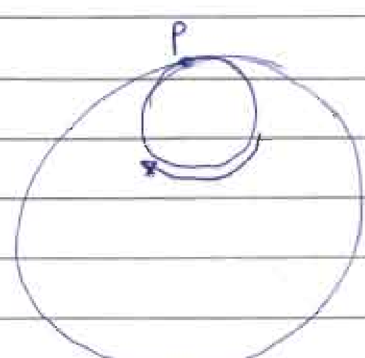
(A) Cycloidal curve



Cycloid

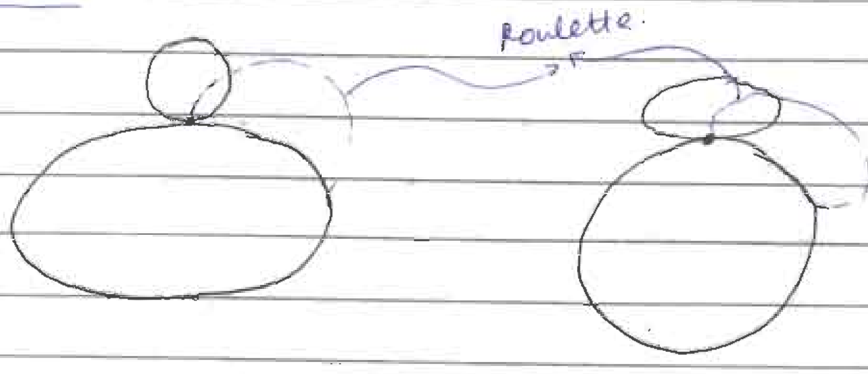


Epicycloid



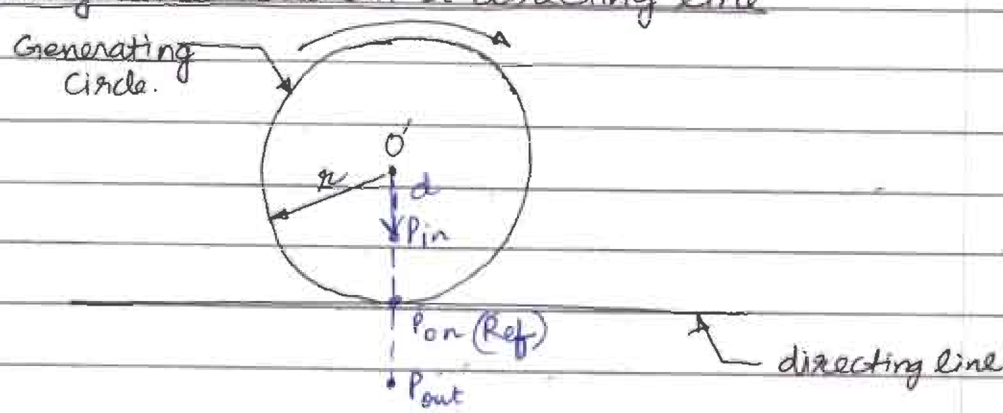
Hypocycloid

→ When one curve rolls over another curve without slipping or sliding, the path of any point of the rolling curve is called as roulette



→ When a rolling curve is a circle known as generating circle and the curve on which it rolls is either a straight line known as directing line or rolls on a circle known as directing circle, the locus is known as cycloidal curve.

⇒ Generating circle rolls on a directing line

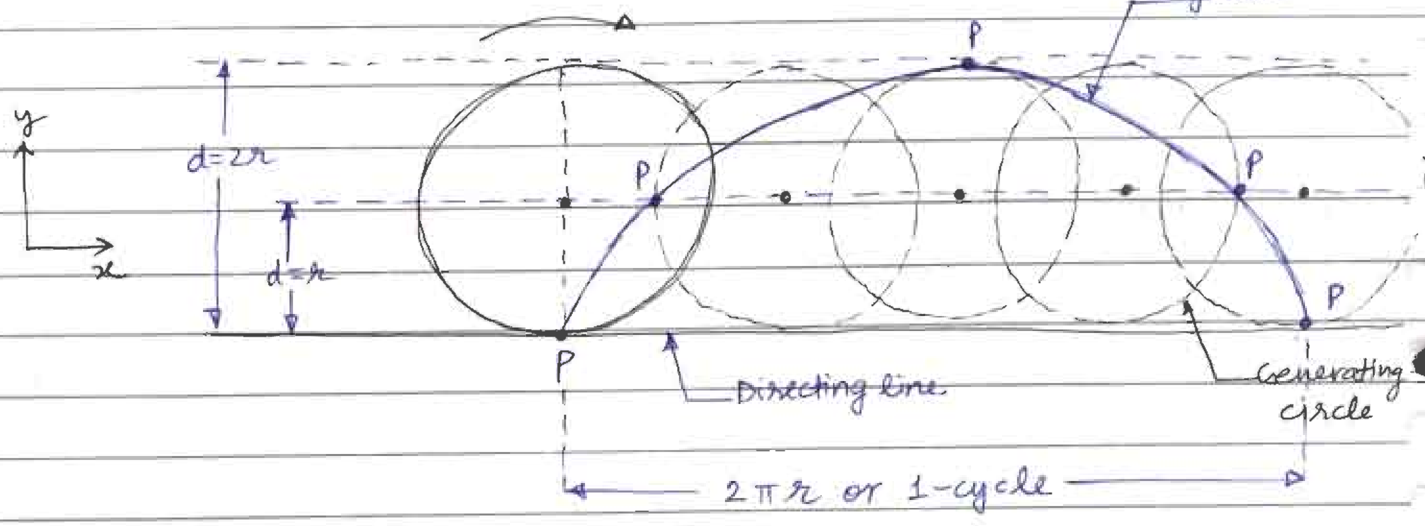


if $d = r \rightarrow$ cycloid

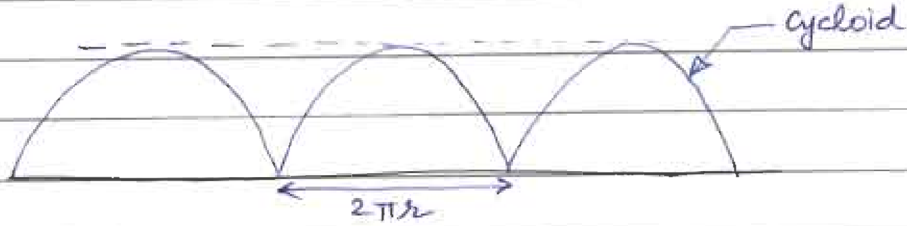
$d > r \rightarrow$ Superior trochoid

$d < r \rightarrow$ Inferior trochoid.

(i) Point lying on the generating circle → Cycloid.



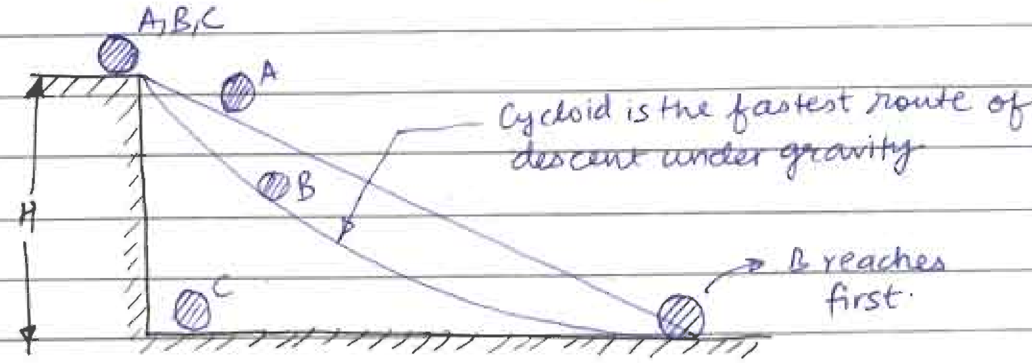
Locus of P



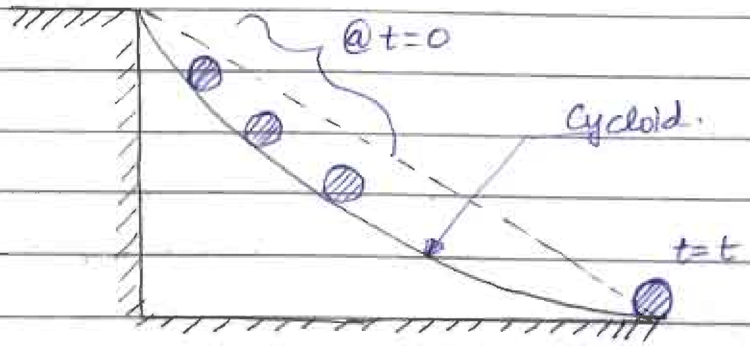
→ In one complete cycle of rotation only 1 cycloid is formed.

→ Application

1) Cycloid is the solution to Brachistochrone problem.

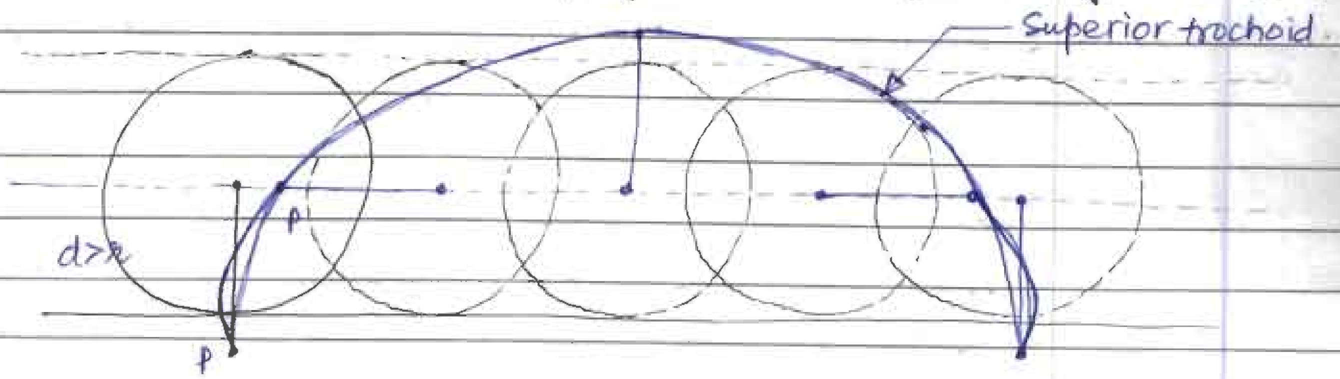


2) Cycloid is the solution to tautochrone problem.

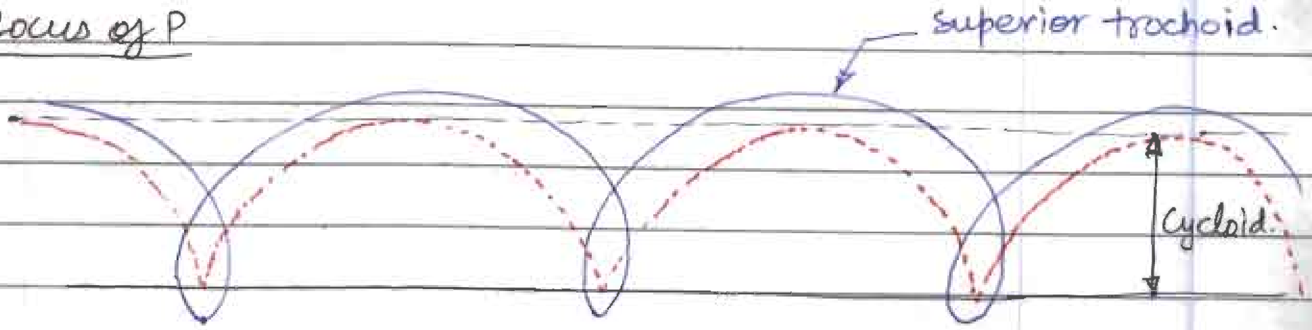


⇒ The time period of an object in descent without friction inside the curve does not depend on the objects starting position.

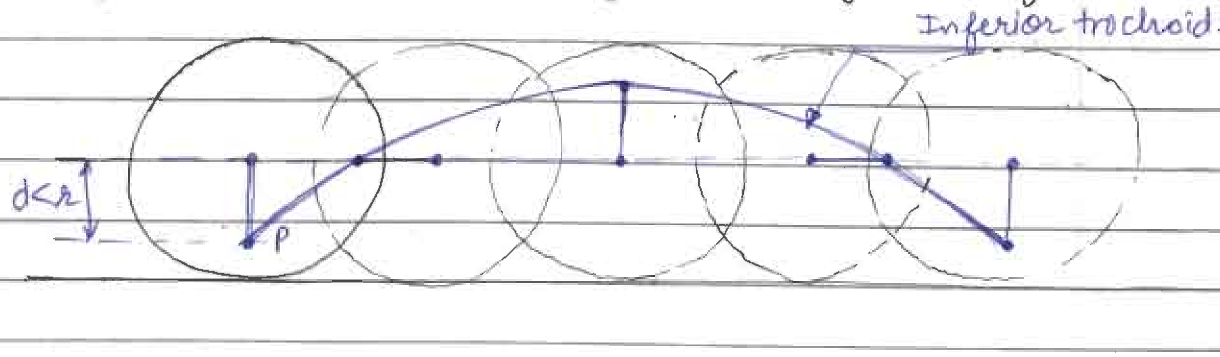
(ii) Superior Trochoid → Point lying outside the generating circle ($d > r$)



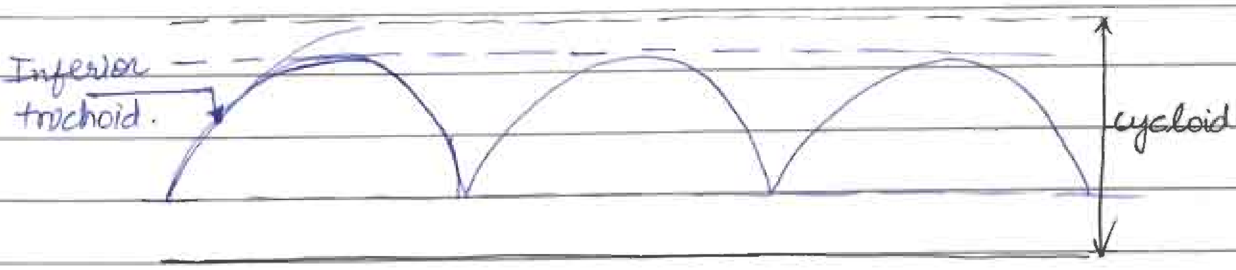
Locus of P



(iii) Inferior trochoid → Point lying inside the generating circle ($d < r$)



Locus of P

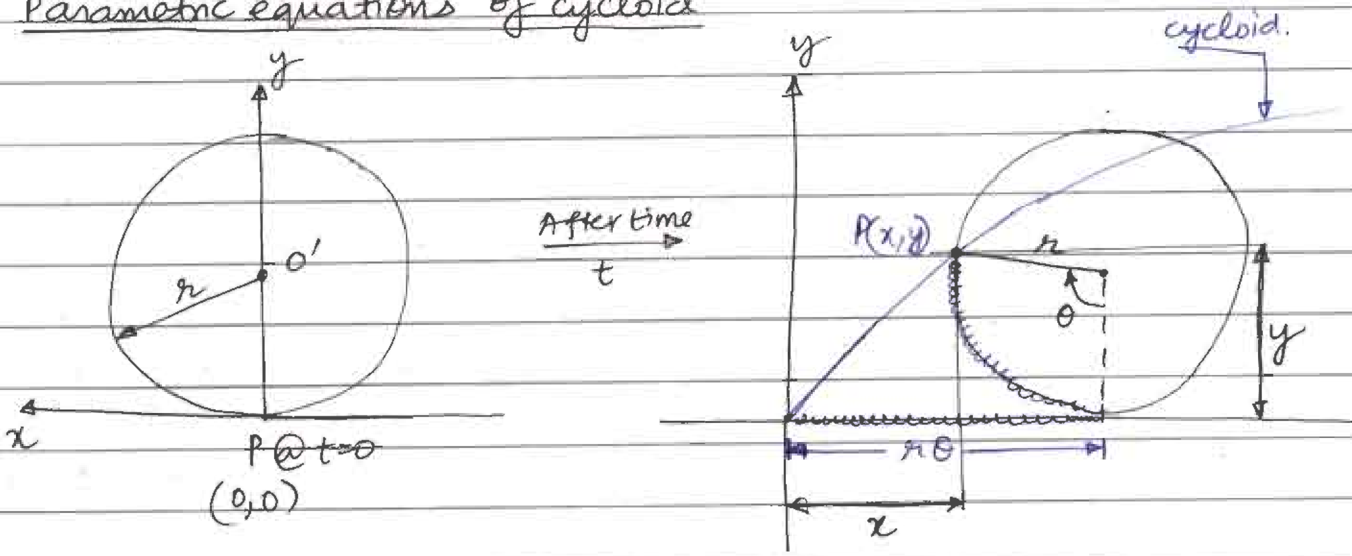


NOTE: Application of both inferior and superior

⇒ Naval Architecture

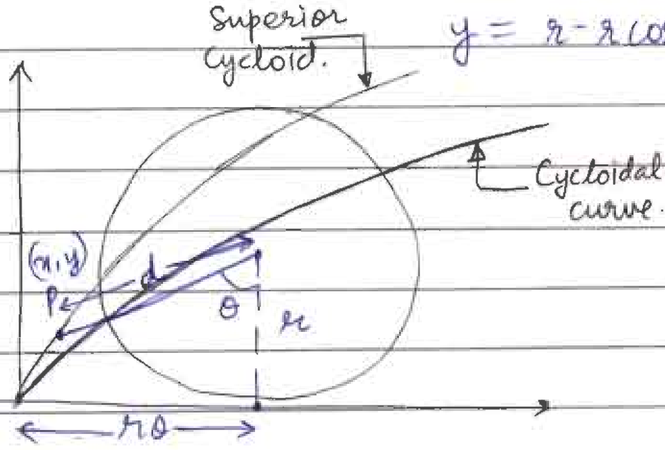
→ It approximates wave profile used in naval architecture

⇒ Parametric equations of cycloid



$$x = r\theta - r\sin\theta$$

$$y = r - r\cos\theta$$



In general,

$$x = r\theta - d\sin\theta$$

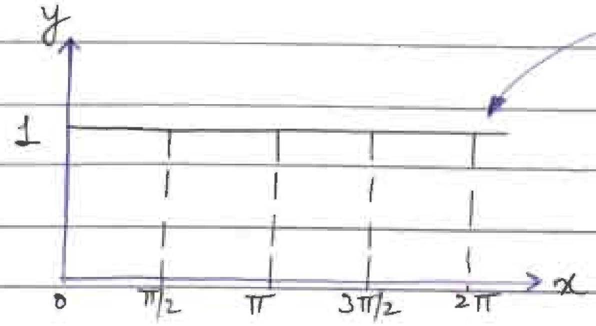
$$y = r - d\cos\theta$$

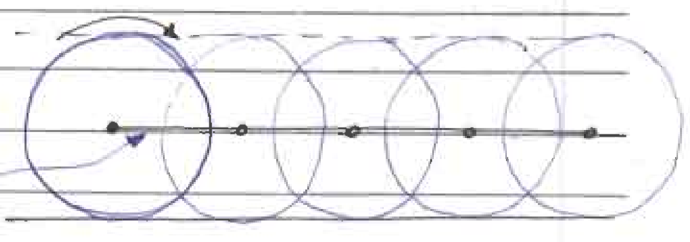
⇒ valid for $d < r$, $d = r$, $d > r$

NOTE: (i) if $d > r \rightarrow$ superior trochoid
(ii) if $d = r \rightarrow$ cycloid
(iii) if $d < r \rightarrow$ inferior trochoid
(iv) if $d = 0 \rightarrow$ straight line.

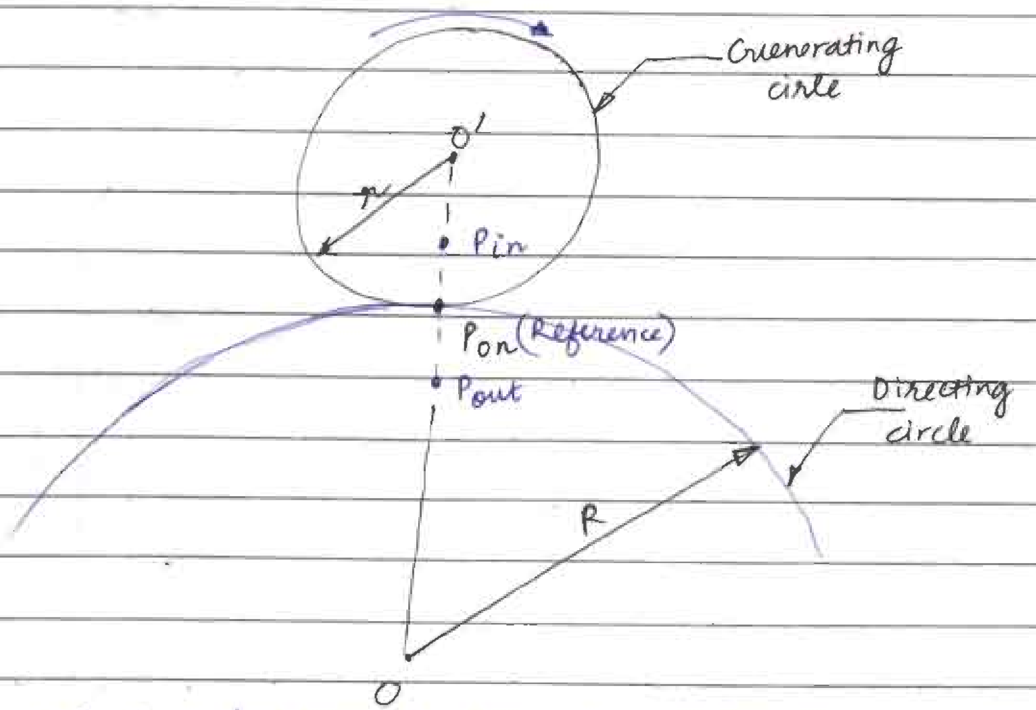
$x = r\theta$
$y = r$

For $r = 1$





B) ⇒ Generating circle rolls outside the directing circle



Let d is distance of point from centre of generating circle:
(i) if $d = r \rightarrow$ epicycloid
(ii) if $d > r \rightarrow$ superior epitrochoid
(iii) if $d < r \rightarrow$ inferior epitrochoid.

