MADE EASY

India's Best Institute for IES, GATE & PSUs

ESE 2023 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-2

Highway Engineering + Surveying and Geology [All Topics]

Strength of Materials-1 + Environmental Engineering-1 [Part Syllabus]

Name : .....

Roll No :

Test Centres	Student's Signature
Delhi ☑ Bhopal ☐ Jaipur ☐ Pune ☐ Kolkata ☐ Bhubaneswar ☐ Hyderabad ☐	

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. Answer must be written in English only.
3. Use only black/blue pen.
4. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
5. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
6. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

FOR OFFICE USE	
Question No.	Marks Obtained
Section-A	
Q.1	28
Q.2	—
Q.3	40
Q.4	—
Section-B	
Q.5	24
Q.6	38
Q.7	46
Q.8	—
Total Marks Obtained	176

Signature of Evaluator: Akuman

Cross Checked by: .....

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

Remarks:

- Accuracy is good.
- Improve presentation.
- Excellent work in Section-B.
- Read theory thoroughly.

Section A : Highway Engineering + Surveying and Geology

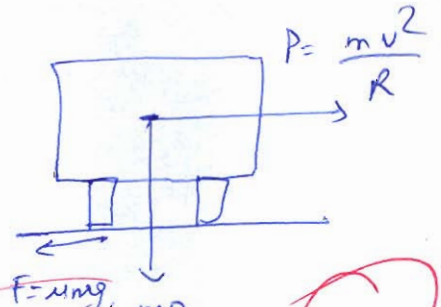
Q.1 (a) Discuss the stability aspects of a vehicle negotiating a horizontal curve with no superelevation.

[12 marks]

There are two stability aspects which ~~should be taken~~ are there during no superelevation.

1.) Possibility of overturning

- Vehicle can overturn during a horizontal curve if ~~centrifu~~ overturning moment is higher than resisting ~~moment~~ as there is no other resisting ~~non~~ moment ~~or~~ except self weight of vehicle.



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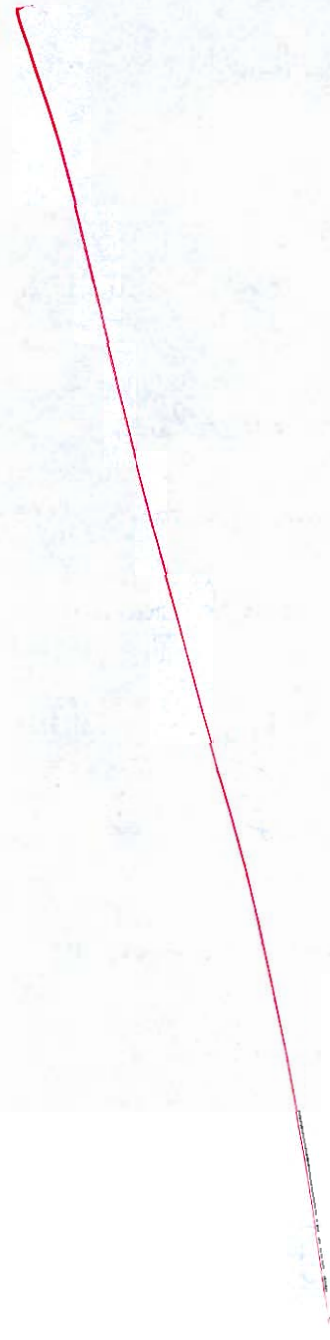
2.) Possibility of sliding / skiding

- In case vehicle doesn't overturn, there is possibility of ~~skiding~~ is lateral pushing force ($\frac{mv^2}{R}$) is greater than friction force (μmg).



Q.1 (b) What do you understand by the term 'mixed traffic flow'? Also explain the concept of PCU value and factors affecting PCU value.

[12 marks]

• 'Mixed traffic flow' describes all kinds of vehicle type that move simultaneously on the road. For ex:- Cars, bikes, trucks, Bus etc.

• PCU value means Passenger Car Unit. It represents how much the vehicle type is affecting the traffic flow.

For ex -> Car has PCU value of 1.

Truck has PCU value of more than 1.

Basically, higher the PCU value, more the congestion will be caused by the vehicle.

• Factors affecting PCU value

a.) Speed of vehicle b.) Length of vehicle.

-> More speed mean less PCU value. & vicevers.

-> More length means higher PCU value.

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PCU value is given with respect to car as

$$PCU = \frac{\text{Speed ratio}}{\text{Length ratio}}$$

$$\Rightarrow \frac{V_c}{V_i} \times \frac{L_c}{L_i}$$

$$\Rightarrow \frac{V_c}{L_c} \times \frac{L_i}{V_i}$$

where V_c & L_c are speed & length of car & V_i & L_i are speed & length of vehicle for which PCU is being calculated.

Q.1 (c) The length of a base line was measured using two different EDM instruments *A* and *B* under identical conditions with the following results as tabulated below:

A(m)	*B(m)*
1002.677	1002.678
1002.671	1002.682
1002.666	1002.676
1002.683	1002.679
1002.673	1002.676
1002.680	1002.681
	1002.678
	1002.674

Determine:

(i) The standard deviation of measurements done by instrument *A*.

(ii) The standard deviation of measurements done by instrument *B*.

(iii) The relative precision of the two instruments.

(iv) The most probable length of the base line.

[12 marks]

i) Mean from instrument A $= \frac{\sum_{i=1}^{6} x_i}{n}$

$\bar{x}_A \Rightarrow 1002.675$ m

So, Standard deviation $\Rightarrow \sqrt{\frac{\sum_{i=1}^{6} (x_i - \bar{x}_A)^2}{n-1}}$

$\sigma_A \Rightarrow 6.2289 \times 10^{-3}$ m

ii) Mean from instrument B $= \frac{\sum_{i=1}^{8} x_i}{n}$

6

$\bar{x}_B \Rightarrow 1002.678$ m

So, Standard deviation $\sigma_B = \sqrt{\frac{\sum_{i=1}^{8} (x_i - \bar{x}_B)^2}{n-1}}$

$\Rightarrow 2.672 \times 10^{-3}$

iv) Most probable length $\Rightarrow \frac{\bar{x}_A + \bar{x}_B}{2} \Rightarrow 1002.6765$ m

iii) Relative precision of two instrument.

$$\Rightarrow \frac{\sigma_A}{\sigma_B}$$

$$\Rightarrow \frac{0.2289}{2.672}$$

$$\Rightarrow 2.331$$

Q.1 (d) The fore bearings and back bearings of the lines of a closed traverse *ABCDA* were recorded as below:

Line	Fore Bearing	Back Bearing
AB	77°40′	259°20′
BC	110°40′	289°40′
CD	228°10′	48°10′
DA	310°00′	129°20′

Compute the values of the corrected bearings.

[12 marks]

Sol:

Difference between FB & BB of CD = 180°

So, station C & D are free from any local attraction.

So, F.B. of DA = 310° 00′

BB of DA = 310° − 180° ⇒ 130° 00′

Correction at A ⇒ + 40′

So, FB of AB = 77° 40′ + 40′

⇒ 78° 20′

Traverse ≠ ?. Check for int. angle ≠ ?

& So, BB of AB = 258° 20′

Correction at B ⇒ − 1°

So FB of BC = 109° 40′

BB of BC = 289° 40′ ok

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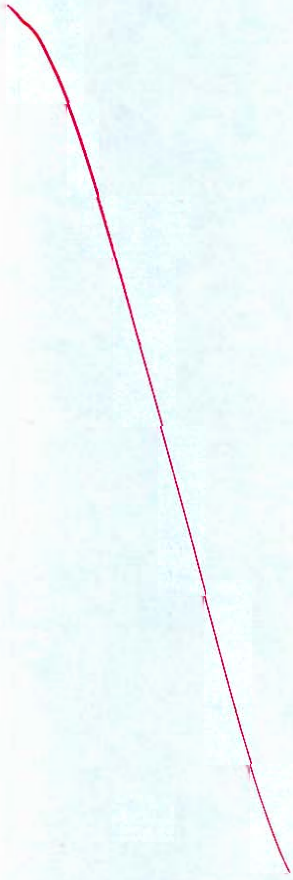
Line	FB	BB
AB	78° 20'	258° 20'
BC	109° 40'	289° 40'
CD	228° 10'	48° 10'
DA	310° 00'	130° 00'

Q.1 (e) Briefly discuss about the structural features in rocks along with their utility in civil engineering.