AIR-1 Notes
Pages: 72

Handwritten notes by

Kartikay Kaushik
AIR-1 ESE 2021
IES Master classroom Student

Engineering Ethics

1) Basic concepts – Morals, Ethics, Values and Attitudes (MEVA)
2) Theory of ethics
3) Code of conduct and code of ethics
4) IPR and Plagiarism
5) Ethical dilemma and ethical issues
6) Corruption and whistleblower
7) Miscellaneous Topics
   (a) Environmental Topics
   (b) Business Ethics
   (c) Media Ethics etc.
8) Principles and Values that guide Engineering Ethics

Relationship b/w
1) Science
2) Ethics
3) Engineering
4) Technology

→ Science is a body of systematized knowledge gathered by observing and measuring events.

→ Outstanding features of science:

1) Observation – Studies events of interest with as much precision and accuracy as possible.
→ Science permits controlled observation i.e experimentation

to arrive at definite cause-effect relationship

2) Measurement – assignment of numbers to objects and events according to some rule.

→ To achieve definite cause-effect relationship:

1) Replication
2) verification
3) Skepticism

} Objectivity — ensures

→ Subjectivity leads to suspective cause-effect relationship
or speculative

⇒ Engineering is transforming science to create products for human comfort and to create systems that maximize human efficiency and minimize human labour
→ application of science for practical purpose

⇒ Engineering is about process and Technology is about product otherwise there is not much difference b/w the two

⇒ Ethics is a normative science that enables the individual to distinguish b/w right and wrong and follow the path of righteousness.

Science
- Positive
  "what is"
  "facts as they are"
  ↓
  Physics, Chemistry, Biology
- Normative
  "what ought to be"
  ↓
  speculative cause-effect relationship

⇒ Why should an engineer study ethics ?

1) Public Service ⇒ Public Welfare ⇒ Ethics

2) Ethical dilemma } ⇒ eg → Employer Loyalty v/s Public Loyalty.

↳ how to resolve.

⇒ MEVA → Morals, Ethics, Values and Attitudes

→ MEVA are mental constructs that serve as an instrument for behaviour regulation

↳ a human without ethics is like a beast loosed on the world (Camus)

⇒ Behaviour regulators → Thoughts
→ Emotions

⇒ How MEVA serves as an instrument for behaviour regulation

1) when our behaviour voilates our morals we experience "GUILT" (Emotion)

something which I dislike

Guilt is an aversive state that an individual experiences when there occurs moral transgression (उल्लंघन)

2) When our behaviour violates our ethics we experience threat of social ostracization. (out casted from society)
"SHAME"

⇒ Morals are far stronger and powerful behavior regulator as compared to ethics.
⇒ External forces v/s Internal forces.

Hedonism - physical pleasure

Altruism - selfless service to society.

Set of standards

Society places on itself (Ethics)

An individual places on himself (Morals)

to guide its / their choices, behaviour and actions.

MORALS	ETHICS
1) Morals are internal	1) Ethics are external
2) Personal	2) Societal
3) "GUILT"	3) "SHAME"

both provide motivation for action.

Self discipline

self control

eg Honesty

"abstract ideals"

3) when our behaviour violates our values we experience "CONFLICT"

within the individual

Hedonism v/s Altruism

b/w individual and society

between different individuals or society

4) when our behaviour violates our attitude we experience "DISSONANCE"

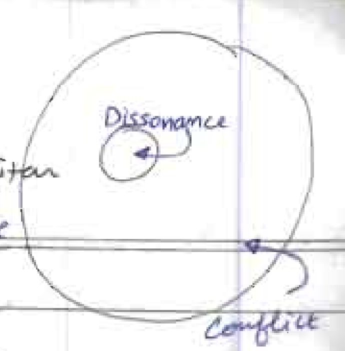
2 or more attitudes

attitude of behaviour

~~Before~~

Because I value music → abstract

↳ therefore I have a positive attitude towards guitar ← concrete



Mashmallow experiment ⇒ Emotional Intelligence.

↳ Life is all about how to delay gratifications.

↳ succumb to temptations.

⇒ DISSONANCE → is a negative drive (→ something which we want to avoid.) state that an individual experiences when there occurs incompatibility b/w his attitudes or b/w his attitude and behaviour or discrepancy b/w his attitude and behaviour. (discrepant v/s congruent).

⇒ Why does MEVA often fails to act as a self regulatory mechanism

1) Selective perception and interpretation of ~~this~~ ones actions.
2) Justification of ones actions.

→ MORAL DISENGAGEMENT

→ Selective ~~—~~ activation and deactivation of morals and values.

→ Selective perception of information and facts.

⇒ Why do we need laws when MEVA is in place

Behavior regulations can operate at 3 levels

- → Individual (Moral) — fails due to moral disengagement
- → Society (Ethics)

Individual and Society: more or less informal

- → Institution (Law) — (1) fails due to lack of evidence
  - 1) Formal
  - 2) Explicit
  - 3) Works on Evidence.

→ What is lawful may not be ethical.

→ What is ethical may be unlawful / illegal.

conscience of the nation ← Law > Ethics → conscience of the society / individual

Explicit, concrete ← Law > Ethics → imagination

→ Mind is abstract, brain is concrete.

⇒ Moral arch of the universe bends at the elbow of justice

⇒ How to ensure that MEVA becomes an effective tool for behavior regulation

1. Reward pro-social behavior.
2. Punish anti-social behavior.
3. These rewards and punishment should be fair, systematic and consistent.
4. Seeing the role model being rewarded / punished can also change behavior.
5. Increasing the perceived probability that on the display of undesired behavior one will be ~~caugh~~ caught, punished when caught and punishment will be severe and no one will buy ones justification.

Structure of MEVA – Building Blocks

mind

(a) Cognitive → beliefs, opinions and ideas held by the individual towards the MEVA object. (abstract)
["Knowing"]
→ may or may not be factually correct.

(Morals, Ethics, Values are all abstract) [Attitude is an exception]

(b) Affective
→ emotions and feelings generated wrt MEVA object
→ provides energy for action
→ makes MEVA an evaluative tool
→ Hard to master as compared to cognition.
→ one approaches MEVA object with mixed feelings (eg. Eros / Thanatos)

heart

EROS – Life instinct THANATOS – Death instinct

(c) Action tendency components - Our readiness to respond in specific ways to MEVA object

→ predisposition (रुझान) to act in specific ways.

↳ does not imply an actual response.

⇒ These 3 components of MEVA are generally consistent with one another and as well as the behaviour displayed.

⇒ Our thoughts, beliefs, action tendency and ultimate action should be consistent.

Nature of MEVA

i) Culture specific and Universal

↳ each culture is unique.

→ Challenges faced by the people of a given culture are also unique.

→ Therefore, to meet these challenges MEVA should be culture-specific.

⇒ India ⇒ Agrarian Economy

↓

Joint family

Collectivism

Patriarchal values.

↳ ill effect is Nepotism

Universal

Promotes brotherhood and growth of society

Generosity, Voluntary Donation

eg - Patriotism, Kindness, commitment

→ Every society aims to achieve Social integration

→ All values which promote brotherhood and bind people together will be universal.

→ Entity common to the human race is relatedness → Empathy

↳ compassion, integrity

⇒ Industrial economy

⇓

Nuclear family ⇒ Individualism

means to destination

⇑

MEVA are a means ~~to an end~~

destination

⇑

an end in itself

2) Instrumental v/s Intrinsic

eg Honesty (Value) $\xrightarrow{\text{for}}$ Promotion (end) ⇑ external reason

eg- Honesty $\xrightarrow{\text{for}}$ the reason of Honesty and for no other reason other than honesty. ⇑ intrinsic reason.

↓ because honesty ~~gives an individual~~ satisfaction

⇒ What ~~me~~ is intrinsic may become instrumental and something which is instrumental may become intrinsic.

⇒ Something which is instrumental remains instrumental even when it is no longer tied with the original motive.

3) Absolute v/s Relative.

Absolute	Relative
→ Means are independent of ends and ends cannot justify means	→ ends justify the means or all that ends well is well.
→ A right is a right even when nobody does it, a wrong is a wrong even when everyone does it.	→ i.e. consequences determine the morality of an action.
→ Context independent.	→ focus should be on greatest good of the greatest number. ⇓ Extreme state → Majoritarianism
	→ context dependent
→ Deontological approach ⇓ Duty bound	→ Teleological approach ⇓ end bound.

Relativism → Teleological → Consequentialism

Relativism → Teleological → Utilitarianism

↳ Every thing should be just in value of utility it holds.

MEVA is neither dynamic nor static, it is relatively permanent
→ difficult to Change MEVA once established.

(4) Dynamic v/s Static

Dynamic	Static
↓	↓
Rapid change	Immutable

Argument → Values help us to adjust in our environment and environment is ~~not~~ dynamic, so should values not be dynamic.

→ Statement(1) → With changing environment, what changes is behaviour and not the underlying MEVA.

→ i.e. the modes of expression of values change and not the value themselves.

→ Different behavioral modes of expression ensure uniqueness of an individual.

→ Statement(2): MEVA provides the basis for our identity.

→ Identity gets formed after the investment of considerable time, labour and energy.

→ Because of this person is likely to resist any change in his identity ⇒ Relatively permanent nature of MEVA.

→ Statement(3): Our identity provides us with a framework to deal with the objects around us.

→ The frame of reference given to us by our identity is likely to change when individual undergoes identity transformation.

→ Thus it puts the individual in emotional turmoil and no individual wants that ⇒ Relative permanency.

$\boxed{\text{Hedonism} \xrightarrow[\text{Turmoil}]{\text{Emotional}} \text{Altruism}}$

(5) Some Innate and v/s Largely Acquired

Innate ⇓ Inborn

Acquired ⇓ As a result of Socialization

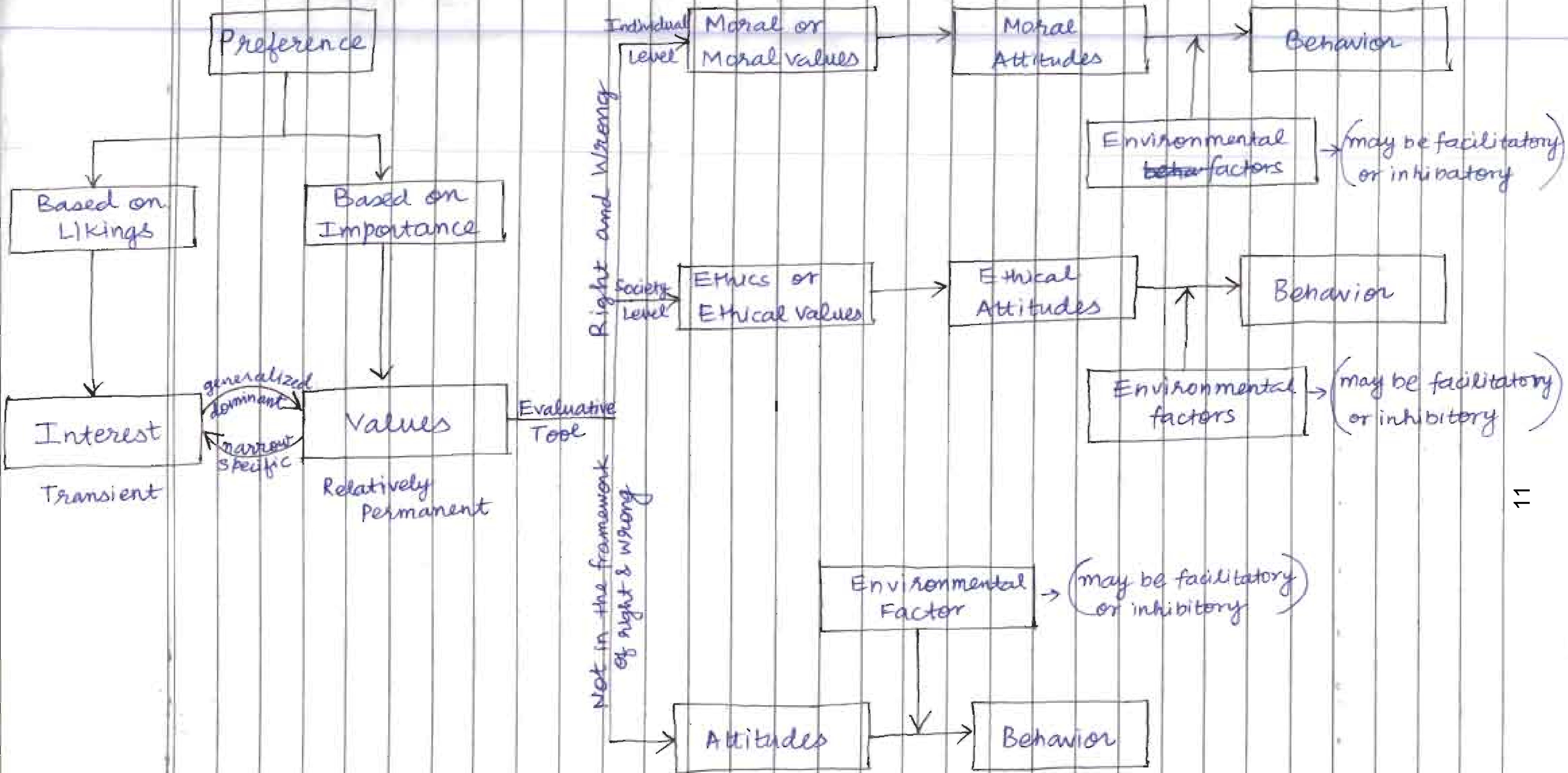
→ some emotional predispositions and behavioral orientations may be pre-acquired } but MEVA is principally acquired

⇒ Inference from flowchart

1) Values are general determinants of behavior and attitudes are specific ~~behavio~~ determinants of behavior.
i.e. ~~behavior~~ attitude predicts behavior better than values.

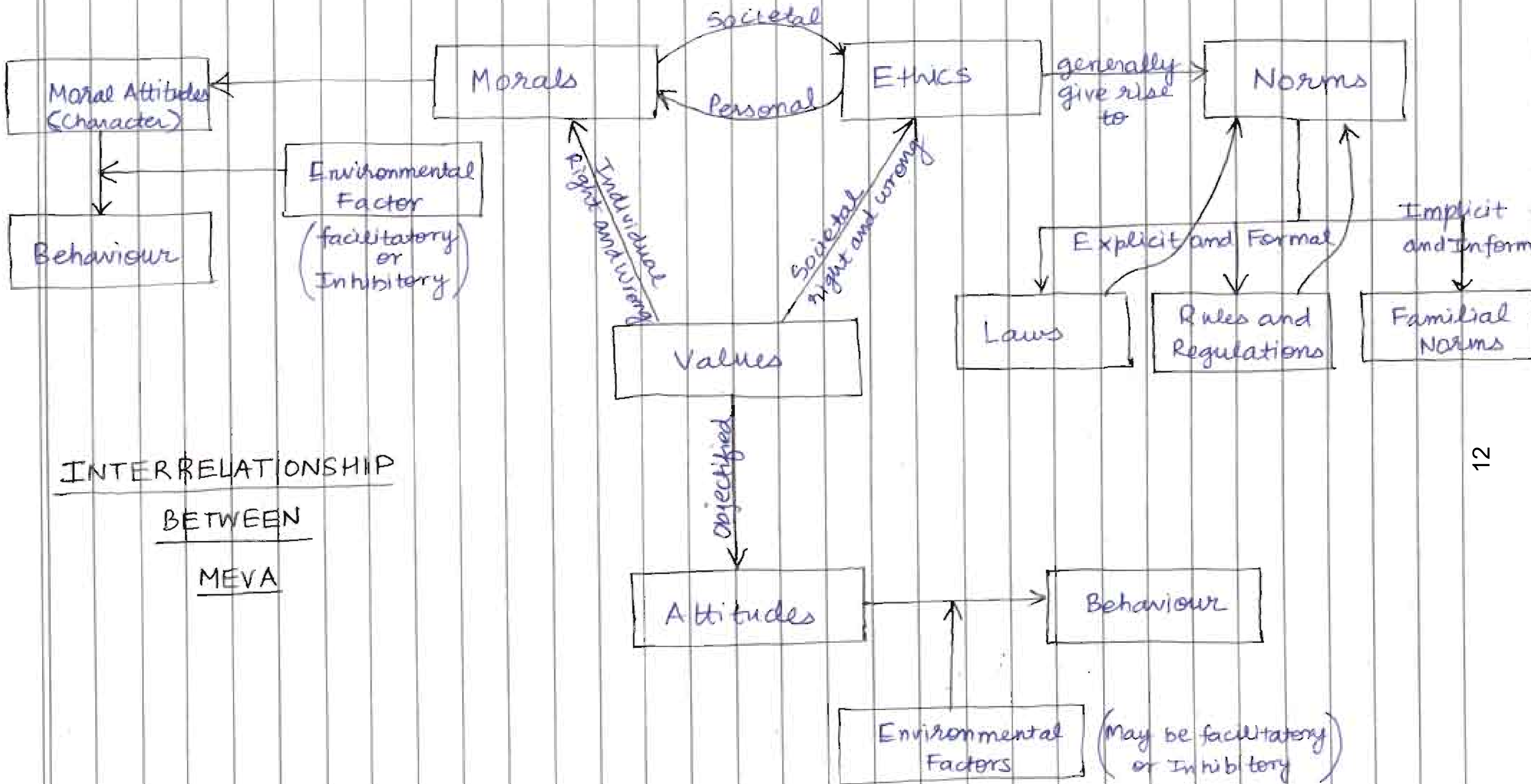
2) Every attitude may convert into behavior provided environmental factors are facilitatory. If the environment is inhibitory generally a positive attitude may not result into behavioral action. [It is possible that moral/ethical attitude prevail over environment]

3) Everything is not black and white (right and wrong) there exist shades of grey. eg - Aesthetic attitude is neither moral nor ethical.



RELATIONSHIP BETWEEN MORALS, ETHICS, ATTITUDES AND BEHAVIOR

INTERRELATIONSHIP BETWEEN MEVA



Inference from flowchart

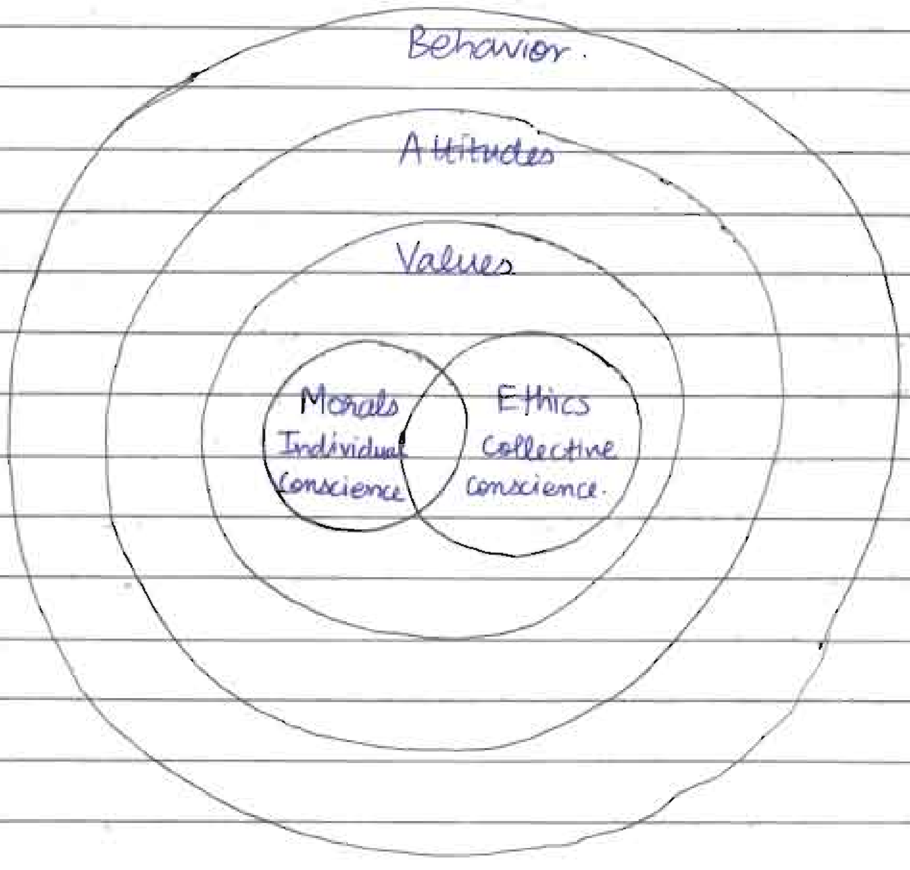
1) When a single man leads to a social change → bottom up.
When government " " " " → top down.

2) Ethics may change into morals and morals may change into ethics.

3) Cost-Benefit analysis governs who prevails over morals or ethics when they contradict each other.

4) Ethics is broad while Norm is specific.

5) Similarly laws are broad and rules and regulations are specific.



⇒ Development of MEVA

→ MEVA developed as a result of socialization.

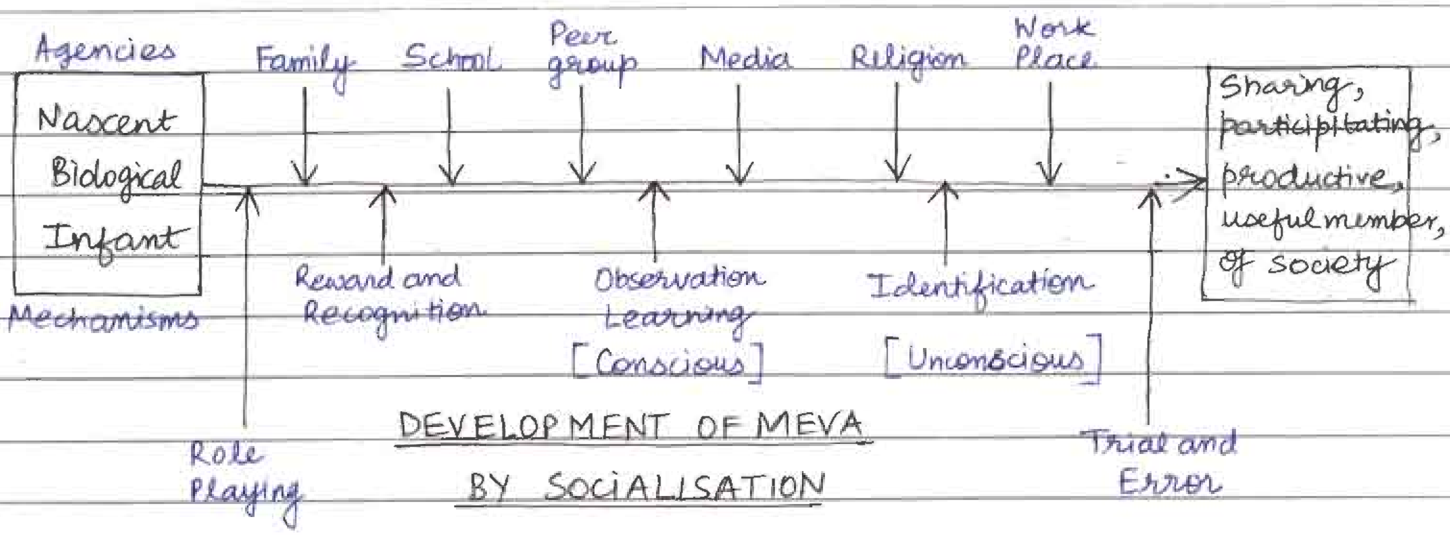
→ Socialization – It is a life long process of shaping an individuals' social tendencies so that he becomes and remains a useful and productive member of it's society.

OR

→ Socialization – is the process by which:

(a) Culture is transmitted from 1 generation to next.

(b) Individual develops his personality by learning the contents of it's culture. Personality is culture transmitted into an individual while culture is personality of individuals combined.



DEVELOPMENT OF MEVA BY SOCIALISATION

An individual guided by self preservation ~~guide~~ drive —Conversion by Socialisation→ A relatively selfless individual.

AIR-1 Notes
Pages: 304

Handwritten notes by

Kartikay Kaushik
AIR-1 ESE 2021
IES Master classroom Student

Engineering Mathematics (15M & 20+)

Syllabus

1. General Probability ✓ } (3M-4M)
2. Distribution Probability ✓ }
3. Linear Algebra ✓ (2M-3M)
4. Differential Calculus ✓ }
5. Integral Calculus ✓ } (5M-7M)
6. Vector Calculus ✓ }
7. Numerical Methods (0M-2M)
8. Complex Function Theory (1M-2M) Not in GATE
9. Differential Equations (2M-3M)
10. Laplace Transform, Fourier series (0M-1M)

CP
Revision TM
Practice

1. General Probability

→ **Permutation and Combination** (used for counting)

→ Principle of addition

	Methods	Ways
T (Task)	M_1	$\longrightarrow n_1$
	M_2	$\longrightarrow n_2$
	M_3	$\longrightarrow n_3$
	⋮	
	M_K	$\longrightarrow n_K$

Total number of ways $= n_1$ or n_2 or n_3 or ---- or n_K

$= n_1 + n_2 + n_3 + ---- + n_K$

→ 60T / 40T

→ ways to purchase 1 garment

$$TNW = {}^{60}C_1 + {}^{40}C_1 = 100$$

> NOTE:
> Add only after the task has been finished
> keep multiplying till the task is completed.

Task — Sub-Task

$$T \to \begin{cases} T_1 \to n_1 \\ T_2 \to n_2 \\ T_3 \to n_3 \\ \vdots \\ T_K \to n_K \end{cases}$$

Task will be completed when T_1, T_2, T_3 and T_K are completed.

$$TNW = n_1 \times n_2 \times n_3 \times \ldots \times n_K$$

→ <u>Linear Permutation without repitition</u>

Selection + Arrangement

${}^nP_r$ → arrangement of n distinct objects taking r at a time

or

Filling r places using n distinct objects.

_ _ _ .... _ (r places)

$$n \times (n-1) \times (n-2) \times \ldots [n-(r-1)] = \frac{n!}{(n-r)!}$$

$$^{n}P_{n} = n \times (n-1) \times (n-2) \times \cdots \times 2 \times 1$$
$$= n!$$

$$^{n}P_{1} = n$$

→ Permutation comprises of Selection and Arrangement

→ <u>Linear Permutation with repitition</u>

$^{n}P_{r}$ → repitition is allowed

$$\underline{\ \ }\ \underline{\ \ }\ \underline{\ \ }\ \underline{\ \ }\ \underline{\ \ } \cdots \underline{\ \ }\ (r\ \text{places})$$
$$n \times n \times n \times n \times n \ - \times n$$

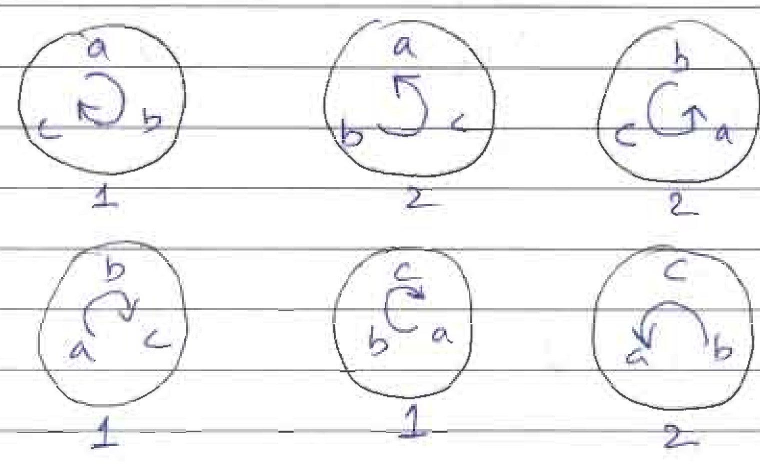
$$^{n}P_{r} = n^{r}$$
$$^{n}P_{n} = n^{n}$$

NOTE:

Number of arrangements that can be formed using n objects out of which p are identical q are identical r are identical and rest are different. $= \dfrac{n!}{p!\,q!\,r!}$

→ <u>Circular permutation</u>

a b c
a c b
b a c
b c a
c a b
c b a



$\dfrac{6}{3} = 2$

$$^nP_n = \begin{cases} \dfrac{n!}{n} = (n-1)! & \text{when clockwise and anti-clockwise distinction is made.} \\ \dfrac{(n-1)!}{2} & \text{when c.w. and a.c.w. are not distinct.} \end{cases}$$

$$^nP_r = \begin{cases} {}^nC_r \times (r-1)! & \text{when cw and acw are distinct} \\ {}^nC_r \times \dfrac{(r-1)!}{2} & \text{when cw and acw are not distinct.} \end{cases}$$

NOTE:
Hence, 1 circular arrangement corresponds to n unique row arrangements. If we are orranging n object at n circular places

→ Combination (Selection)

^nC_r → Selection of r objects out of n distinct objects.

$$^nP_r = \text{Selection \& Arrangement}$$
$$^nP_r = {}^nC_r \times r!$$

$$^nC_r = \frac{^nP_r}{r!}$$

$^nC_1 = n$

$^nC_n = 1$

$^nC_0 = 1$

NOTE:

If we are given n things for selection without given the condition, how many things we should select:
Then we can select none of them, 1 of them, 2 of them, ... all of them. In this case total number of selections $= {}^nC_0 + {}^nC_1 + {}^nC_2 + \ldots\ldots + {}^nC_n$
$= 2^n$

→ Selection of similar objects

$1\ 1\ 1\ 1 \rightarrow$ TNW to select $= 1+1+1+1+1 = 5$

none is selected.

$P \rightarrow$ TNW $= p+1$

$\underbrace{1\ 1\ 1}_{(3+1)}\ \underbrace{2\ 2\ 2\ 2}_{(4+1)} \rightarrow$ TNW $= 4\times5 = 20$

$\underbrace{1\ 1\ 1}_{(3+1)}\ \underbrace{2\ 2\ 2\ 2}_{(4+1)}\ \underset{2}{\overset{7}{\downarrow}}\ \underset{2}{\overset{3}{\downarrow}}\ \underset{2}{\overset{9}{\downarrow}} \rightarrow$ TNW $= 4\times5\times2\times2\times2$
$= 20\times2^3 = 160$

NOTE:

Total number of selection possible by taking some or all out of $p+q+r+\ldots$ things where p are alike 1 kind, q are alike 2^{nd} kind, r are alike 3^{rd} kind and so on
Then total no of possible selections $= (p+1)\times(q+1)\times(r+1)\times\ldots$

NOTE:
Total no. of selections possible by some or all out of $p+q+r+s+\ldots$ where p are alike 1 kind, q are alike 2^{nd} kind, r are alike 3^{rd} kind, ... and s are distinct objects.
Then TNW for selection $= (p+1)(q+1)(r+1)\, 2^{s}$

Q-

9 M
4 A
9 G

TNW given 1 guava has to be selected $= 10 \times 5 \times 9 = 450$

$\downarrow$ none of the guavas cannot be selected

→ Derangement principle

Derangements are arrangements of some number of objects into positions such that no object goes to it's specified position.

$$TNW = n!\left(\frac{1}{0!} - \frac{1}{1!} + \frac{1}{2!} - \frac{1}{3!} + \cdots - \frac{1}{n!}\right)$$

$$D_n = n!\left(\frac{1}{2!} - \frac{1}{3!} + \frac{1}{4!} - \frac{1}{5!} + \cdots - \frac{1}{n!}\right)$$

Deck of cards (52)

(Red) Diamond (13)	(Red) Heart (13)	(Black) Spade (13)	(Black) Club (13)

Diamond (13): K, Q, J / A, 2, 3, ⋮, 9, 10

→ DPP

Q-1

$\underline{9}\ \underline{10}\ \underline{10} = 900$

Q-2

$\underline{8}\ \underline{9}\ \underline{9}$ No 7 $\Rightarrow 900 - 8\times9\times9$

Q-3

$\underline{6}\ \underline{6}\ \underline{5}\ \underline{4}\ \underline{3}\ \underline{2}\ \underline{1}$ 0, 1, 2, 2, 3, 3, 4

$$TNW = \frac{6\times6\times5\times4\times3\times2\times1}{2!\times2!}$$

Q-4

$\underline{\ }\ \underline{9}\ \underline{4}$ $\underline{\ }\ \underline{\ }\ \underline{1}$

→ Even number ending with 0 → $\underline{8}\ \underline{9}\ \underline{1} \to 72$

→ Even no. ending without 0 i.e. 2, 4, 6, 8 → $\underline{8}\ \underline{8}\ \underline{4} \to 256$

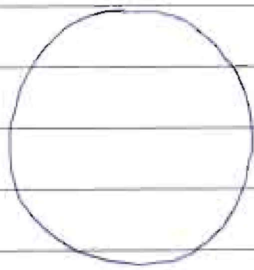
TNW = 256 + 72

classmate

Date

Page

Q-11 10 B, 5 G



first arrange boys → 9! ways.

then arrange girls → ${}^{10}C_5 \times 5!$

TNW = $9! \times {}^{10}C_5 \times 5!$

Q-12 ${}^{20}C_9 \times 8!$

Q-13 12 students → 4 students

(i) ${}^{12}C_4$

(ii) ${}^{10}C_2$

(iii) ${}^{10}C_4 + 2\,{}^{10}C_3$ or ${}^{12}C_4 - {}^{10}C_2$

(iv) ${}^{10}C_2 + {}^{10}C_4$

Q-14 $2^7 - 1$

General Probability
(Study of chances)

→ **Experiment**

An operation which has a well-defined outcome is termed as an experiment.

eg: flipping a coin, rolling dice are experiments.

→ **Random Experiment**

Iff all the outcomes of an experiment are known in advance and performance of any outcome is not known in advance that experiment is known as random experiment.

Random Experiment can be completed under similar conditions.

→ **Trial** –

Set of similar experiment conducted under same set of conditions for a random experiment and each experiment is known as trial.

eg: flipping 10 coins together is a random experiment which is comprised of 10 trials

→ **Outcome**

The result of a trial is known as outcome.

→ **Sample Space** (S)

Set of all possible outcomes of a random experiment is called sample space.

$$\boxed{\begin{matrix} HH, HT \\ TH, TT \end{matrix}}$$

$S \rightarrow$ universal set

$$S = \{HH, TT, HT, TH\}$$

$$n(S) = 4$$

$n(S_{1\,Dice}) = 6$

$n(S_{2D}) = 36$

$n(S_{nD}) = 6^n$

$n(S_{nD\,nCoin}) = 6^n \times 2^n$

→ Sample space plays same role like universal set.

→ Event (E)

Subset of sample space / favourable outcomes

E → Event of occurence of 2 heads after flipping three coins together

$S = \{HHH, HTH, HTT, THH, THT, TTT, HHT, TTH\}$

$n(S) = 8 = 2 \times 2 \times 2$

$n(E) = 3 = {}^3C_2 \times {}^1C_1 = 3$

→ $\phi \subseteq S$ → Impossible event

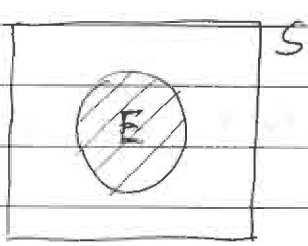
$n(\phi) = 0$

$P(\phi) = 0$

→ $S \subseteq S$ → Sure / certain event

$n(S) = n(S)$

$P(E) = \frac{n(S)}{n(S)} = 1$



$P(E) = \frac{n(E)}{n(S)}$

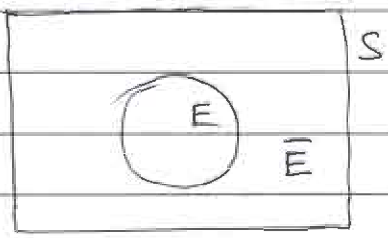
→ Definition of Probability

$$P(E) = \frac{n(E)}{n(S)}$$ where $n(S)$ is finite i.e. the outcomes are finite.

$$= \frac{\text{number of favourable outcomes}}{\text{number of all possible outcomes.}}$$

→ Probability Axioms

1. $P(E) \geq 0$
2. $P(S) = 1$
3. $P(E_1 \cup E_2 \cup E_2 \cup \dots \cup E_n) = P(E_1) + P(E_2) + \dots + P(E_n)$
iff $E_1, E_2, E_3, \dots, E_n$ are mutually exclusive.



$$\phi \subseteq E \subseteq S$$

$$n(\phi) \leq n(E) \leq n(S)$$

$$0 \leq \frac{n(E)}{n(S)} \leq 1$$

$$0 \leq P(E) \leq 1$$

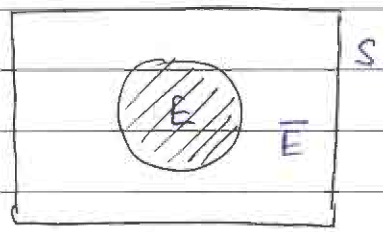
→ E → Event of occurence of E
$\bar{E}$ → Event of non-occurence of E } Complementary events.

$$n(E) + n(\bar{E}) = n(S)$$

$$\frac{n(E)}{n(S)} + \frac{n(\bar{E})}{n(S)} = 1$$

$$\boxed{P(\bar{E}) = 1 - P(E)}$$

→ Odd in favour



$$\text{Odds in favour} = \frac{n(E)}{n(\overline{E})} = \frac{P(E)}{P(\overline{E})} = \frac{P(E)}{1-P(E)}$$

→ $$\text{Odds against} = \frac{n(\overline{E})}{n(E)} = \frac{P(\overline{E})}{P(E)} = \frac{1-P(E)}{P(E)}$$

→ Mutually Exclusive Events

Two or more events are said to be mutually exclusive if one of them occurs, others cannot.

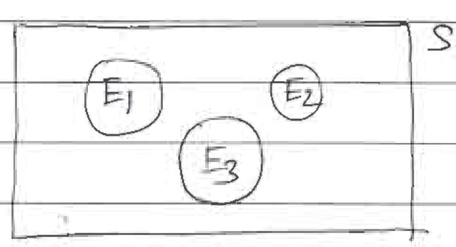
if E_1, E_2, E_3 are mutually exclusive events, then,

$E_1 \cap E_2 = \phi \Rightarrow P(E_1 \cap E_2) = 0$

$E_2 \cap E_3 = \phi \Rightarrow P(E_2 \cap E_3) = 0$

$E_1 \cap E_3 = \phi \Rightarrow P(E_3 \cap E_1) = 0$

and $E_1 \cap E_2 \cap E_3 = \phi \Rightarrow P(E_1 \cap E_2 \cap E_3) = 0$



→ Exhaustive events

Two or more events are said to be exhaustive if they include set of all possibilities

if E_1, E_2, E_3 are exhaustive events, then

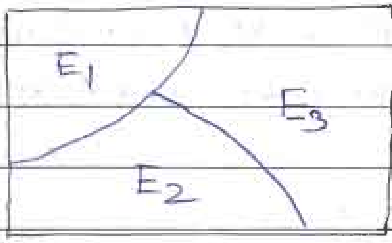
$E_1 \cup E_2 \cup E_3 = S \Rightarrow P(E_1 \cup E_2 \cup E_3) = 1$

→ Mutually exclusive and exhaustive events

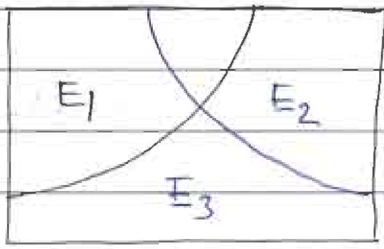
$P(E_1 \cap E_2 \cap E_3) = 0$

$P(E_1 \cup E_2 \cup E_3) = 1$

$P(E_1) + P(E_2) + P(E_3) = 1$



→ E_1, E_2, E_3 are mutually exclusive and exhaustive



→ E_1, E_2, E_3 are exhaustive but not mutually exclusive

$P(E_1) + P(E_2) + P(E_3) \neq 1$

→ Dependent and independent events

Two or more events are said to be independent events if occurence or non-occurence of 1 event does not effect the probability of occurence or non-occurence of 2nd event otherwise they are dependent events.

→ If A and B are 2 independent events: then:

- → $\bar{A}$ and B independent
- → $\bar{A}$ and $\bar{B}$ independent
- → A and $\bar{B}$ independent

→ If $P(A \cap B) = P(A) \cdot P(B)$ then A and B are independent.