[12 marks]



Q.2 (a) A two lane state highway passing through a rolling terrain has a horizontal curve of radius equal to the ruling minimum radius. Design the following geometric features of this horizontal curve:

(i) Ruling minimum radius.

(ii) Rate of superelevation.

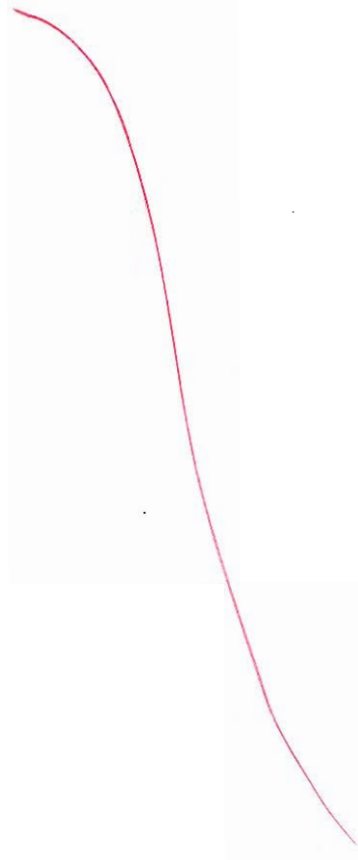
(iii) Extra widening of pavement.

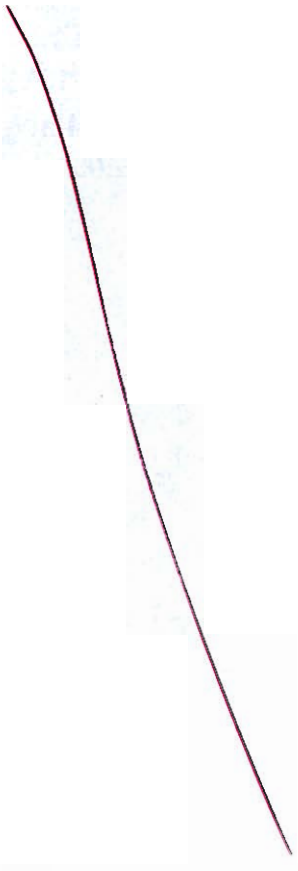
(iv) Length of transition curve.

(v) ISD and set-back distance (assuming length of circular curve to be greater than the desired sight distance) required to provide a clear vision for the calculated ISD.

Assume any suitable data required as per IRC.

[20 marks]





Q.2 (b) (i) A base line was measured by a tape suspended in catenary under a pull of 150 N, the mean temperature being 15° C. The length of various segments of the tape and the difference in levels of the two ends of a segment are given below:

Span	Length (m)	Difference in levels (m)
1	29.980	+0.251
2	29.890	-0.214
3	29.840	+0.310
4	29.935	-0.101

If the tape was standardized on a flat surface under a pull of 100 N at 20° C, then determine the correct length of the line. Take:

Cross-sectional area of the tape = 3.25 mm^2

Mass of the tape = 0.020 kg/m

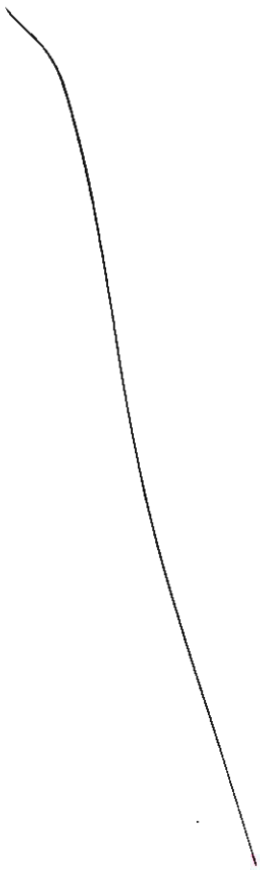
Coefficient of linear expansion = 0.8×10^{-6} per °C