NOTE:

Mutually exclusive events cannot be independent & independent events can't be mutually exclusive

→ Compound and conditional probability

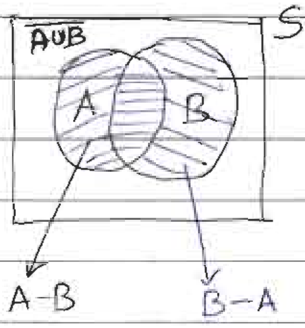
$A \cup B \rightarrow$ Event of occurence of A or B or both

$A \cap B \rightarrow$ Event of occurence of both A and B

(Simultaneous occurence of A and B)

(Exactly A) $A - B \rightarrow$ occurence of A but not B

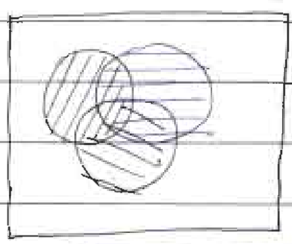
(Exactly B) $B - A \rightarrow$ occurence of B but not A



$$n(A \cup B) = \underbrace{n(A) - n(A \cap B)}_{n(A-B)} + \underbrace{n(B) - n(A \cap B)}_{n(B-A)} + n(A \cap B)$$

$$n(A \cup B) = n(A) + n(B) - n(A \cap B)$$

$$\boxed{P(A \cup B) = P(A) + P(B) - P(A \cap B)}$$



$$n(A \cup B \cup C) = n(A) + n(B) + n(C) - n(A \cap B) - n(B \cap C) - n(A \cap C) + n(A \cap B \cap C)$$

$$\Rightarrow \boxed{P(A \cup B \cup C) = P(A) + P(B) + P(C) - P(A \cap B) - P(B \cap C) - P(C \cap A) + P(A \cap B \cap C)}$$

* if A, B, C are mutually exclusive events.

$$P(A \cup B \cup C) = P(A) + P(B) + P(C)$$

$$P(A \cup B) = P(A) + P(B)$$

AIR-1 Notes
Pages: 82

Handwritten notes by

Kartikay Kaushik
AIR-1 ESE 2021
IES Master classroom Student

General Studies

Environment & Ecology

⇒ Basic terms related to Ecology, Environment and Energy

1) Species

2) Population

3) Factor

4) Environment and Atmosphere

5) Latitudinal division of earth

6) Community / Biocenosis

7) Ecosystem / Geo biocenosis

8) Ecology / oekologie

9) Autecology v/s synecology

10) Ecotone / principle of edges

11) Technoecosystem

12) Biosphere and Biosphere-2

13) Natural Capital / Ecosystem Services

14) Ecological Foot Print / E.F.P and Earth Overshoot Day

15) Bio capacity

16) C.C.S. / Carbon Capture and Storage
Carbon Sequestration

17) Concept of Carbons

18) Carbon Footprint

19) Carbon Hand print

20) Ecological Equivalent

21) Ecological Guild

22) Ecological Succession

Miscellaneous.

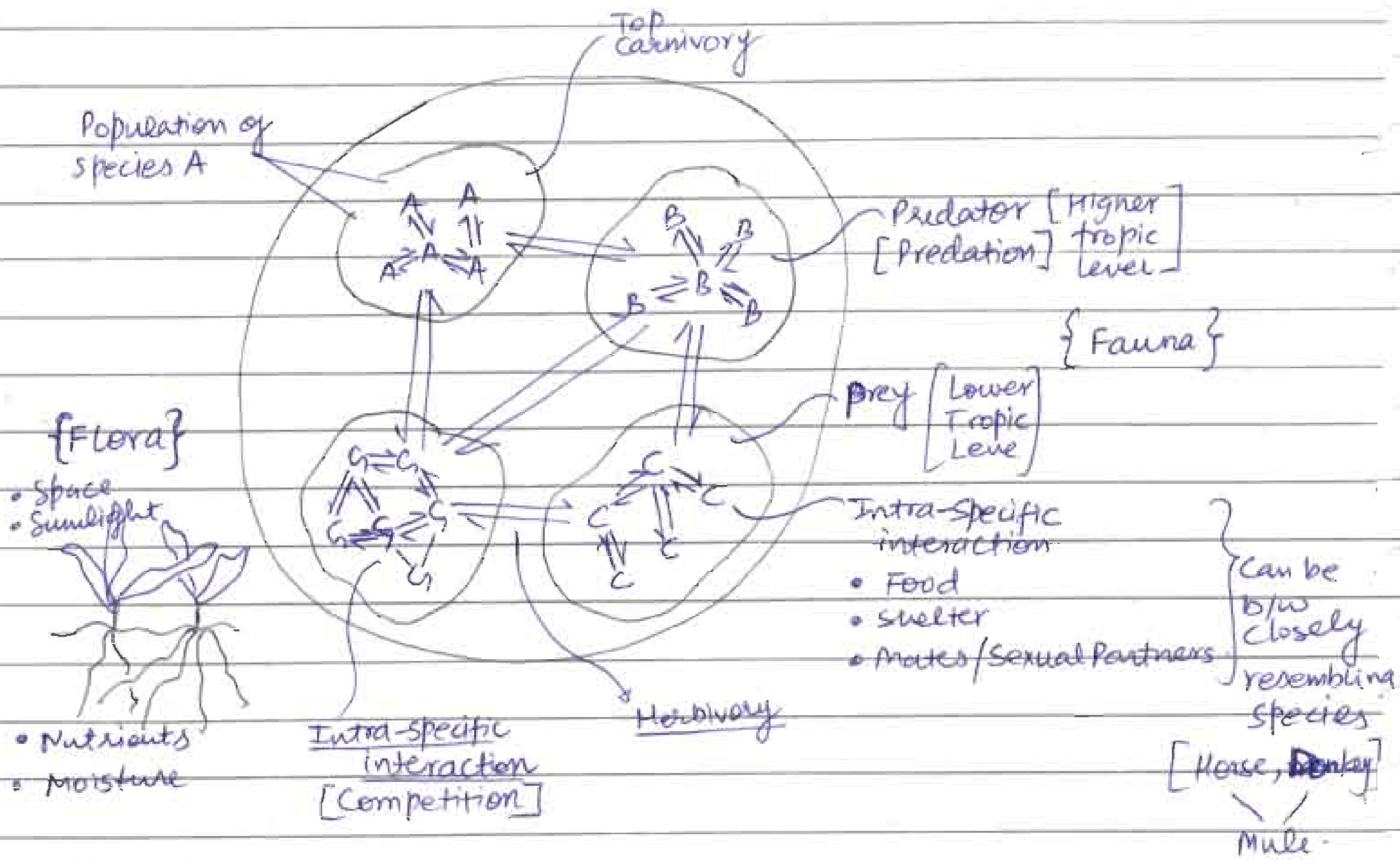
⇒ Species concept

1) There are different concept of species like morphological, genetic and biological.
2) Species is basic unit of Taxonomy that deals with nomenclature and classification.
3) In ecology and environment, biological species concept given by Mayr is widely used.
4) According to Mayr, when individuals can interbreed or reproduce and can form fertile offspring, then they belong to same species.
(ant. sterile)

M ♂ F ♀ Bi ⚥

NOTE : Linneaus → Father of Taxonomy gave morphological species concept which is on the basis of large similarity in external morphology (appearance) (Concept was rejected)

Lotsy → gave genetic species concept. According to which members of same species are genetically identical. In humans, only identical twins are genetically identical



⇒ Population

It is sum of all individuals that belongs to a given species present in a given area.

⇒ Community / Biocenosis

→ It is sum of all different populations present in a given area.

→ It includes population of all plants [Flora], animals [Fauna] and micro-organisms. ex- bacteria and fungi.

→ Community forms biotic component of the locality.

⇒ Factor

→ Factor is any force or substance or condition that affects individuals in any way

→ For ex- light, temperature, rainfall, chemical fertilizer, wind, competition, herbivory, carnivory.

NOTE: When interaction occurs among members of same species it is called as intra-specific interaction. ex- competition among members of same species.

→ When interaction occurs among members of different species it is called as inter-specific interaction ex- herbivory, carnivory and competition.

→ Bamboo is the longest grass and it is monocarpic as flowering occurs only once

→ when flowering occurs multiple times, it is called as polycarpic ex- mango tree.

⇒ Environment

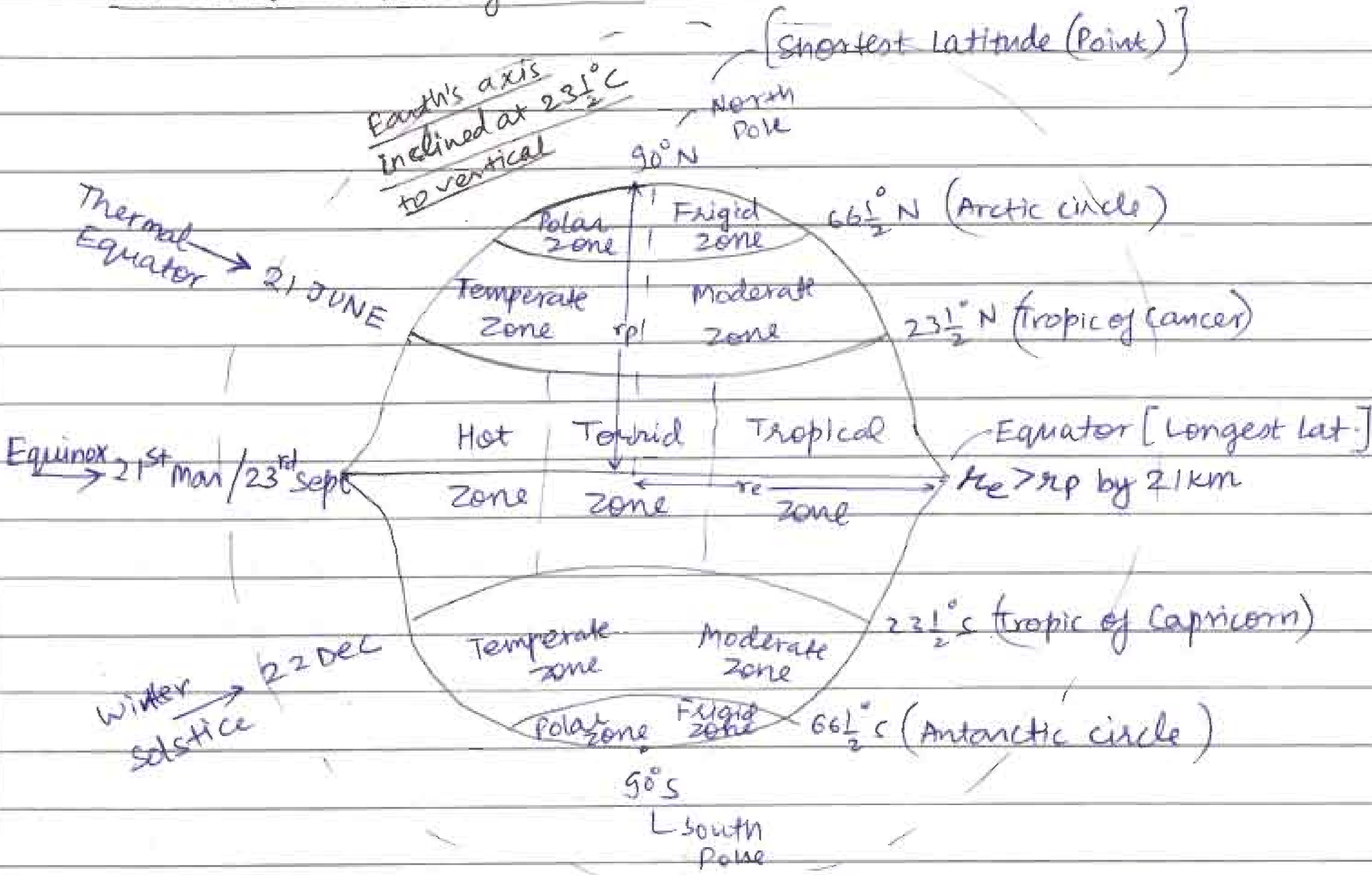
It is sum of all biotic and abiotic factors.

NOTE: 5th June is declared as world Environment Day due to Stockholm Conference or Stockholm Declaration (5th June 1972).

→ For 5th June, 2018, India was host country and theme was beat plastic pollution.

→ For 5th June, 2019 China was the host country and theme was air pollution.

⇒ Latitudinal Division of Earth



Shape of earth ⇒ Geoid [Oblate spheroid]

(Max at Poles)

↑ decreases ⇑ Increases

Productivity Stability Biodiversity Rainfall Temp Gravity

Tropical Zone

↓ decreases ⇓ Increases

(Max at Poles)

⇒ Atmosphere

- It is gaseous envelope surrounding earth surface which is endogenous in origin i.e. gases are released from interior of earth.
- Atmosphere is responsible for maintenance of low diurnal range of temperature i.e. habitable temperature

→ Atmosphere is held by means of force of gravity which is maximum at the surface of earth.

NOTE: The difference in temperature between day and night is called as diurnal range of temperature.
→ moon is devoid of atmosphere like that of mercury
(1/6th gravity) (Solar impact)

⇒ Ecosystem

→ British plant ecologist A.G. Tansley gave the term ecosystem.
→ According to Tansley, it is a system formed by Interaction b/w interacting biotic component with that of interacting abiotic component
→ Spatial dimension of ecosystem is highly variable. For ex - small drop of water having few bacteria upto the whole earth. When whole earth is taken as ecological model, it is the largest ecosystem called as ecosphere.
→ For natural ecosystems, sun is the main source of energy

⇒ Ecology

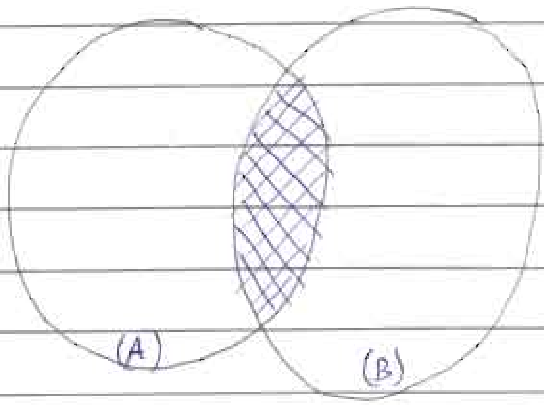
→ German scientist, Haeckal gave the term ecology. ~~it is the study of~~
→ Ecology is the study of structure and function of ecosystem.
→ While performing ecological studies, when focus is on single individual species, it is called as Autecology.
→ In Autecology focus is on single species about it's geographical location, taxonomic position (species) and functional role in ecosystem (producer, consumers)
it is called as Autecology.
→ While performing ecological studies, when the focus is on entire community or biotic component it is called as Synecology.

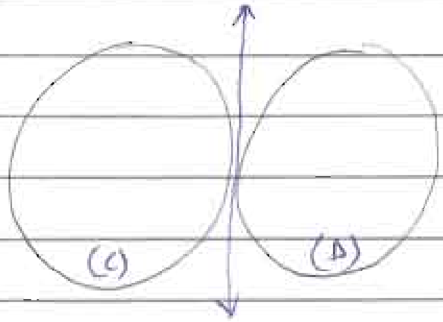
Homo sapiens.
$\underbrace{\text{Homo}}_{\text{Genus}}$ $\underbrace{\text{sapiens}}_{\text{species}}$

→ Synecology gives true picture of ecosystem

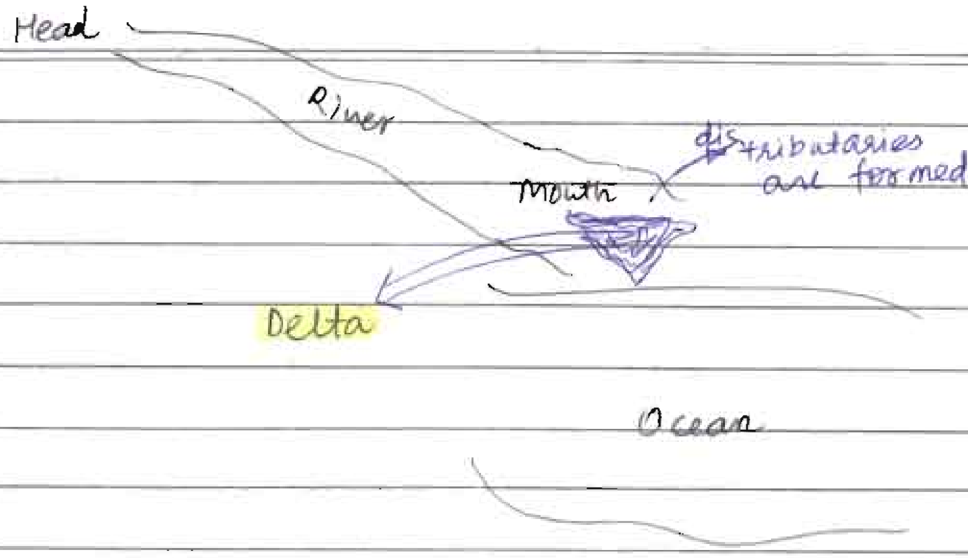
⇒ Ecotone / Principle of edges / Edge effect

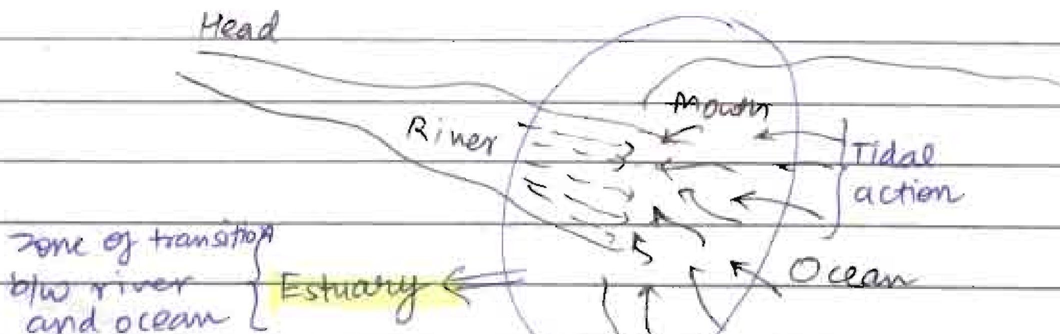
Q- Which of the following is not example of ecotone.
(A) swamps ✓
(B) Marshes ✓
(C) Bogs ✓
(D) wetlands ✓
(E) Estuary ✓
(F) Savanna ✓
(G) None.





→ Ecotone is zone of transition b/w 2 adjacent ecosystems.
→ As it is zone of transition, it has high value of species richness or variety component which is responsible for high value of biodiversity.
→ As the value of biodiversity is maximum at the edge or margin of adjacent ecosystem, it is called as edge effect or principle of edges.





When $\boxed{\text{F.W.I} = \text{Tidal action or currents}}$

→ Nutrient trap ⇒ rate of photosynthesis ⇑

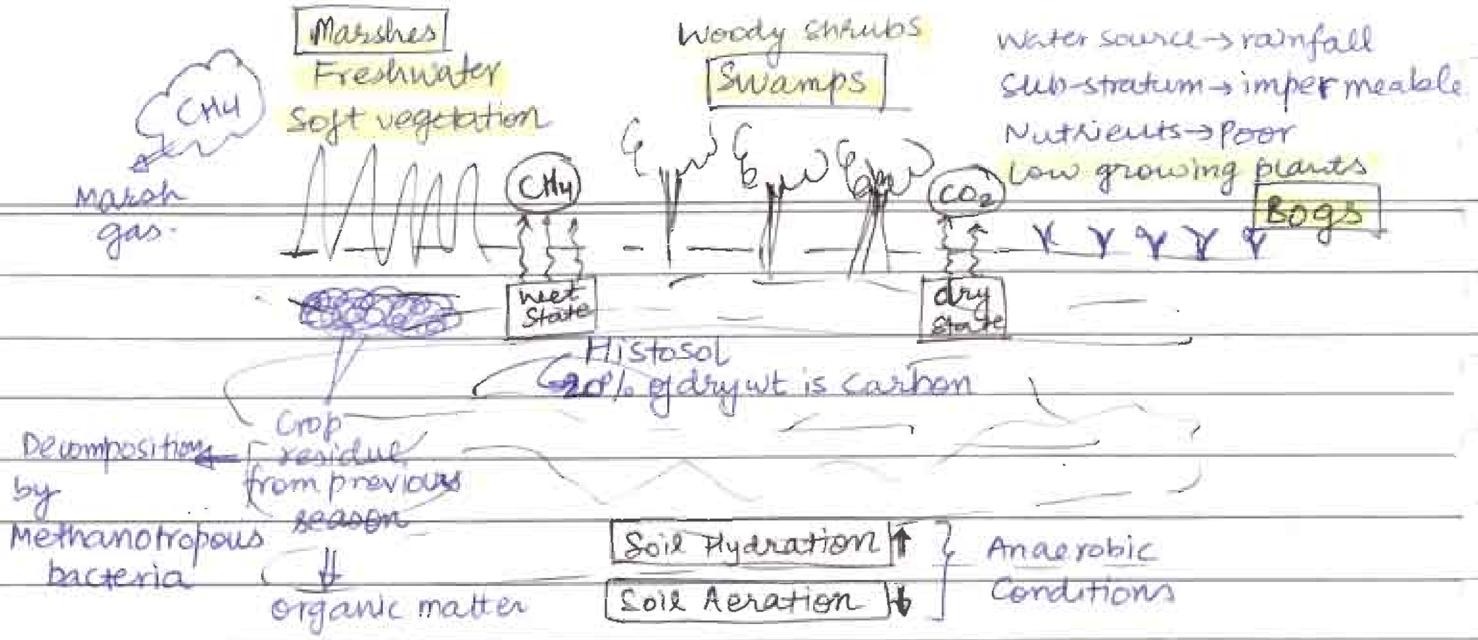
Savanna

Zone of transition

Grass ↑
→ Herb Savanna

Shrubs ↑
→ Shrub Savanna

Trees ↑
→ Tree Savanna



2nd Feb, 1971 ⇒ Ramsar Convention [Ramsar, Iran]

⇓ World Wetland Day

~~27~~ 42 Ramsar sites in India.

Montreaux Record ⇒ ecological threat
→ ~~Chilka Lake~~ — has been removed now as restored.
→ Loktak → Keibul Lamjao NP (Only Floating park)
→ Keoladeo N.P. (Rajasthan)

NOTE:

1) Wetlands are zone of transition b/w land and marine ecosystem.
2) When wetlands are dominated by soft vegetation ⇒ Marshes
eg - Paddy crop.
3) When wetlands are dominated by woody shrubs ⇒ Swamps
eg - Mangroves.
4) When substratum is hard / rocky / impervious, rain fall is main water source, nutrients are poor and low growing plants are found ⇒ Bogs eg - Spaghnum.

Q- List out whether the given statement is True / False

1) Montreax Record is register of wetlands which are under ecological Threat i.e. either ecological character has changed or changes are likely to occur (True)
2) Forest, grassland, savanna are example of carbon sink. (~~False~~ True)
3) In India, maximum wetland is under paddy cultivation around 70° / . (True)
4) Ramsar Convention is regarding wetlands and it was signed on 2nd Feb, 1971 at Ramsar, Iran (True)

5) India is signatory to Ramsar Convention. (True)

6) wetlands are kidney of nature involve in water purification ground water recharging, flood mitigation and nutrient recycling. (True)

7) In India, total 27 Ramsar sites are present in which recently identified is Sunderban. (True)

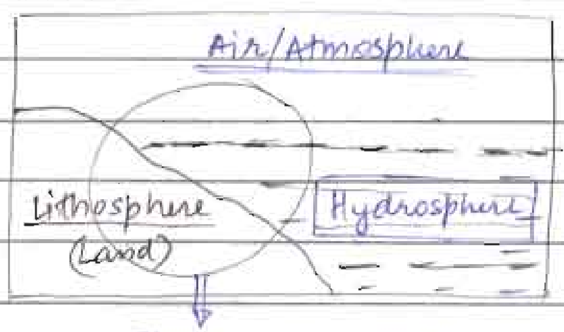
8) In India, 3 wetlands are mentioned under Montreax record (False)

9) Ramsar Convention is legally binding treaty and is part of UN Conventions like UN convention on Biodiversity. (False)

Biosphere and Biosphere-②

→ Biosphere is zone of transition b/w lithosphere, hydrosphere, atmosphere having biotic component

→ when in Biosphere, human is dominating biotic component it is called as Biosphere 2.



Biotic component → Biosphere

⇒ Ecological Equivalent

→ Individuals that occupy different geographical location, diff. taxonomic position, but they have same tropic level or ecological role or food habit or ecological function they are said to be ecological equivalent to each other.

→ eg - Buffalo of Haryana and Mithun of Arunachal Pradesh

eg - Cow of India and Kangaroo of Australia

eg - Doob grass of Delhi and Elephant grass of African Savanna

⇒ Ecological Guild

Ecological Guild is formed by group of individuals that belongs to different species but exploits same class of resources almost in similar manner. Thus membership in guild is on the basis of competition for same class of resources almost in similar manner.

Q- Which of the following forms ecological guild
(A) All nectar feeding insects of sunderbans
(B) All flowers in which anemophily occurs.
(C) Group of insects performing entomophily.
(D) Detrivores present at the floor of forest ecosystem.
Select the correct code:
1) A and B 2) B and C 3) A, B, C 4) A, B, C and D.

Agent →	Classification of Pollination
Wind	Anemophily
Water	Hydrophily
Insect	Entomophily
Ant	Myrmecology
Human/Elephant	Zoophily
Snails	Malacophily

⇒ Natural Capital / Ecosystem Services

→ All those services and benefits provided by nature or natural ecosystem or unmanaged ecosystem, free of cost is called as ecosystem services or natural capital.

→ As energy is currency of ecology, it is expressed in unit of energy.

Q- Which of the following is not an example of natural capital or ecosystem services

1) Pollination of crops by wind, water and insects.
2) Purification of air through rainfall
3) Olericulture, cultivation of vegetables
4) Artificial rainfall /Project / Cloud seeding.

Select the correct code:

(A) 1 and 2 (B) 2 and 3 ✓(C) 3 and 4 (D) 1, 2, 3 and 4

Technoecosystem → Naveh gave the concept of technoecosystem
→ which is technologically advanced ecosystem that behaves as energetic island as consumption of fossil fuels like coal and petroleum is very high that causes high level of environmental degradation
→ As in this system, there is high level of green house gas emmission emission of ODS (Ozone Destroying substances) and various other pollutants, it behaves like parasite on natural surrounding.

Ecological Foot Print (E.F.P.)
→ Concept was given by Rees and wackernagel
→ The used the phrase "small is beautiful"
→ EFP is defined as area present outside any given technoecosystem i.e. required to support life activities by fulfilling the demand i.e. demand of fresh water, food, air and also to absorb, recycle and regenrate resources.
→ The value of EFP depends upon:
(a) Demand of Technoecosystem ($EFP \propto Demand$)
(b) Biocapacity of surrounding area ($EFP \propto \frac{1}{Biocapacity}$)

NOTE:

1) Resource regenerating capacity of a given area or ecosystem is called as it's Biocapacity.
2) Biocapacity also takes into account capacity of ecosystem to absorb waste, regenerate resources and thus different assets of ecosystem that maintains it's biocapacity are forests, lakes rivers and wetlands

Q. Fill in the blanks, with the help of given table:

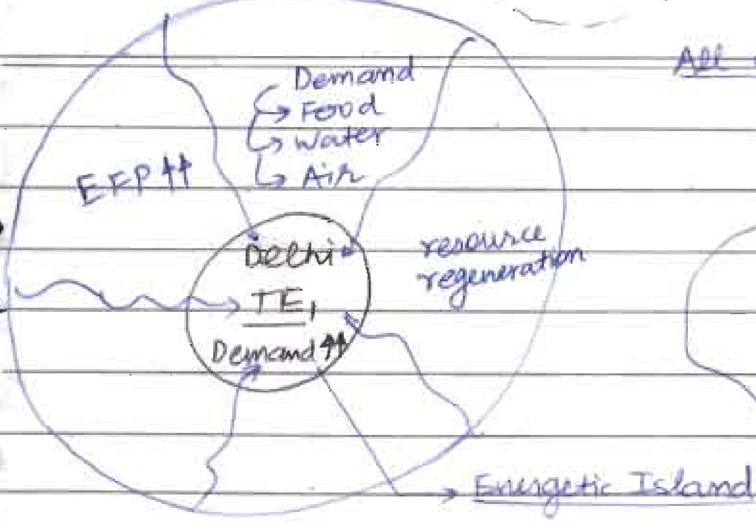
Techno ecosystem	Ecological Foot Print per capita
A	0.75 ha/ per person
B	1.50 "
C	2.99 "
D	4.75 "
E	5.50 "

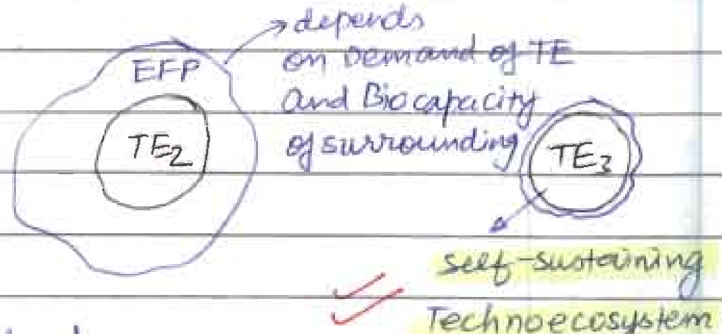
1) ___A___ is most stable. A
2) In ___E___ environmental degradation is very high E
3) ___A___ is least parasitic on natural surrounding A
4) ___E___ is least sustainable. E
5) ___E___ is stronger or intense energetic island. E
6) Impact of pollution is maximum in ___E___ E
7) ___A___ has maximum biocapacity. A

NOTE:

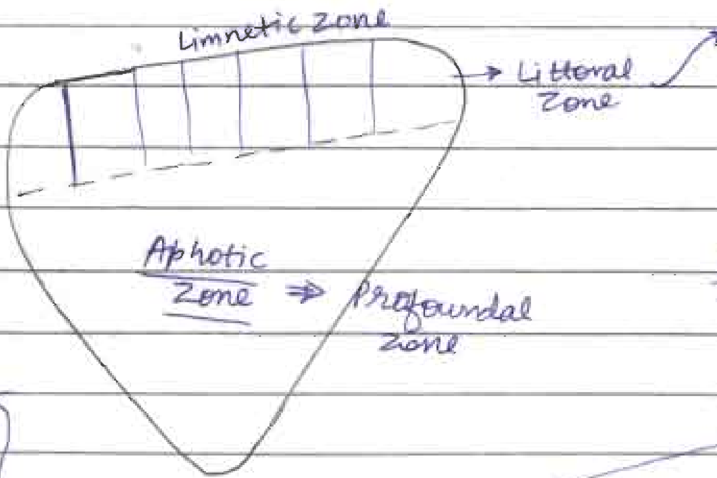
1st August 2019 is observed as Earth overshoot day as resources allocated for their 2019 got consumed by 1st Aug. Thus remaining months are parasitic on ecosphere and conditions are ecologically not stable.

All are Islands





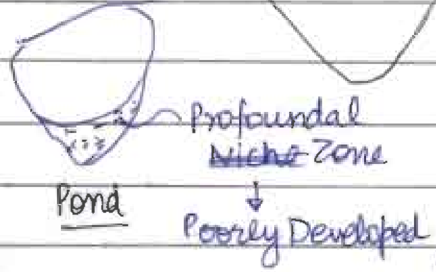
⇒ Ecological Niche → Grinnel



1) Habitat / Spatial Niche [Microhabitat]

2) Trophic niche / Functional Zone
Autotrophs (Producers) v/s Consumers

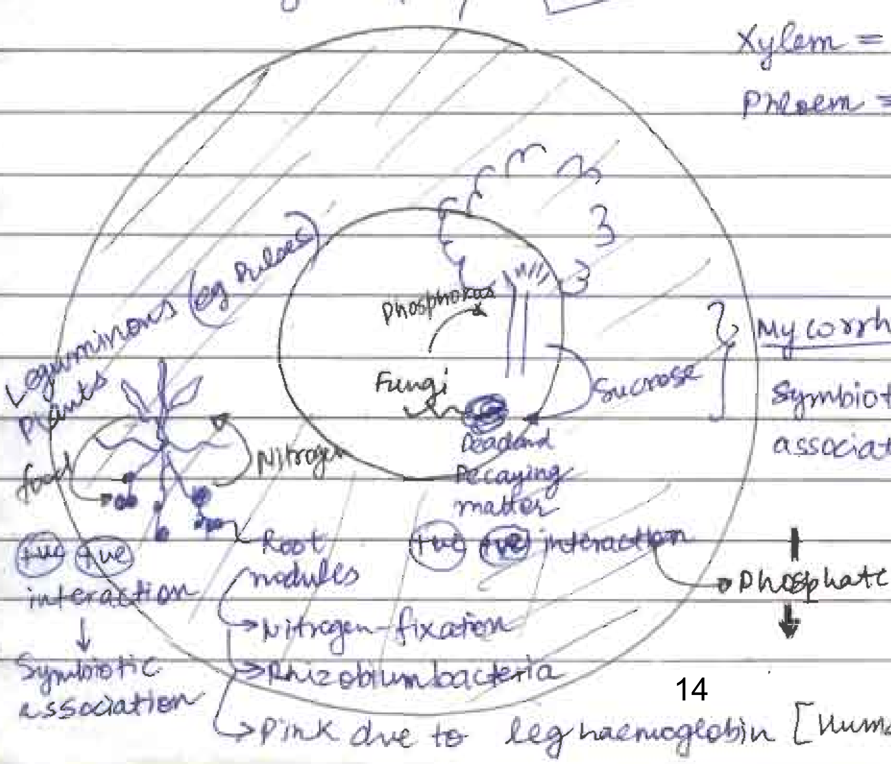
3) Multifactor Niche [Fundamental Niche] → Hutchinson



$\boxed{\text{realised Niche} > \text{Fundamental Niche}}$

Xylem = Water + Nutrients → Ascent of Sap

Phloem = Translocation of food ≡ Sucrose



In humans
DNA, RNA
ATP

→ all contain phosphate.

AIR-1 Notes

Pages: 80

Handwritten notes by

Kartikay Kaushik

AIR-1 ESE 2021

IES Master classroom Student

ICT
(Information, Communication & Technology)

→ ICT is the convergence of telecommunication tools on a single link system which is controlled by computer systems. It acts as a unified communication tool which helps to integrate following:

1) Telecommunication tools and telephone lines.
2) Wireless communication tools and mobile phones.
3) Computers and computer networks
4) Enterprise softwares
5) Middlewares [Help to increase user accessibility]
6) Storage devices.
7) Audio Video signals etc.

⇒ Middleware – They act as a software glue. It helps to provide additional applications to a software and a program according to user accessibility they can be an extension to Operating System, Applications or softwares

Types of Middlewares:

① Enterprise Application Integration – It helps to integrate distributed applications of enterprise programs and softwares.
eg – Supply Chain Management Middleware, Human Resource management middleware etc.

② Data Integration Middleware (DIM) – It helps to synchronise distributed data to provide a unified view.
eg – Bio Informatics, Big Data.

③ Message Oriented Middleware – These are used as a software or hardware which helps in sending and receiving messages over a distributed system

④ Enterprise Service Bus (ESB) – It acts as a communication system b/w mutually interacting softwares.

⇒ Unified Communication

→ It acts as integration of many communication tools which helps to optimize processes and increase communication efficiency.

→ Unified communication helps to unify human and device communication in a common context and experience. It has following tools:

① Instant Messaging
② Mobile Communications
③ Location features and presence information
④ Audio, video and web conferencing
⑤ Desktop and data sharing.
⑥ Unified Call control.

⇒ Advantages of ICT

① It helps in electronic distribution of information
② It helps in electronic data storage.
③ It helps in abolishing language and cultural barriers
④ It reduces response time in communication.
⑤ It increases communication reliability and reduces communication gaps and glitches.
⑥ It helps to increase social participation, reduces barriers between governments and citizens
⑦ It helps to transform society into knowledge society
⑧ It helps in inclusive growth and increases human development
⑨ It helps in resource management, mobilization and sustainability

Hence it is one of the powerful tool for sustainable development.

⇒ Disadvantages of ICT

① Unemployment - ICT leads to loss of employment for core, unskilled and unorganised sectors whereas it can also increase skill development which may improve the quality of jobs.

② Overuse of ICT would lead to loss of Emotional Quotient of citizen service delivery where the emotional values of front end human customer service would be lost.

③ ICT may lead to loss of personal privacy, data privacy and social equilibrium.

④ Overuse of Social media tools may also lead to Social polarization which can disbalance the knowledge society.

⑤ ICT can also lead to loss of social, data and device security.

⇒ Roles of ICT

⇒ Role of ICT in Internal Administration

It helps in following:

① Centralized storage of files and data.
② Reduced delay in file processing
③ Efficient communication and transparent platforms of communication between all the stakeholders.
④ It makes administration paperless.
⑤ It helps in skill improvement of employees.
⑥ It helps in development of electronic administration.

PRAGATI → PRO-Active Governance and Timely Implementation.

Tools used in Internal Administration are,

① Componentware: It helps to unify computers and different physical equipments used in file processing and communication.

② Groupware: It helps to integrate different works of a project together on a single point

③ Wireless devices likes phones and wireless networks.

④ Unified messaging: It integrates messaging, mail and fax services together.

⑤ File tracking module: It acts as a software system to provide file tracking tokens and logins

⑥ Intranet - It acts as an internal communication network of any organization. It acts as a wide Area Network which can have search engines, profiles, blogs etc.

⑦ Video conferencing - It is a real-time audio video signal transmission tool which helps in peer to peer communication using a public network, a lease line, a wireless network or a private network.

Ex- PRAGATI - Initiated in 2015 as an internal administration tool. It is headed by the PM and uses ~~Geo~~ video conferences, digital data management and Geospatial technology in management of hurdles related to policy implementation.

→ It connects PM to Union secretaries and chief secretaries of states to discuss problems in governance and implementation.

→ It is an example of cooperative federalism.

→ Every month 4th Wednesday is celebrated as PRAGATI day in internal administration.

→ Issues to be discussed on PRAGATI day are flagged on every 3rd Wednesday and are to be answered in 2 working days after the PRAGATI day.

→ Role of ICT in planning and Management

→ ICT in planning and management can utilize following tools

① Trasaction Processing systems - It helps to create indivisable units of work, hence it is used to divide and distribute works to lower level employees, clerks etc. It is a hardware and a software combination. which is used in batch processing or real time.

② Management Information System - It is useful for control analysis and visualisation of information required for coordination, management and planning. It is utilized by middle level officers ~~of~~ or managers in an organization. Types of MIS are:

(a) Human Resource MIS - For jobs and employment management

(b) Accounting MIS - For bills and wages

(c) Decision support systems - For planning and making decisions by senior managers.

(d) Executive Information system (EIS) - Helps in decision making of executives and highest officials.

→ Advantages of MIS

① Paperless administration

② Increased productivity and efficiency

③ Integration of distributed systems.

④ Centralization

⑤ Electronic records and feed backs.

→ GIS / Geographic Information System

→ It helps to provide geo spatial information about any area which can be utilized, edited, mobilized and used in planning and management

→ GIS act as a large scale imaging tool which consists of 3 components

① Imaging component which help in local, regional and satellite imaging

② Software component helps in integration of images collaterally.

③ Observation stations - These are ground based stations which help to validate geospatial information.

Uses of GIS

(a) Provides geospatial data for internal administration and planning

(b) Used in remote sensing search and rescue

(c) It is used in agricultural irrigation planning.

(d) It is used in validation of land and revenue records.

(e) It is useful in natural resource management

(f) Useful in wildlife and forest management.

(g) Quantification of MNREGA works and it's wage distribution.

Q. Which of the above are applications of ICT in administration.

① It helps to create inter-departmental coordination, hence reduce delay due to interdepartmental barriers.

② It helps to establish centralized governance

③ ICT in administration helps to increase public participation which also helps in new public management.

④ ICT in administration helps in improvement of delivery of citizen services and large scale analysis of citizen service requirements.

(a) Only ① and ③ (b) ① ③ and ④ (c) ① ② and ④ (d) All of the above.

Q- Which of the following can be applications of ICT:
① In management of wages and payments for Dept of Personnel and Training (AccountingMIS)
② Development of watershed management plan by central Water commission. (GIS)
③ Management of rural Infrastructural project by State PWD
④ Management of Tiger conservation by NTCA (National Tiger Conservation Authority) (Forest MIS)

(a) Only ① and ② (b) Only ② and ③ (c) ①, ② and ④ (d) All of these ✓

⇒ E-governance

→ It is development of electronic citizen service delivery where government, it's stakeholders, administration and citizens can be synchronised to singular participation ~~over~~ mediated by ICT tools.

APJ Abdul Kalam → E-governance is inter-departmental participation through computer mediated tools, telephone lines, communication medium, which helps to reduce hurdles and increase efficiency of government policy implementation.

→ Stages of e-governance

① Emerging presence - It is meant by computerization and computer data generation.
② Enhanced presence - It is meant by electronic data generation and development of web resources for citizen information and services.
③ Transactional Presence - It is development of ICT network to initiate government citizen transactions.
④ Network Presence - It is development of large scale public policies over ICT tools to generate networked benefits
⑤ Transformational Presence - It is large scale transformation mediated by ICT based service delivery. It can relate to infrastructural development, improvement in service delivery and a large scale social Transformation.

Models of e-governance

① G2C – Government to Citizen

It refers to benefits provided by governments to citizens through ICT. It involves following:

① e-registration – to register for government policy and benefits. eg- Online examination forms etc.

② e-citizenship – to get citizenship related documents online. eg- AADHAR, PAN Card, Voter's ID, Passports etc.

③ e-transport – to achieve transport benefits. eg- e-tickets, online driver's license, RTO registration.

④ e-education – to provide education tools electronically. eg- e-Basta

⑤ e-Health – for patient registries, online appointment etc.

⑥ e-Help – to provide search, rescue, preparedness etc during the state of disaster.

⑦ e-Taxation – for online income Tax submission.

② G2G – Government to Government Initiatives

① e-Administration – for improvement of Internal administration. eg- Bhumi Project for Land Revenue in Rajasthan, e-chaupal initiatives, Lok-Mitra initiatives for grievance redressal etc.

② e-Courts – for web-based judicial documents.

③ e-Police – for online police records, inter-state police coordination, centralized Criminal Tracking and System (CCT&S)

③ C2G – Citizen to Government Initiatives

① e-Democracy – to participate in democratic practices.

② e-Feedback – To provide public policy feedback.

④ G2B – Government to Business Initiatives

① e-Taxation – for corporate tax, GST, Sales Tax

② - e-Tenders
③ e-Licensing

⇒ Advantages of e-governance

① It makes the government a SMART government which is Simple, Moral, Accountable, Responsive and Transparent.
② It reduces response time and increases efficiency and grievance redressal.
③ It reduces Red-Tappism of bureaucracy
④ It increases citizen-centric policy making
⑤ It establishes new public management
⑥ It utilises participatory goremance or P_4 governance (People-Public-Private-Partnership).

⇒ Disadvantages of e-governance

① Low Emotional Quotient (EQ).
② Privacy and security.
③ Overdependency may lead to chaos during failures due to glitches.

⇒ ICT in Education
It is helpful in qualitative and quantitative improvement of education.
It helps in following:

① Management of Education system and Syllabus.
② Training and skill improvement of teachers.
③ Remote access to education.
④ To reduce effort and cost spent in education.
⑤ To reduce language barriers of education.
⑥ Helps to increase learner's interaction and motivation.
⑦ Helps to link academic institutes together and develop a knowledge network

(8) It helps to reduce, physical, regional and cultural barriers to attain education.

(9) It increases flexibility of the learner and the educator.

(10) It can bring self paced learning tools

(11) It helps to promote technology based learning and increases involvement of engaging tools in education.