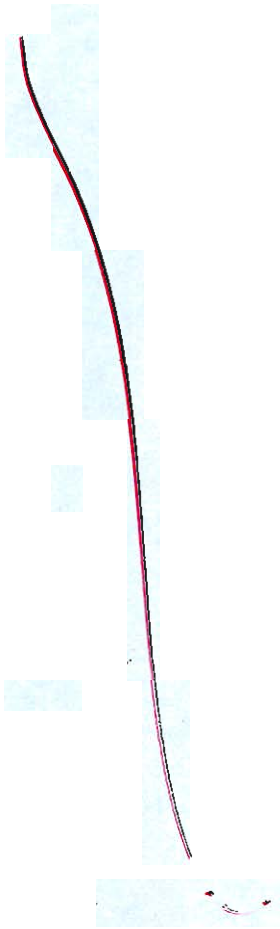
Young's modulus = 15×10^4 MN/m^2

Mean height of the line above MSL = 100.4 m

Radius of earth = 6400 km

[15 marks]



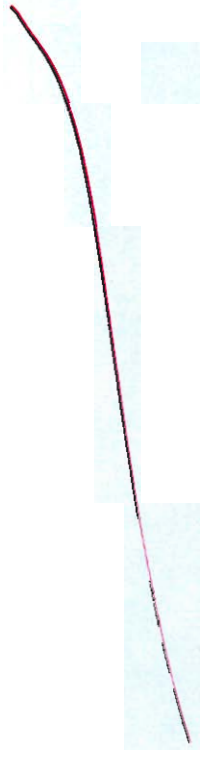


Q.2 (b) **(ii)** Briefly discuss about the temporary adjustments made to a theodolite.

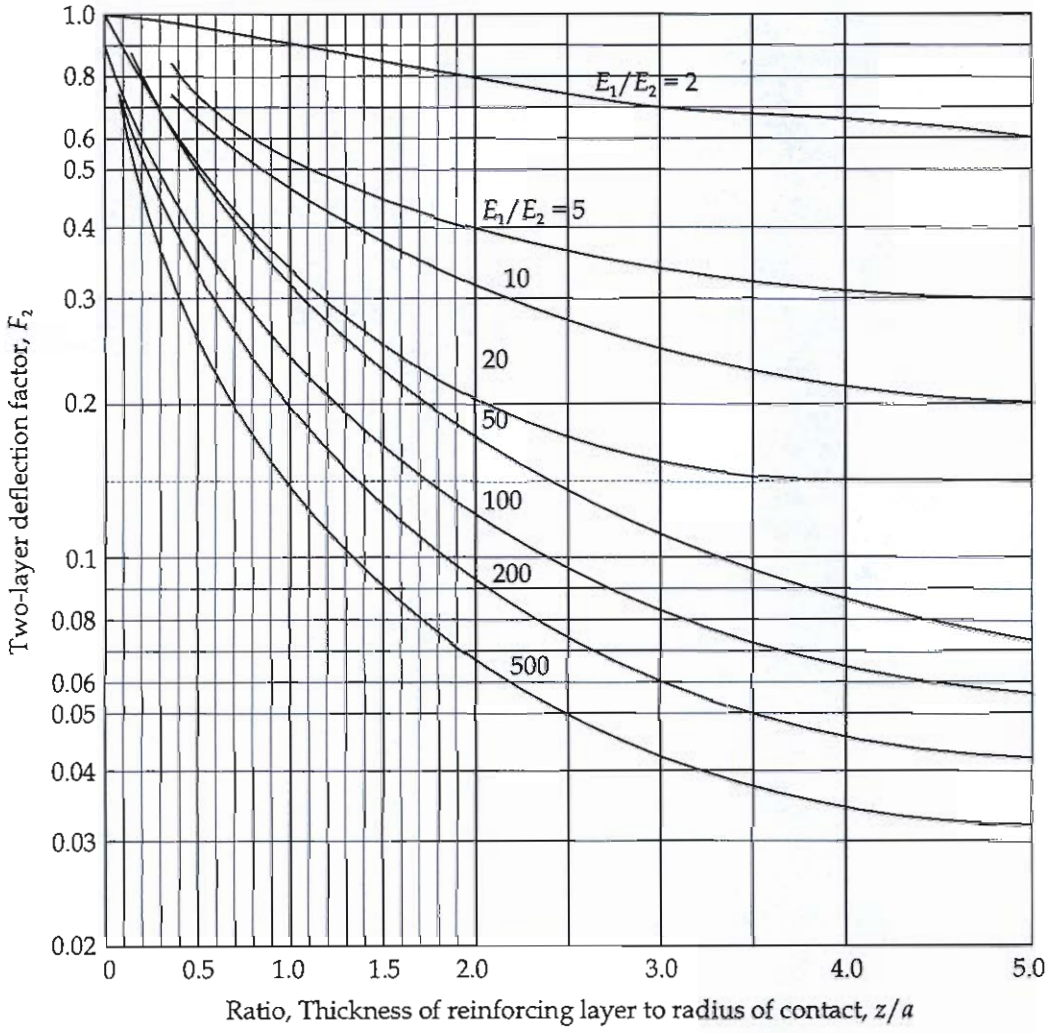
[5 marks]