⇒ Tools used in education

(1) Smart books – They are web-based repositories of books or content sources which can be distributed easily.

(2) Smart diaries – It is a web based resource which can help to store notes, notices and notifications. required for education. It helps to connect educator, learner and parent together in education assessment.

(3) Smart Boards – It is a LED or OLED ~~monitor~~ monitor which can be connected to internet and used to display pictures, write, edit and provide print commands.

(4) OCR (Optical Character Recognition) – It is a scanner based tool which can convert offline data or content into editable electronic data. It is used to achieve editable soft copies of books and education resources.

(5) Speech Recognition – It is a real time transliteration and translation tool, which helps in translation of 1 language to another based on an electronic database. It has 3 components:

(a) Input audio device or mike

(b) Output audio device or speakers

(c) Universal software for translation.

Uses of speech Recognition

① Development of Indic language tools for education.

② Used in kisan Call centres to provide technical help in local languages.

③ Used to reduce cultural and language barriers in international diplomacy

eg- SARTHAK by Ministry of Agriculture

*

⑥ 3-D displays - It is a projection tool to provide depth perception in imaging. It places barriers b/w image source and observer such that light reaches to one eye of observer prior to other which formes ~~a~~ 2-resolved images with a depth perception

Uses of 3D displays

① In display of education models and interactive learning.

② Gaming, animation

③ Geomorphological and Geological exploration.

④ Marketing and advertisement.

⑤ Town and country planning etc.

⑦ Virtual Reality - It is an integration tool of display and observer such that light reaches from ~~ob~~ display to observer in it's complete angle of sight which creates perception of one-ness. hence, observer realises itself to be integral part of virtual surrounding.

Uses of VR

① Display of education models and increased classroom interaction

② Animation, Gaming.

③ Search and Rescue and disaster planning.

④ Urban Planning and management.

Page No.

⑧ Augmented Reality: It integrates VR and physical world objects together such that observer and physical objects have a closed interaction and observer finds the object to be extension of virtual surrounding.

⑨ Uses of AR

① Education Models
② Planning
③ Mining
④ Animation.

eg- SAAKAR - It is an AR tool of ISRO which is used for space ~~educa~~ exploration education to school students of class 9th to 12th.

⑨ Merged Reality - It is an integration of Augmented Reality such that the physical objects can control Virtual Reality surrounding.

Uses of MR

① Animation- ~~Project Alloy~~
② Project Alloy Developed by IBM in 2016. It is an headset which can control VR functions.

→ ICT and Distance Education - ① Internet Forums

They are web based platforms which help to develop electronic info to aid education. It can operate as a blog, or microblogging platform to share educational content and to discuss hurdles in education.

② MOOC (Massive Open Online Courses)

They act as an open source platform that can help to host large scale multimedia, audio and video formats related to educational content delivery - eg - NPTEL (National Programme on Technology Enabled Learning).

I) NPTEL - It is an initiative of MHRD. It was started in 2003 by IISc Bangalore and 7 major IITs. It is divided into 2 phases:

(a) Phase I (2003-2008) where it hosted 235 courses of engineering discipline through audio-video lectures.

(b) Phase II (2008-2014) where it hosted 600 courses of engineering and fundamental science discipines

II) Swayam - MOOC - It is an initiative of MHRD. It is developed for providing school education to remote inaccessible students and elderlies. Initially it provided education from class 9th to Post graduation through video lectures, self assessment tools and online content

→ It is also supported by AICTE (All India Council for Technical Education)

③ VSAT (very Small Aperture Techuology / terminals)

→ It is a peer to peer communication tool which is developed through a small satellite operatable at a narrow radio bandwidth)

→ It helps to communicate b/w classroom relay centres and remote reception centres.

→ It heeps in distance education and providing quality teaching to remote inaccessible ares.

⇒ Other tools in Distance Education.

① Data Storage tools like CD, DVD, BluRay and Holostore.

② Cloud Computing

③ Public and Private Networks.

(4) USB and other solid state storage devices.
(5) Video conferencing.

⇒ Learning Management System (LMS)

(1) It is a tool which helps to develop Management Information Systems (MIS) and other Integrated systems for improvement of education, administration, quality and delivery.

(2) It is useful in:
(a) Improvement in administration
(b) Develop learning, research and development programs
(c) Organise training programs.
(d) Documentation, tracking and reporting errors during education delivery and reception.
(e) Development and management of curriculum and syllabus.
(f) Online delivery of education and its processes.

(3) eg – School Management Systems, College Management System, University Integration Systems etc.

⇒ Knowledge Networks

→ They help to create inter-communicated channels or open source platforms to share educational content and information.
→ It helps in improving content distribution and Intellectual Property Right (IPR) Reservation of important researches
eg –

(1) National Knowledge Network (NKN)
→ It is a multi-Gigabit interconnectivity program of the important educational research Institutions of India
→ The core network operates at 10 Gb/s connectivity and provides services at 1 Gb/s connectivity on end nodes.
→ It helps to share important educational content and research

AIR-1 Notes

Pages: 147

Handwritten notes by

Kartikay Kaushik

AIR-1 ESE 2021

IES Master classroom Student

Material Science

→ It is a branch of science which deals with the investigation of relationship that exist between structure and property.

Structure → Properties.

→ Property - It is a characteristic of a material which can be measured.
  → Property can be observed by applying external stimulus and hence a response can be measured.
  → Stimulus can be electrical, magnetic, optical, mechanical force etc.

→ Following are the different types of structure:

1) Macrostructure - External shape and forms such as shape and size by naked eye.

Mechanical POV

2) Microstructure - In it we study shape and size of grains by optical microscope

3) Sub-structure - In it we study defects in the grains by ~~magnif~~ scanning electron microscope.

4) Crystal structure - In it we study arrangement of atoms by X-Ray Diffraction technique.

Electronics and Electrical POV.

5) Electronic structure - In it we study electrons distribution around an atom by Electron spectroscopy.

6) Nuclear structure - In it we study about the nucleus by nuclear magnetic Resonance or Moss-Bauer Spectroscopy

→ Following are the important engineering materials:

1) Metals and Alloys - Aluminium, Iron, Copper, Magnesium, Zinc, Titanium, Nickel, Tin and Lead.

2) Polymers
   (a) Thermoplastic polymers.
   (b) Thermo-setting plastic polymers

3) Composite

4) Ceramics - Oxides, carbides, Nitrites, glasses etc.
~~Depending upon the atomic arrange~~

→ Depending upon the atomic arrangement of the above materials are classified into 2 groups.

Crystalline	Non-crystalline / Amorphous
1) Atoms are regularly arranged over large atomic distances.	1) Atoms are irregularly or randomly arranged.
2) Long range order exist.	2) No long range order exist.
3) Since Bond length is same everywhere, hence sharp melting point exists.	3) No sharp melting point exists.
4) Mechanical property depends on no. of atoms on a given line hence crystalline materials are anisotropic in nature	4) Since no of atoms on each and every line is same, hence property is isotropic in nature.
5) It is true solid having fixed external shape and size.	5) It is called super cooled liquids which doesn't have fixed shape and size.
eg- All metals, many ceramics and some polymers. (Crystalline materials are hard and brittle)	eg- charcoal, glass, many polymers and some ceramics

⇒ Crystal Structure

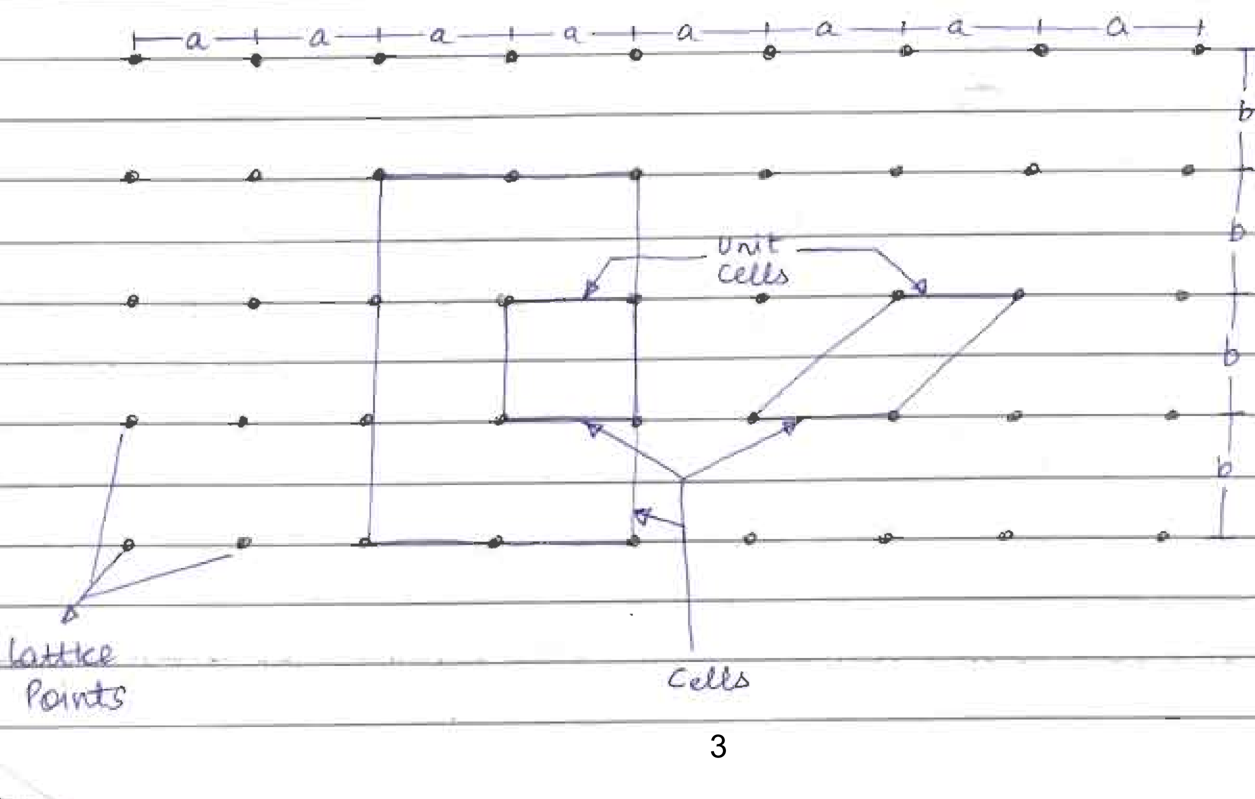
In it we study arrangement of atoms and the science involved is called crystallography.

→ In this we assume atoms to be having some well defined diameter i.e. It is assumed to be sphere. This model is called Hard Sphere Model

→ Assumptions of Hard Sphere Model

1) Cation is always smaller than its respective anion.
2) Cations and Anions always are in contact with each other.
3) Since cation has higher charge Density (charge per unit Surface area) hence it is always surrounded by maximum no. of anions as permitted by geometry.

→ Space Lattice - It is an infinite array of points arranged in 3-dimensional space which is periodically repeated and has identical surroundings.

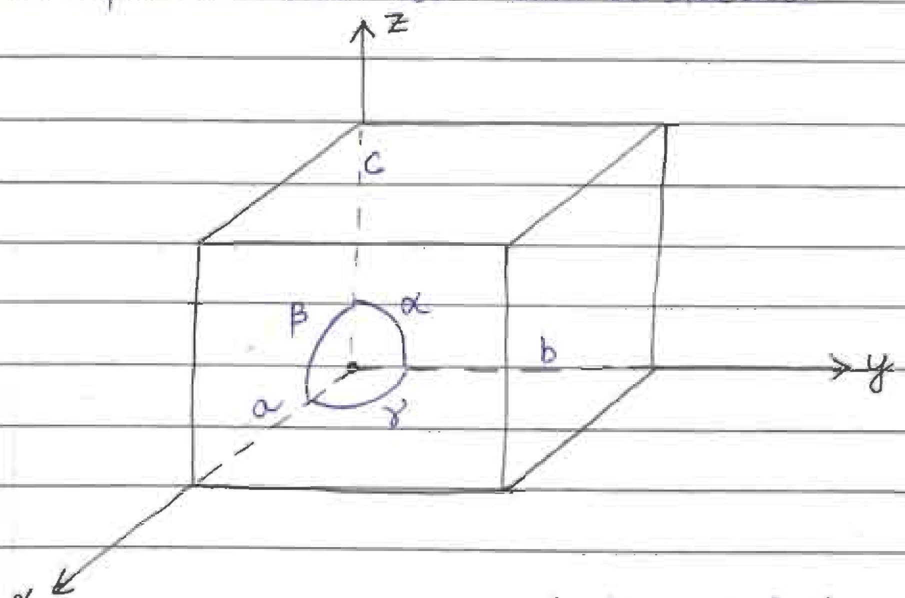


→ These space Lattice are periodically repeating in three directions (x, y, z) and the periodic distance along those directions are called Lattice Parameter (a, b, c).

→ With the help of these 3 Lattice parameter, we can create a volume which is called cell.

→ A cell can be said to be unit cell if it has smallest size, maximum symmetry and if it is repeated in space lattice then it can cover entire space lattice.

→ There can be ∞ number of unit cell possible and out of them some important unit cells will be studied.



6 Lattice Parameters → Angles → α, β, γ
→ length → a, b, c

→ With the help of 6 Lattice Parameters there are large no. of unit cell possible but we have to study only those unit cells which have smallest size and maximum possible symmetry and Bravais found out that there are only such 14 unit cell available which is called crystal class and they can be grouped into 7 crystal systems.

⇒ Following are the 7 crystal systems:

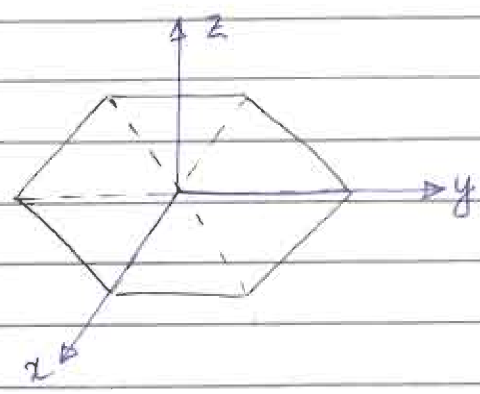
1) Cubic Crystal → $a = b = c$, $\alpha = \beta = \gamma = 90^\circ$

2) Rhombohedral → $a = b = c$, $\alpha = \beta = \gamma \neq 90^\circ$
(Cube + Shear on all faces)

3) Tetragonal → $a = b \neq c$, $\alpha = \beta = \gamma = 90^\circ$
(Duster)

4) Orthorhombic → $a \neq b \neq c$, $\alpha = \beta = \gamma = 90^\circ$
(CPU)

5) Hexagonal → $a = b \neq c$, $\alpha = \beta = 90^\circ$ and $\gamma = 120^\circ$

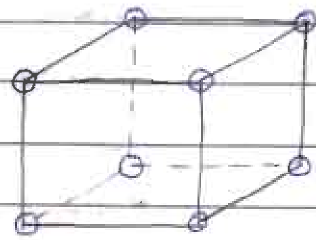


6) Triclinic → $a \neq b \neq c$, $\alpha \neq \beta \neq \gamma$
(Highly unsymmetrical)

7) Monoclinic → $a \neq b \neq c$, $\alpha = \gamma = 90^\circ \neq \beta$.

⇒ Cubic crystal system

1) Simple Cubic crystal



→ No. of Lattice Points = 8

→ Contribution of each corner atom $= \frac{1}{8}$

→ Atoms per unit cell $= 8 \times \frac{1}{8} = 1$

→ Geometrical relationship $\boxed{a = 2r}$

a → Lattice Parameter; r → Radius of atom.

→ Coordination Number → No. of nearest neighbour atoms.

$\boxed{CN = 6}$ (2×3) ↳ No. of axes.

→ Atomic packing factor / efficiency → It represents the fraction of volume of unit cell that is filled by atoms and is given by a ratio as:

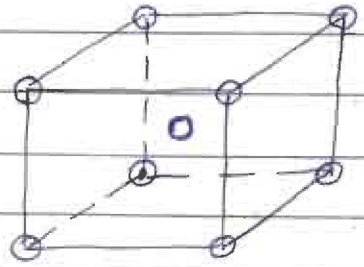
$$\boxed{APF = \frac{n \times \text{Volume of atom}}{\text{Volume of unit cell}}} = \frac{1 \times \frac{4}{3}\pi \left(\frac{a}{2}\right)^3}{a^3}$$

n → no. of atoms per unit cell

$$\boxed{= 0.52}$$

eg - Manganese (Mn)

2) Body Centered cubic



No. of Lattice points = 8 + 1

8 → Corner; 1 → Body centre.

→ Contribution of each corner atom = $\frac{1}{8}$

→ contribution of body centered atom = 1

→ No. of atoms per unit cell = $\frac{1}{8} \times 8 + 1 \times 1 = 2$

→ CN = 8

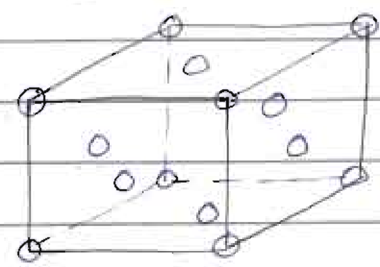
→ Geometrical Relationship → $\sqrt{3}a = 4r$

→ $\boxed{a = \frac{4r}{\sqrt{3}}}$

→ APF = $\dfrac{2 \times \frac{4}{3}\pi \times \frac{3}{16} a^3 \frac{\sqrt{3}}{4}}{a^3} = \dfrac{\sqrt{3}\pi}{8} \boxed{= 0.68}$

→ eg – (α) Iron, Chromium, Tungsten, Molybdenum

3) Face Centered Cubic (FCC)



→ No. of Lattice points = $\underbrace{8}_{\text{Corner}} + \underbrace{6}_{\text{Face centered}} = 14$

→ Contribution of each corner atom = 1/8

→ Contribution of each face centered atom = 1/2

→ No of atoms per unit cell = 1/8 × 8 + 1/2 × 6 = 4

→ CN = 12 = 4 × $\underbrace{3}_{\text{No. of planes.}}$

→ Geometrical Relationship ⇒ $\sqrt{2}a = 4r$

→ APF = $\dfrac{4 \times \frac{4}{3}\pi \left(\frac{\sqrt{2}a}{4}\right)^3}{a^3} = \boxed{0.74}$

→ eg – Iron, copper, Aluminium, Silver, nickel, gold, platinum.

Allotrops – When 2 elements exist in more than 1 form at different temperature and pressure then they are called Allotrops and this phenomena is called Allotropy.

eg – Carbon → Graphite, Diamond.

Iron → α-Iron (BCC), γ-Iron (FCC), δ-Iron (BCC).

Tin → α-Tin and β-Tin

⇒ As atomic packing factor increases, ductility increases.

$\boxed{\text{Simple Cubic} < \text{BCC} < \text{FCC}}$

Ductility ↑↑ →

4) **Hexagonal Closed Packed Structure (HCP)**

→ No. of lattice points = 6X2 + 2 + 3

→ Contribution of corners = 1/6
→ Contribution of face atom = 1/2
→ Contribution of centre atom = 1
→ $N = 12 \times \frac{1}{6} + 2 \times \frac{1}{2} + 3 \times 1 = 2+1+3 = 6$

→ CN = 12
→ APF = 0.74
→ $\boxed{\text{Eg – Titanium, }^{\#}\text{Zinc, Cobalt Cadmium, }^{\#}\text{Graphite}}$

⇒ Difference b/w FCC and HCP
→ Although FCC and HCP have same coordination no. and same APF and both are called closed packed structure (voids are low) but arrangement of atom sequence is different.
→ Stacking sequence of FCC structure is ABCABC
→ Stacking sequence of HCP is ABABAB

⇒ Closed Packed structure

→ These are those structures which creates minimum empty space and these empty spaces are called voids or interstitial or holes.

Q- What is the diameter of largest sphere in terms of lattice parameter a which will fit the void at the centre of the cube edge of a BCC crystal.

$\sqrt{3}a = 4r$

$d = a - 2r$

$= a - 2 \times \frac{\sqrt{3}a}{4\,2} = a - 0.866a$

$\boxed{d = 0.134a}$

Q- Repeat the above question for FCC structure.

$\sqrt{2}a = 4r$

$d = a - 2r$

$= a - \frac{a}{\sqrt{2}} = (1 - 0.707)a = 0.293a$

$\boxed{d = 0.293a}$

Since size of voids in FCC > size of voids in BCC

→ more carbon can be alloyed with FCC Iron to form steel.

⇒ Types of Void

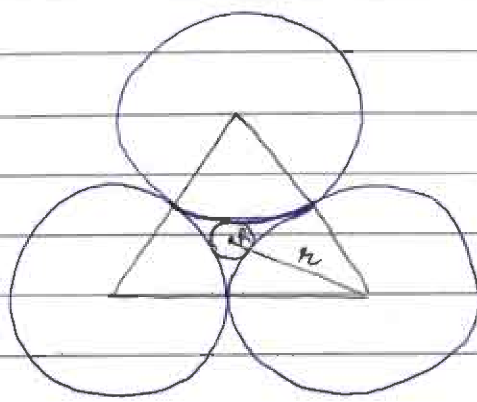
There are 3 types of void:

1) Trigonal void

Formed by 3 spherical atoms.