Q.2 (c) (i) State the assumptions made in the accident analysis, for estimating the original speeds of colliding vehicle.

[5 marks]



Q.2 (c) (ii) Plate bearing tests were conducted using 30 cm diameter plate on soil subgrade and over a base course of thickness 45 cm. The yield pressure at 0.5 cm deflection on the subgrade and base course were 1.2 kg/cm^2 and 7.5 kg/cm^2 respectively. Design the thickness requirement of flexible pavement for a wheel load of 5000 kg with tyre pressure of 6.0 kg/cm^2, for an allowable deflection of 0.5 cm using Burmister's two-layer deflection factor chart.

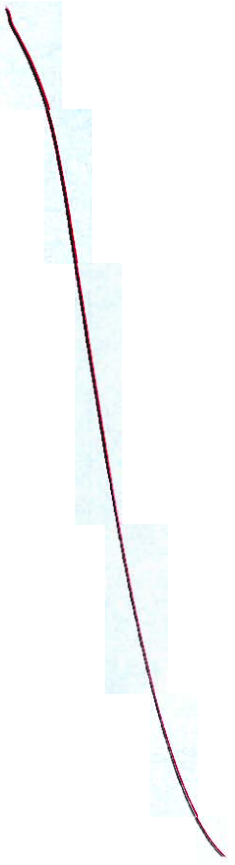


Burmister's two-layer deflection factors

E_1 = Elastic modulus of pavement

E_2 = Elastic modulus of subgrade.

[15 marks]



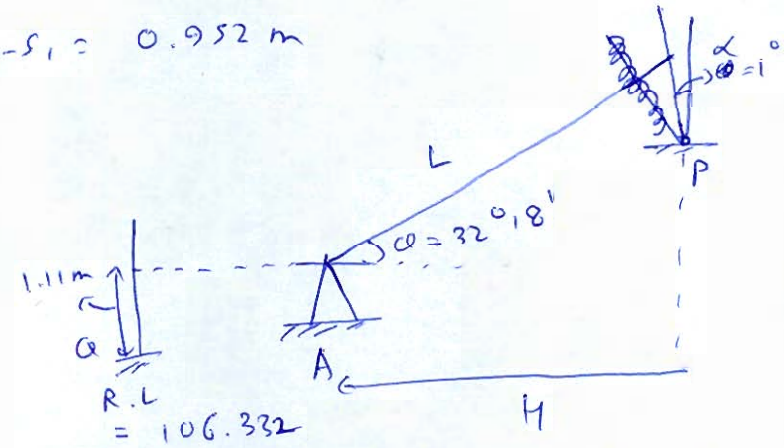
Q.3 (a) **(i)** The following tacheometric observations were made on a point *P* from station A.

Staff at	Vertical Angle	Staff Reading		
		Upper	Middle	lower
P	32°18′	1.385	0.909	0.433

The staff, which was intended to be kept vertical, was inclined towards the instrument station by 1°. The R.L. of instrument station was calculated by sighting a point *Q* of known RL 106.332 m. If the reading obtained at station *Q* was 1.11 m, then compute the horizontal distance of *P* from station A and also determine its R.L. (Take *K* = 100 and C = 0)

[12 marks]

$S = S_3 - S_1 = 0.952$ m



Now, $L = K S \cos(\theta + \alpha) + C$ (when staff is perpendicular)

So, $L = 100 \times 0.952 \times \cos 31°18'$

$L = 81.3444$ m

So, Horizontal distance of P from A.