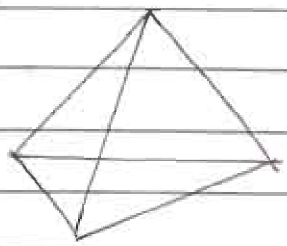
Size of void, $R = 0.155\,r$

Radius of void — Radius of atom



⇒ Tetragonal / Tetrahedral void

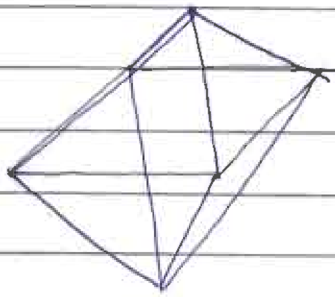
Formed by 3 atoms in one plane and one atom above that plane



$\boxed{R = 0.225r}$

⇒ Octahedral void

Formed by 4 atoms in one plane, 1 atom above and one atom below that plane.



$\boxed{R = 0.414r}$

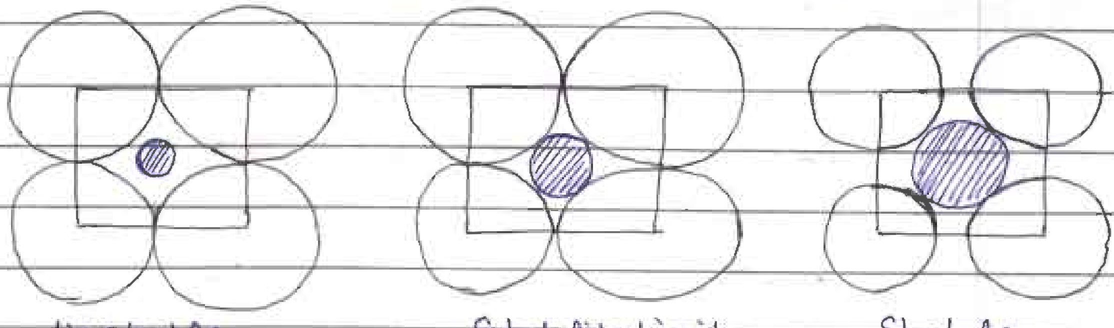
Examples

1) Tetragonal → Zinc Sulphide (ZnS) → Zinc Blende
2) Trigonal → Boron Oxide.
3) Octahedral → Sodium Chloride (NaCl)

⇒ Rules of stacking cations and anions for stable configuration

① Cation and anion must touch each other.

② Cation is surrounded by maximum number of anions.



For stable configuration, $\boxed{\text{Size of atom which fits in the void} > \text{Size of void.}}$

⇒ Density of crystal

Avogadro No. 6.022×10^{23} ← N atoms weigh A gms. → Atomic weight.

no. of atoms per unit cell ← n atoms weigh $\frac{A}{N} \times n$ gms.

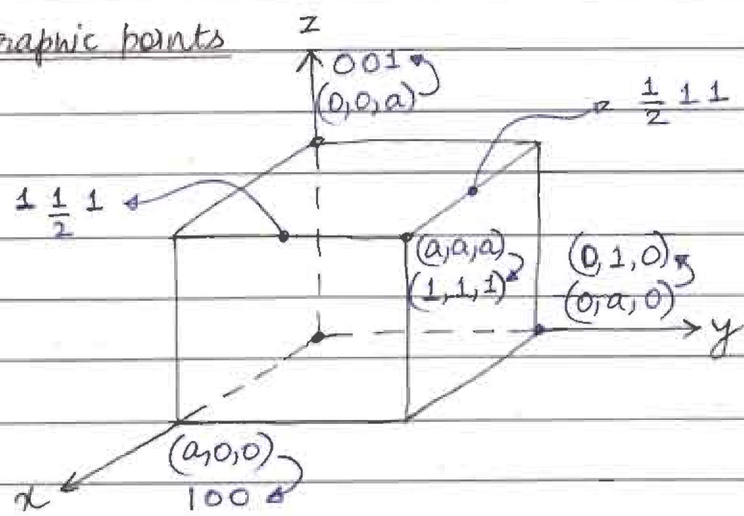
$$\therefore, \quad \boxed{\rho_{crystal} = \frac{A \times n}{N \times a^3}}$$

Q- Find the density of γ-Iron (FCC) if atomic weight is 56 gm/mole and length of unit cell is 10 Å. (in kg/m³)

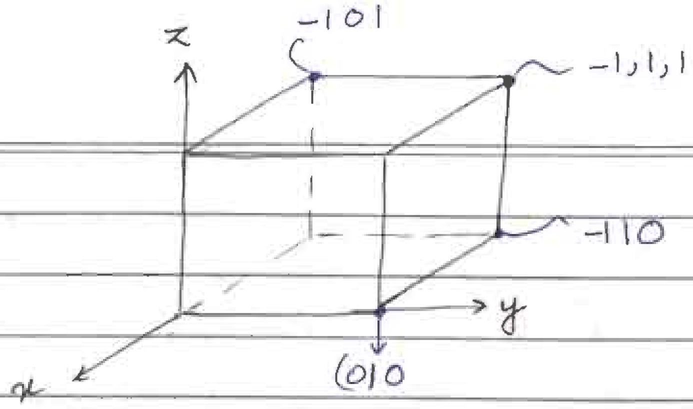
$$\rho_{crystal} = \frac{\frac{56}{6.022 \times 10^{23}} \times 4 \times 10^{-3}}{(10 \times 10^{-10})^3} = 372 \text{ kg/m}^3.$$

⇒ Crystallographic points, directions and planes

1) Crystallographic points



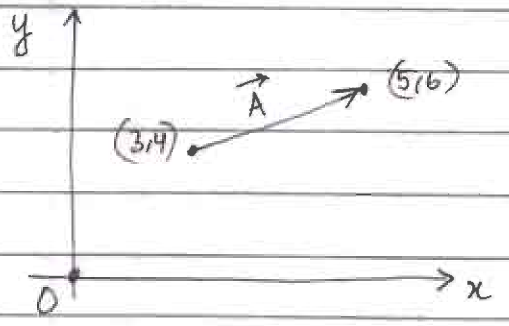
→ Point coordinates are represented as p q r without any comma (,) and bracket [()] as a fraction of a, b, c respectively



→ <u>Crystallographic direction</u>

→ Since it is a vector quantity and it can be represented by an arrow. and that arrow has a tail and head.

→ Head represents the direction.



$\vec{A} = 2\hat{i} + 2\hat{j}$

→ In order to find a vector quantity it's tail and head coordinate is desired but if tail of vector passes through origin, then only head coordinate is desired. There fore, in order to find a direction vector, we shift the origin to the tail.

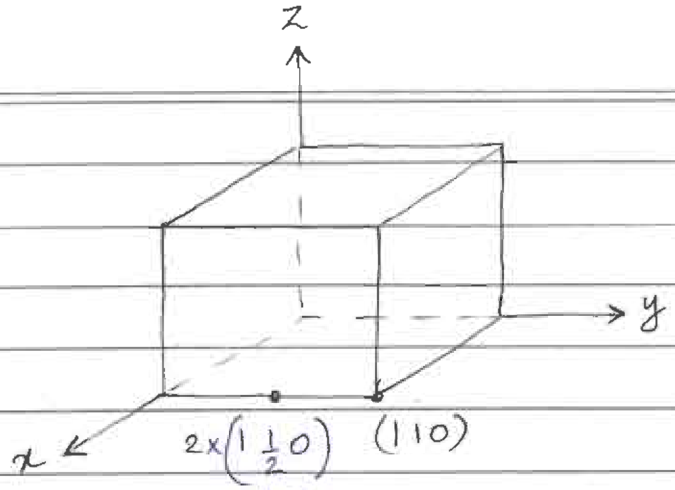
#

→ <u>Rules for finding direction vector</u>

<u>Rule 1</u> → Check whether the direction vector is passing through origin or not.

→ If the tail of vector is not passing through Origin then shift the origin to it's tail.

<u>Rule 2</u> → Find the head coordinate as a fraction of a, b, c.



$2 \times (1\ \tfrac{1}{2}\ 0)$

$= 2\ 1\ 0$

Rule 3 - The indices obtained in step 2 is converted into nearest integer values.

Rule 4 - The obtained indices after reduction is written as

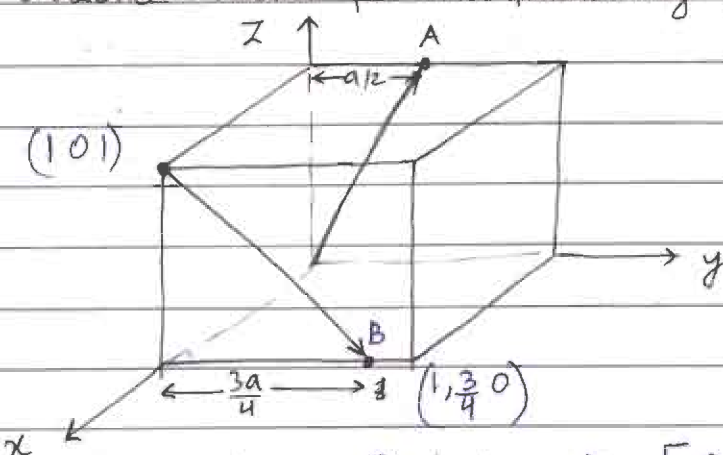
$[u\ v\ w]$

without any comma in square bracket

If any value comes out to be negative, we put a bar over it eg - $[u\ \bar{v}\ w] \rightarrow v$ is negative.

	x	y	z
Intercept of head	1	1	0
Reduction	1	1	0
Direction	$[1\ 1\ 0]$		

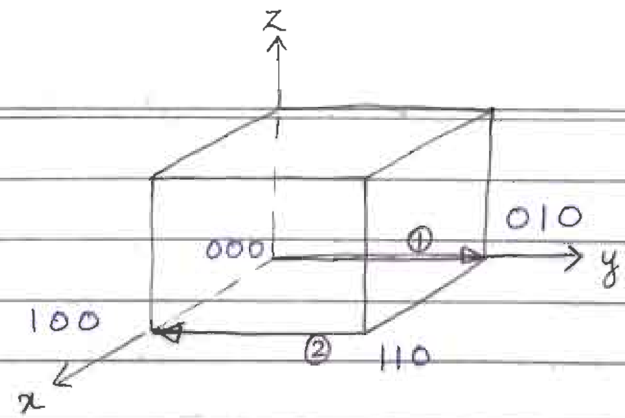
Q- Find the direction vector for the following figure



$\vec{B} \equiv 0\ \tfrac{3}{4}\ -1$

$\Rightarrow [0\ 3\ \bar{4}]$

$A = 0\ \tfrac{1}{2}\ 1 \Rightarrow [0\ 1\ 2]$



① ≡ $[0\,1\,0]$

② ≡ $0\,{-1}\,0$ ≡ $[0\,\bar{1}\,0]$

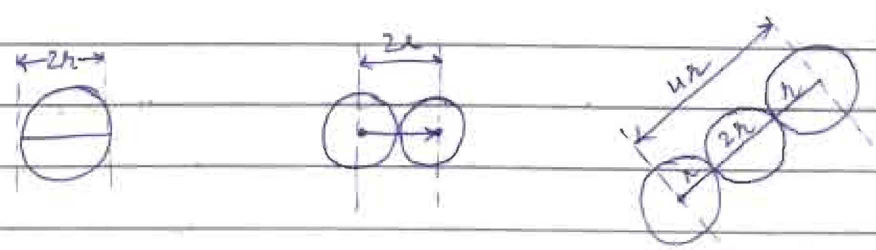
NOTE:

① When a direction vector $[u\,v\,w]$ is multiplied by -1 then it will give an antiparallel direction vector

② The indices u, v, w in direction vector $[u\,v\,w]$ is proportional to lattice parameters a, b, c respectively.

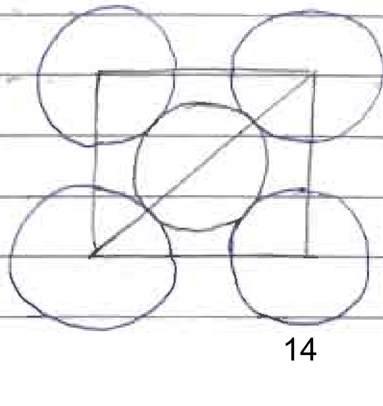
⇒ **Linear Density**

→ It is defined as the number of atoms centered on a given direction vector per unit length of that direction vector.



$2r \equiv 1$ atom $2r \equiv 1$ atom $4r \equiv 2$ atoms.

FCC



LD along $[0\,1\,0]$

$$LD_{[010]} = \frac{1}{a}$$

~~LD along~~ $[0\,1\,1]$

$$LD_{[011]} = \frac{2}{\sqrt{2}a} = \frac{\sqrt{2}}{a}$$

AIR-1 Notes

Pages: 35

Handwritten notes by

Kartikay Kaushik

AIR-1 ESE 2021

IES Master classroom Student

Project Management

1. Basics of Project Management
2. Project Initiation
3. Risk Management
4. Project Execution, Monitoring and Closing
5. Project Financing

→ Project is a temporary endeavour undertaken to create a unique product, service or result

→ Each project is temporary because it has a definite beginning and a definite end.

→ A project is not a continuous ongoing activity.

→ A project is unique because some aspects related to the project will be specific to that project only.

⇒ Project Management - It is the application knowledge, skiles, tools and techniques to the project activities to meet project requirements.

→ It has increasingly become significant because:

1) Many projects are large and complex which require a lot of coordination and communication with the suppliers, sponsers, government agencies etc.
2) Large amount of money may be involved in the project.
3) There is risk and uncertainty involved.
4) The market situation is dynamic and the prices of various inputs continuously fluctuate.
5) Management of stakeholders is required.
6) There is increased competition and increased focus on meeting the client's requirements.

classmate
Date
Page

⇒ Features/Characteristics of a project

1) Change
→ Projects can be considered as agents of social change
2) Temporary
3) Unique
4) Risk → Because each project is unique
5) Requirement of effective communication & coordination with various stakeholders.
6) Multifunctional → as it requires involvement of people from different departments.
7) There should be a defined objective so as to avoid any confusion and conflict at a latter stage.
8) Sub-contracting – A specialized knowledge or work force may be required for a very small duration. Hence they may be outsourced to another agency.
9) Made to order –
10) Life Cycle – Each project has a life cycle irrespective of its scope and cost → initiation, planning, execution, closing.

⇒ Comparison of operations and projects

1) Both require planning, execution and control and both are subjected to constraints of time cost and quality.
2) Projects are temporary while operations are continuous activities.
3) While projects have unique outputs, operations result in similar products
4) Projects involve more risk whereas operations involve less risk.
5) Management of projects is more difficult in comparison to operations.
6) Projects involve wide variety of skills whereas operations require limited skills.
7) Projects involve many outside agencies whereas operations require relatively few outside agencies.

→ <u>Project Stakeholder</u> - It refers to an individual, group or organizati[on] who may affect, be affected by, or percieve itself to be affected by a decision, activity or outcome of a project.

→ Stakeholders can be of 2 types:

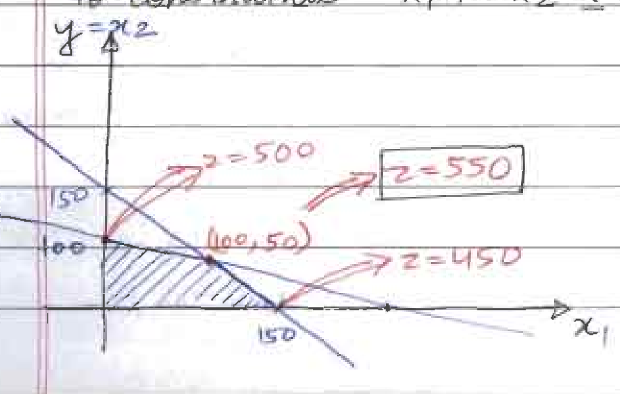
1) <u>Internal Stakeholders</u> → Project Manager, team manager, sponsors etc
2) <u>External Stakeholders</u> → Govt regulating bodies, local people, suppliers, external funding agencies.

<u>OR</u>

1) <u>Positive stakeholders</u> - They have a positive view about the project and are likely to be benefitted by the project's outcome.
→ They help in successful completion of the project.
2) <u>Negative Stakeholders</u> - They have a negative opinion about the project and are likely to be negatively impacted. They may present hurdles in successful completion of the project. Hence, they need to be managed and taken into confidence by effective communication and coordination.

→ <u>Project constraints</u>
→ Time, Cost & Scope → universal constraints.
→ Resources, Quality → other constraints.
→ These are the limiting factors or the boundaries within which the project should be completed.

Q- The objective function $z = 3x_1 + 5x_2$ is to be maximized subject to constraints $x_1 + 2x_2 \le 200$, $x_1 + x_2 \le 150$ and $x_1, x_2 \geq 0$



classmate

Date
Page

→ Types of organizations.

① Functional Organization

→ The organization is divided into specialized departments with each department performing one type of function.

→ The functional manager will have full authority regarding decision making, allocation of funds, resources etc. in that particular functional domain.

→ The position of Project Manager either does not exist or if it exists, he will have limited powers and will act more as a coordinator.

→ The decision making is slow and there is poor inter-departmental communication and coordination.

→ At any point of time, a department may have one or more no. of projects, hence the project oriented focus is missing. There is no one person responsible for the project as a whole.

→ The functional manager may adopt analytical approach rather than systems approach.

② Projectised Organization

→ Here the PM has full authority to take decisions and allocate resources.

→ Either there will be no functional manager or if he/she exists, he/she will have very limited powers.

→ It leads to fast decision making and fast completion of projects

→ The PM uses systems approach

→ The PM can directly communicate with the top management and hence there are shorter communication channels.

→ Employees may become less loyal to the organization because once the project is complete they may lose their jobs.

→ Project team forms a separate identity which results in high level of motivation for the employees [non-monotonous work]

→ It creates an internal rift in the organization because the project team members feel that they are more important to the organization in comparison to other employees of parent org. [Projectitis]

③ Matrix Organization

→ It is a mixture of the projectised type of org structure and functional type of org structure.

→ There are 2 chains of command, one on the functional lines and other on the project lines.

→ Hence, there might be some practical difficulties in reporting to 2 bosses. Thus, there must be clear communication and division of power to avoid any confusion and conflict.

Matrix Organization
- → Strong matrix → PM has more power → similar to projectised org.
- → Balanced matrix
- → Weak matrix → Functional manager has more power → similar to functional org.

⇒ Project Manager

→ A PM is an individual with the authority, responsibility and accountability for managing a project to achieve the desired objectives.

→ PM should have skills related to leadership, communication, motivation, decision making, teammaking, conflict resolution, negotiation, Human Resource Management, time management, budgeting, political and social awareness

⇒ Powers of a PM

① Positional Power
- → Legitimate / Formal
- → Reward
- → Coercive / Punishing

} Relevant for Projectised and Strong matrix organisations.

(a) Legitimate / Formal Power – The team members will obey the instructions of the PM because they know that he has the authority to issue such orders.

(b) Reward Power – The project Manager can reward the team members / sub-ordinates monetarily / non-monetarily if they perform well.

(c) Coercive / Punishing Power – The team members will obey the PM because they may be punished if they do not perform well.

→ The positional powers need a pre-justification before their use. But in case of emergency, they can be used without approval and subsequently the post justification may be given.

② Personal Power → Referent
Personal Power → Expert

(a) Referent Power – It is due to the respect and admiration of the subordinates.

(b) Expert Power – It is based on the skill, knowledge, experience & expertise of the PM.

→ Project Management Office (PMO)

→ This a group of individuals who are responsible for centralised and coordinated management of the projects.

PMO → Supportive → Low degree of control over projects → weak matrix ↗ functional
PMO → Controlling → Moderate degree of control → Balanced matrix
PMO → Directing → High degree of control → Projectised, Strong matrix.

→ Project, Program, Portfolio management

Portfolio → Programs

Alternate Energy → Wind, Solar, Hydro → Multiple Projects under each program.

→ **Program** - It is a group of related projects managed in a coordinated way to obtain the benefits and control which is not available from managing them individually.

→ Programme management leads to better utilisation of resources, minimised resource constraints, reduced conflicts b/w projects, good communication and coordination b/w projects and overall improvement in the organization's performance.

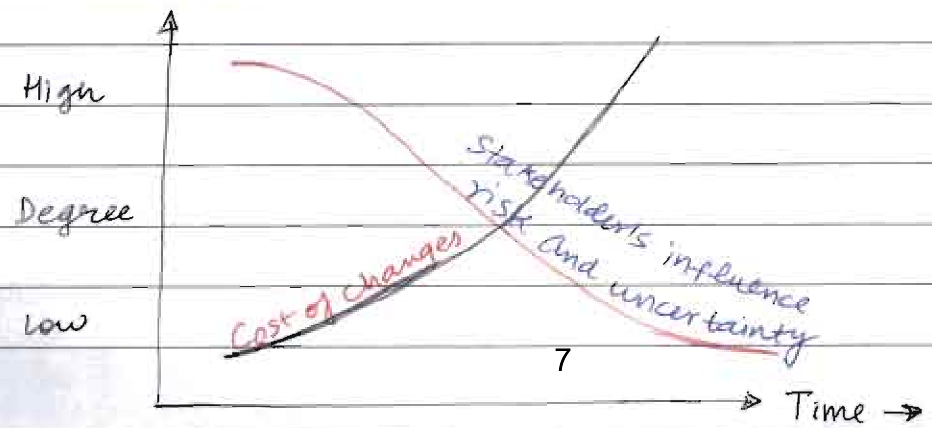
→ **Portfolio management** - A portfolio is a group of related or non-related programs or projects. Portfolio management will have a larger scope than the programme management.

→ The portfolio management helps in achieving the strategic objectives of the organization, ~~privat~~ prioritization of the works and optimization of organization's performance.

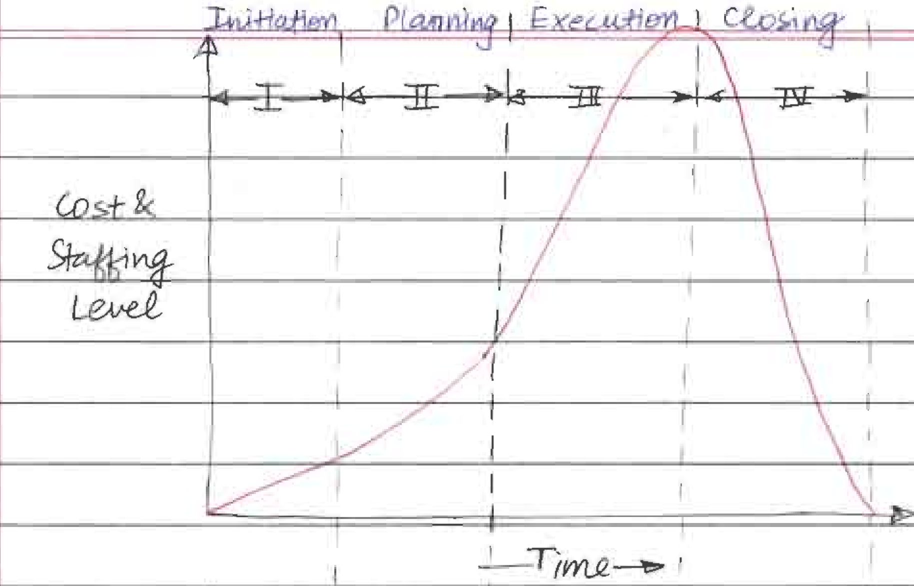
→ **Project Lifecycle**

1. Initiation ⟶ o/p Project Charter
2. Planning ⟶ o/p Project Management Plan
3. Execution ⟶ o/p Accepted deliverables to client.
4. Closing ⟶ o/p archived documents → Both Physical and financial closure.

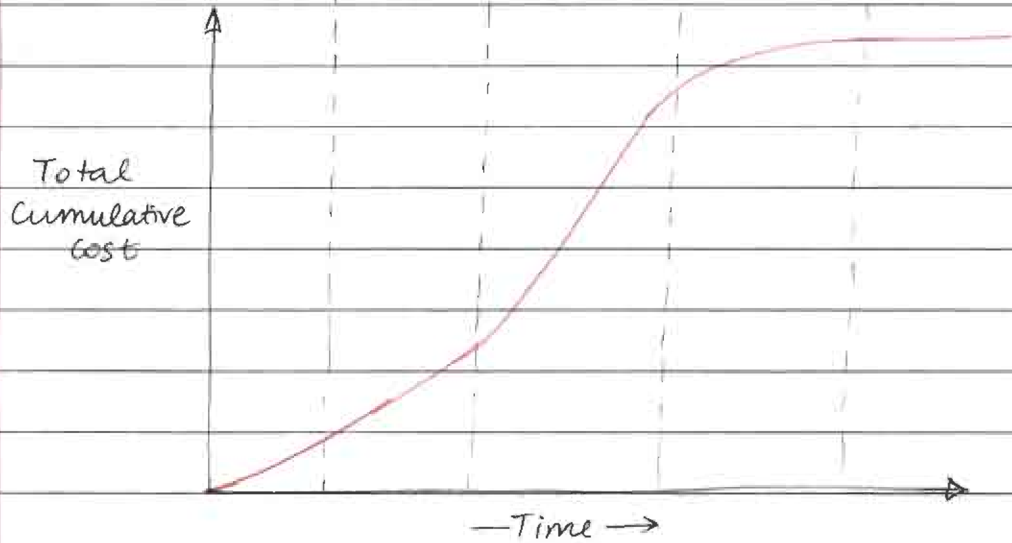
→ Irrespective of the scope, cost and complexity, any project goes through a series of stages during its life which are collectively called the project lifecycle. It helps in better management and control over the projects



47 Project processes → divided into 5 process groups
(1) Initiating, (2) Planning (3) Executing (4) Monitoring & Control
(5) Closing.



In the initiation stage(I), the cost of the project is minimum.



Chapter 2 - Project Initiation

→ Project Identification → Pre-feasibility study → feasibility study → DPR $\xrightarrow{\text{Appraisal}}$ Project Charter

⇒ Project Identification

→ The process of project management starts with the project identification

→ At this stage, the project authority generates various ideas about the possible projects that can be undertaken.

Project Identification → SWOT Analysis → Strength, weakness (Internal factors), opportunity & threats. (External factors)

Project Identification → Brainstorming

first look

⇒ Pre-feasibility analysis or Preliminary filtration or Prima-facie analysis

→ Most of the identified projects are screened out and eliminated at this stage. The decisions are made on the basis of the following factors:

1) Whether sufficient funds are available
2) Whether the demand is high and stable
3) Whether the project is adequate from the locational aspects
4) Whether there are any major problems related to environment or land acquisition.
5) Whether there is too much competition
6) Whether the performance of existing industries is encouraging.
7) Whether the govt policies are favourable.

⇒ Feasibility study
- → Market Feasibility
- → Financial Feasibility
- → Technical Feasibility
- → Socio-economic feasibility
- → Environment Feasibility

→ If the project is selected on the basis of pre-feasibility report then the practicality of the proposed project is further examined in greater detail in the feasibility study.

① Market Feasibility

→ It includes the current market analysis, existing competition, anticipated future market growth and the potential size of the market that can be captured.

→ The analysis is carried out through fore casting of the future demand.

Market Forecasting
- → Qualitative Forecasting → Subjective
  - → Delphi method
  - → Sales force composite
  - → Consumer panel survey
- → Quantitative Fore casting → Objective
  - → Moving avg method
  - → Weighted moving avg
  - → Exponential smoothing
  - → Regression Analysis

Qualitative Forecasting

→ Qualitative methods will be used when the past data is not available, a brand new product is to be launched, or when the forecasting has to be done for long time period.

→ The Qualitative forecasting is based on personal judgement, intuition and experience. Hence, it is subjective in nature.

(a) Delphi Technique

→ It is an iterative process which employs a group of experts to obtain forecasts.

→ The interaction b/w the experts takes place through a coordinator.

→ The coordinator obtains the forecasts from all the experts and each of the experts whose estimate is at either extremes, are asked to give a justification for their forecast which is then circulated to all the experts.

→ Based on this additional information, experts may revise their original forecast.

→ This process is repeated many times so that a consensus forecast is reached.

(b) Salesforce method

→ All the members of the sales team of the company are asked to estimate the likely sales in their respective areas.

→ These estimates are combined at the regional and national level to obtain the overall forecast.

(c) Consumer Panel Survey

→ The company uses the consumers on the consumer panel for obtaining the forecasted demand. These consumers are assumed to be representative of the actual consumers in the market.

classmate
Date
Page

Quantitative Forecasting

(a) Moving Average method

Year	Sales (Cr)
1	50
2	60
3	70
4	50
5	70

3 year moving average

$\Rightarrow F_6 = \frac{D_3+D_4+D_5}{3} = \frac{190}{3} = 63.33$

$\Rightarrow$ 4 year moving average

$F_6 = \frac{D_2+D_3+D_4+D_5}{4} = \frac{250}{4} = 62.5$

→ This method averages the data of few recent periods while ignoring the older observations.

→ Equal weightage is assigned to all the periods selected for averaging

(b) Weighted moving average method

→ The highest weight is assigned to the most recent value and progressively smaller weights are assigned to the preceding values

→ 3 year weighted moving avg

$F_6 = \frac{3\times70 + 2\times50 + 1\times70}{6}$

→ 4 year weighted moving avg

$F_6 = \frac{4\times70 + 3\times50 + 2\times70 + 1\times60}{10}$

(c) Exponential Smoothing

$$\boxed{F_t = F_{t-1} + \alpha\,(D_{t-1} - F_{t-1})}$$

α = smoothing constant

Q. $\alpha = 0.4$

Year	Demand (D_t)	(F_t)
1	70	70
2	60	70
3	80	66
4	90	71.6
5	?	

Forecasting → Assume $F_1 = D_1 = 70$

$$F_2 = F_1 + \alpha (D_1 - F_1) = 70$$
$$F_3 = F_2 + \alpha (D_2 - F_2) = 66$$
$$F_4 = F_3 + \alpha (D_3 - F_3) = 71.6$$
$$F_5 = F_4 + \alpha (D_4 - F_4) = 78.96$$

(c) **Regression Analysis** → most commonly used in the project initiation stage.

$$y = a + bx$$
$$\rightarrow \Sigma y = an + b\Sigma x \qquad \times \Sigma x$$
$$xy = ax + bx^2$$
$$\rightarrow \Sigma xy = a\Sigma x + b\Sigma x^2 \qquad \times n$$

$$\cancel{\rightarrow n\Sigma y = an^2 + bn\Sigma x}$$
$$\cancel{\rightarrow n\Sigma xy = an\Sigma x + bn\Sigma x^2}$$

$$\Sigma y \cdot \Sigma x = an\Sigma x + b(\Sigma x)^2$$
$$n\Sigma xy = an\Sigma x + bn\Sigma x^2$$

$$\boxed{b = \frac{n\Sigma xy - \Sigma x \cdot \Sigma y}{n\Sigma x^2 - (\Sigma x)^2}}$$

$$\boxed{a = \frac{\Sigma y - b\Sigma x}{n}}$$

Take $\Sigma x = 0$

Then → $b = \dfrac{\Sigma xy}{\Sigma x^2}$

& $a = \dfrac{\Sigma y}{n}$

Q-

Year	Sales (in crores)	Deviation from 2016
2014	50	−2
2015	60	−1
2016	70	0
2017	50	1
2018	70	2
	(y)	(x)

$$b = \frac{\Sigma x \cdot y}{\Sigma x^2} = \frac{30}{10} = 3, \quad a = \frac{300}{5} = 60$$

So, $y = 60 + 3x$

$$y\Big|_{@x=3} = 60 + 9 = 69$$

② Financial Feasibility

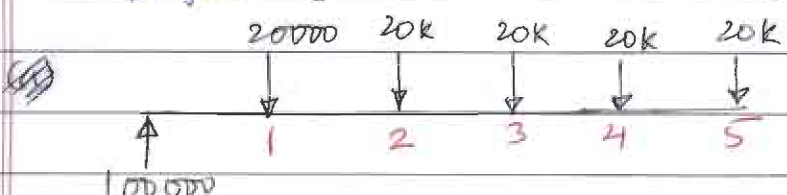
→ It assesses the feasibility of a proposed project by evaluating the various costs and thus making fore casts of the future profitability of the investment.

- Non-Discounting Techniques
  - Payback Period
  - Accounting Rate of Return
- Discounting techniques
  - NPV
  - Profitability Index $\left(\frac{\text{Benefit}}{\text{Cost}}\right)$
  - Internal Rate of Interest
- Break-even analysis.

→ The non-discounting techniques do not consider the time value of money whereas the discounting techniques take into consideration, the time value of money.

(a) Payback Period

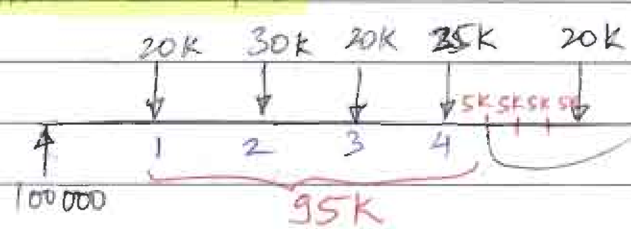
→ It is the time taken by a company to recover the initial cost of the project. (without considering the time value of money)



Payback Period = 5 years.

↳ without considering the time value of money.

→ Payback period is the ratio of initial investment and the annual cash flow.



→ Payback Period = 4.25 years.

→ The projects having lower pay back period may be preferred over the projects having higher payback period.

→ If the payback period of the project is lower than the expected Payback period, then the project may be selected.

(b) Accounting Rate of Return $= \dfrac{\text{Average income}}{\text{Avg. investment}}$ OR $\dfrac{\text{Average income}}{\text{Initial investment}}$

Average Investment $= \dfrac{\text{Initial investment} + \text{Salvage value}}{2}$

$= \dfrac{I+S}{2}$

Q- If the initial investment is Rs 3 lacs and the life of investment is 5 years with the following cash flows
Rs 90K, Rs 90K, Rs 120K, Rs 90K, Rs 150K
Then what will be the ARR based on initial investment and average investment. Assume that the asset has no salvage value after 5 years.

	1st	2nd	3rd	4th	5th
Cash Flow	90K	90K	120K	90K	150K
Depreciation	60K	60K	60K	60K	60K
Income	30K	30K	60K	30K	90K

Average income = 48K $\Rightarrow$ ARR $= \dfrac{48}{300} = 16\%$

$\Rightarrow \text{ARR}\Big|_{\text{based on avg investment}} = \dfrac{48}{300/2} = 32\%$

Q- A machine is expected to generate cash saving of Rs 50000/year for 5 years. Salvage value is 40% of the original cost.
If ARR based on initial investment is 20%, then what will be the cost of 2 such machines

$0.2 = \dfrac{50000 - 0.12x}{x} \Rightarrow x = \dfrac{50000}{0.32}$

$\Rightarrow 2x = 312500$

AIR-1 Notes
Pages: 55

Handwritten notes by

Kartikay Kaushik
AIR-1 ESE 2021
IES Master classroom Student

Standards & Quality Practices

DATE
PAGE

① Basic concepts and Quality → QA and QC
② Quality Thinkers / approaches → TQM
③ Control charts.
④ Six Sigma → Process capability
⑤ Acceptance Sampling → AOQ → benefits of sampling
⑥ Inventory Management → EOQ
⑦ Manufacturing
⑧ Maintenance
⑨ Construction and Services.

⇒ Key concepts related to Quality

1) Degree of fitness for the use of customers. (whether it solves the intended purpose or not)

2) The product or service should meet the customers' expectation.

Expectations → Stated
Expectations → Implied → not clearly specified.

→ Both stated and implied expectation of the customers should be fulfilled.

3) The product / service should be cost-effective. → affordable to the target customers.

→ Using Lean manufacturing and Value engineering cost of manufacturing can be reduced.

→ Wastages ↓ ⇒ Processes standardise ⇒ COM ↓ ⇒ Hence product becomes more competitive

4) Product should conform to specifications (relevant to products only)

eg → 150 ± 0.2 cm → Specification Range.

USL = 150.2 cm   LSL = 149.8 cm

→ If the value of the products quality characteristics falls within USL and LSL then it is of acceptable quality otherwise we say that a defect has taken place.

5) The product should be reliable → time oriented characteristic.

Reliability → 1) should not fail
→ 2) over a period of time
→ 3) perform as per specified standards
→ 4) under given operating time

6) The product should be durable → i.e. It should have a high effective life.

→ The product will become scrap after the durable period and it cannot be restored to it's normal working condition even after performing the maintenance.

7) Aesthetics → appearance of product.
Tangibles → indicator of quality for services.
↳ environment or ambience in which service is provided.

8) The product should be serviceable - means that its after sale service should be easily available at a low cost

9) The product / service should have a good perceived quality
↳ brand image, advertisement → preconceived notion.

10) Quality is a relative term and it is not absolute, it varies with time location and from person to person. [Subjectivity]

11) Due to globalisation, the competition has increased and now the consumers have more choices, hence if a company has to survive in the market, then it will have to continuously improve the quality of it's products and services, in order to meet the changing requirements of the customers

DATE
PAGE

(12) Productivity = $\frac{\text{Output}}{\text{Input}}$

⇒ If Quality ↑ ⇒ Productivity ↑

⇒ Types of quality (Stages)

1. Quality of Design → Most important.
2. Quality of Conformance (Implementation)
3. Quality of Performance

1. Quality of Design (QOD)

→ Most critical of the three.

→ multi-functional. [Interdepartmental → involving various experts]

→ It is easier and less costly to incorporate quality into the product at an early stage of product development.

→ Robust Design → It is a good quality of design such that the product is able to perform satisfactorily under a wide range of operating conditions.

Quality of Design →
1) Market survey
2) Concept Development
3) Detailed specification. (Output)

2. Quality of Conformance (QoC)

→ It deals with whether the product conforms to the specifications finalized at the design stage.

→ Poor QoC ⇒ defects ↑ ⇒ Wastages and Cost of Manufacturing ↑

⇒ Inputs required

(a) Resources
(b) Skilled Manpower
(c) Technology and machines
(d) funds [should be less costly and easily available]
(e) Support of leadership / top management
(f) Participation of grassroot level workers.

(9) → Heavy dependence on the supplier to provide the right quantity and quality of input materials.

③ Quality of Performance (QoP)

→ regular and adequate maintenance
→ good after sales services
→ reliable products.

→ Cost of Quality → 1) Prevention Cost, 2) Appraisal Cost } Cost of conformance or Cost of Good Quality
→ 3) Internal failure cost, 4) External failure cost } Cost of Non-conformance or ~~failure of Cost~~ of Poor quality

→ COQ = CoC + CoNC
→ CoC = CoP + CoA
→ CoNC = CoIF + CoEF

→ cost of quality includes the cost incurred to prevent poor quality, check the quality of products and the losses resulting from Internal and External failures

① Prevention Cost

→ It involves the money spent in preventing the defects.
→ It includes the costs associated with planning, design review, training, quality assurance, supplier evaluation and effective implementation of the quality Management System.
→ As prevention cost increases, failure cost decreases
→ As the company invests more in prevention, it results in long term sustainable profits to the company because of improved brand image and increased sales.

DATE ______
PAGE ______

(2) Appraisal cost

→ As the cost of prevention increases, the cost of appraisal reduces.

→ The appraisal cost includes the cost associated with inspection of the product, testing equipment and salary of the related staff.

(3) Internal Failure Cost

→ It is the loss to the company if a part fails within the company itself.

→ It includes the cost associated with scrap, reworking, failure analysis.

(4) External Failure cost

→ It is the loss to the company if a product becomes defective after reaching the customer.

→ It includes the cost associated with processing of customer complaints, delayed payments, returned products, product recall, and loss of future customers because of damage to the product's image.

Q: $CoF = 1500 + 120X$ where x = Percentage defects.

$CoC = \frac{3000}{X}$ Find $(CoQ)_{min}$ and corresponding x.

$CoQ = 1500 + 120x + \frac{3000}{x} \Rightarrow \frac{d(CoQ)}{dx} = 120 - \frac{3000}{x^2} = 0$

$\boxed{CoQ_{min} = 2700}$

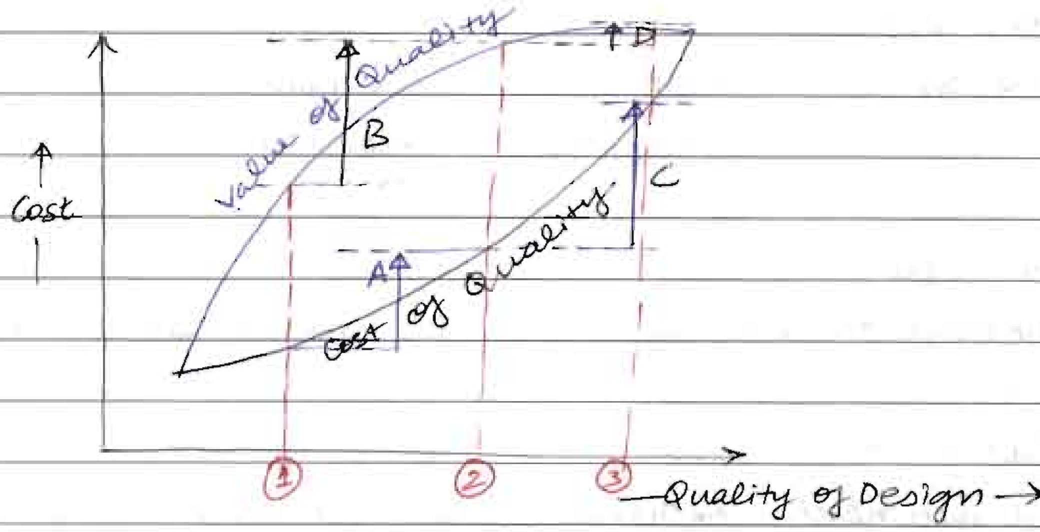
$\Rightarrow x^2 = \frac{3000}{120}$

$\Rightarrow \boxed{x = 5\%}$

DATE
PAGE

→ Balance between Value of quality and cost of quality

→ Value of quality is the returns gained by the company due to various quality related activities. The returns may be due to reduction in defects and due to increased sales and hence profit to the company.



→ If by improving quality from 1 to 2
$\Delta VOQ > \Delta COQ$ i.e. $B > A$
then improvement in quality is justified

→ If by improving quality from 2 to 3
$\Delta VOQ < \Delta COQ$ i.e. $D < C$
then improvement in quality is not justified.

⇒ Evolution of concept of Quality

Phase I Before industrial Revolution
→ less use of machines and technology
→ Low volume of production and less capital involved.
→ No institutionalized framework for maintaining quality
→ Quality dependent mainly on the skills of the individual involved.