$\Rightarrow L \cos\theta + S_2 \sin\alpha$

$\Rightarrow 81.3444 \cos 32°18' + 0.909 \times \sin 1°$

$H \Rightarrow 68.773$ m

& R.L of P

$\Rightarrow$ R.L of $Q + 1.11 + L \sin\alpha - S_2 \cos\alpha$

$= 106.332 + 1.11 + 81.3444 \sin 32°18' - 0.909 \cos 1°$

$R.L._P = 149.999\ m$

Q.3 (a) (ii) Briefly discuss about the applications of remote sensing.

[8 marks]

⇒ Application of remote sensing :-

- Collection of data from a remote location without actually being there due to unaccessibility.
- To track movement of soldiers in our territory or borders.
- To find out the agricultural land where cultivation can be done.
- To check the conditions of glaciers in the mountain range.
- To track various important key factors for development of country.

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Q.3 (b) (i) Give reasons for the following:

1. The parabolic sumit curve produces the best riding qualities.
2. The problem of causing discomfort to the passengers does not arise on summit curves.

(ii) A two-lane, two-way highway is designed for a design speed of 100 km/hr. A vertical summit curve is to be provided at the intersection of an upward gradient of 1 in 50 with a downward gradient of 1 in 80. Due to site conditions, the length of vertical curve has to be restricted to a maximum value of 500 m. Calculate the length of summit curve needed to fulfil the requirements of

1. stopping sight distance.
2. overtaking sight distance or atleast intermediate sight distance.

Discuss the results. The coefficient of longitudinal friction and the acceleration may be taken as 0.35 and 1 m/sec^2 respectively.

[4 + 16 marks]

i) 2. It give no discomfort ~~best riding quality~~ as due to centrifugal force the person travelling feels ~~better~~ lighter on curves.

1. It give best riding quality as vehicle is always under control of the driver & proper light can be used to see larger distance.

ii) 1.) $SSD = 0.278 V t_r + \frac{V^2}{254 f}$

Assume t_r as 2.5 sec.

So, $SSD = 0.278 \times 100 \times 2.5 + \frac{100^2}{254 \times 0.35}$

$= 181.985$ m.

Now, Assume $L > SSD$

So, Length of curve $(L) = \frac{NS^2}{4.4}$ & $N = \frac{1}{50} + \frac{1}{80}$

So, $L = 244.625_m > 181.985_m$ ok

So, provide length of curve = 244.625m for stoping sight distance requirement.

Now, Overtaking sight distance

$OSD = 0.278 V_b t_r + 0.278 \times V_b \times T + \frac{1}{2} \times a \times T^2 + 0.278 V_c T$

$V_A = 100$ kmph

$V_B = 100 - 16 = 84$ kmph.

$V_c = 100$ kmph

Now, $T = \sqrt{\frac{4S}{a}}$ & $S = 0.2V_b + 6$

So, $T = 10.198$ sec.

Assume length of vehicle = 6m

$S = 26m$

So,

$OSD = 0.278 \times 84 \times 2.5 + 0.278 \times 84 \times 10.198 + \frac{1}{2} \times 1 \times 10.198^2 + 0.278 \times 100 \times 10.198$

$OSD = 632.029$ m.

Now, Assume L > OSD & OSD = 632.029 m

So, $L = \frac{NS^2}{9.6} = 1352.33$

But L is limited to 500 m so

$L < OSD$

So, $L = 2S - \frac{9.6}{N}$

$L = 968.673 > OSD$ Not possible

Since no condition is satisfied as Length of curve is limited to 500 m, Thus requirement to fulfil OSD condition is not possible.

In case of ISD, $ISD = 2SD = 363.97$

Assume $L > ISD$

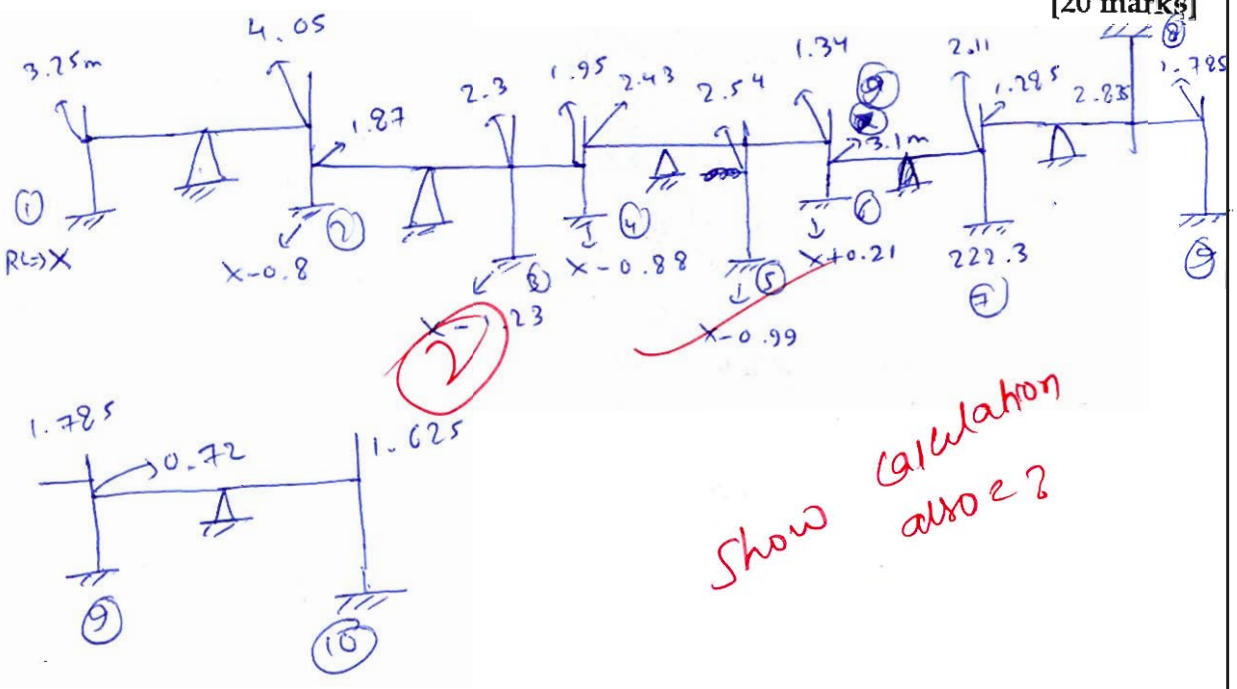
$\Rightarrow L = \frac{NS^2}{9.6} = 448.48 m > 363.97$

So, Length of curve = 448.48 m if ISD condition are fulfilled.

Q.3 (c) A page of level book is reproduced below in which some readings marked as (X) are missing. Complete the page and apply all the suitable checks.

Station	B.S. (m)	I.S. (m)	F.S. (m)	Rise (m)	Fall (m)	R.L (m)	Remarks
1	3.25					X	
2	1.870		4.05X		0.8	X	Control Point
3		2.300			X0.43	X	
4	X2.43		1.950	X.35		X	Control Point
5		2.540			0.110	X	
6	X3.1		1.34X	1.200		X	Control Point
7	1.285		2.110	X0.99		222.300	Control Point
8		-2.835		X4.12		X	Staff held inverted
9	X0.72		1.785		X4.62	X	Control Point
10			1.625		0.905	X	
Σ	12.655 m		X	X	X		

[20 marks]



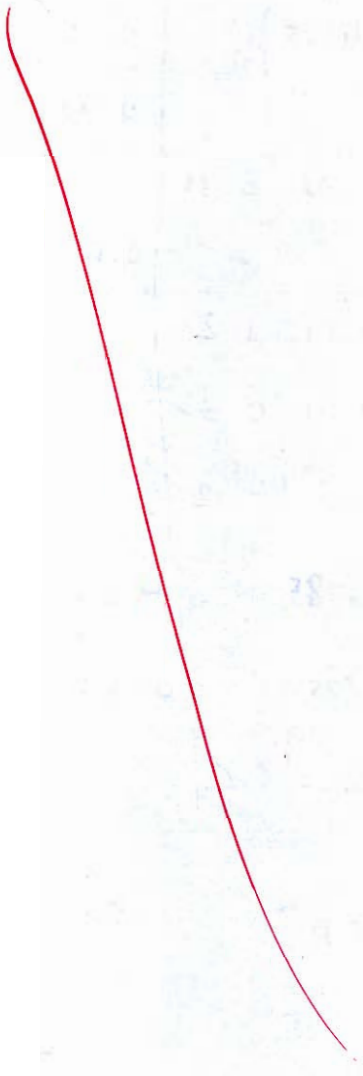
Station	BS	IS	FS	Rise	Fall	R.L	Remark
1	3.25					221.1	
2	1.87		4.05		0.8	220.3	CP
3		2.3			0.43	219.87	
4	2.43		1.95	0.35		220.22	CP
5		2.54			0.11	220.11	
6	3.1		1.34	1.2		221.31	CP
7	1.285		2.11	0.99		222.3	CP
8		-2.835		4.12		226.42	Inverted
9	0.72		1.785		4.62	221.8	CP.
10			1.625		0.905	220.895	
Σ	12.655		12.86	6.66			

$\Sigma BS = 12.655$ m, $\Sigma FS = 12.86$ m

Σ Rise $= 6.66$ m & Σ Fall $= 6.865$

So, $\Sigma BS - \Sigma FS = -0.205$

& Σ Rise $- \Sigma$ Fall $= -0.205$ OK



Q.4 (a) **(i)** Draw the following diagrams obtained from bituminous mix design by Marshall method.

1. Marshall stability vs binder content.
2. Flow value vs binder content.
3. Voids filled with bitumen vs binder content.
4. Density vs binder content.
5. Air voids vs binder content.

(ii) Using the data given below, calculate the wheel load stresses at interior, edge and corner region of a cement concrete pavement using Westergaard's stress equations. Also determine the probable location where the crack is likely to develop due to corner loading.

Wheel load = 4200 kg

Modulus of elasticity of cement concrete = 3×10^5 kg/cm^2

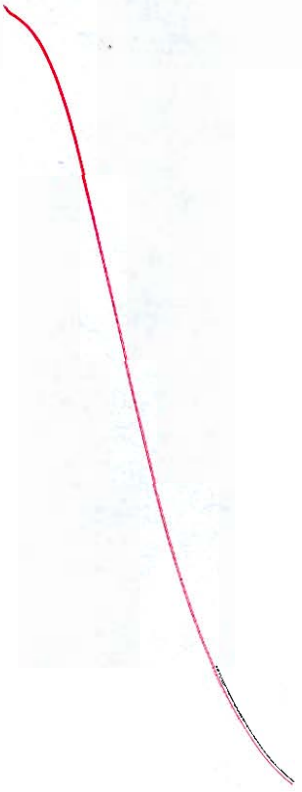
Pavement thickness = 18 cm

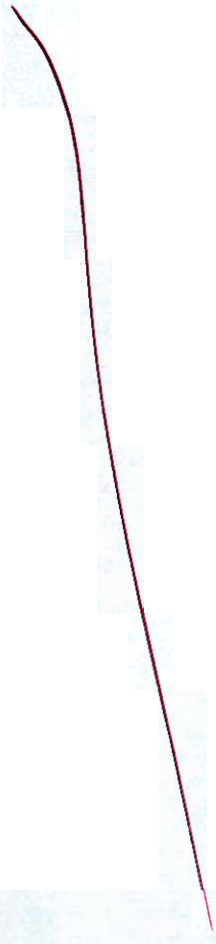
Poisson's ratio of concrete = 0.15

Modulus of subgrade reaction = 7 kg/cm^3

Radius of contact area = 15 cm

[5 + 15 marks]





Q.4 (b) On an approach to a signalized intersection, the effective green time and the effective red time are 30 sec each. The arrival rate of vehicles on this approach is 360 vph between 0 to 120 sec, 1800 vph between 120 to 240 sec, and 0 vph between 240 to 420 sec. The saturation flow rate for this approach is 1440 vphgpl (Vehicles per hour of green per lane). The approach under consideration has one lane. Assume that at time, $t = 0$ sec the light for the approach has just turned red.

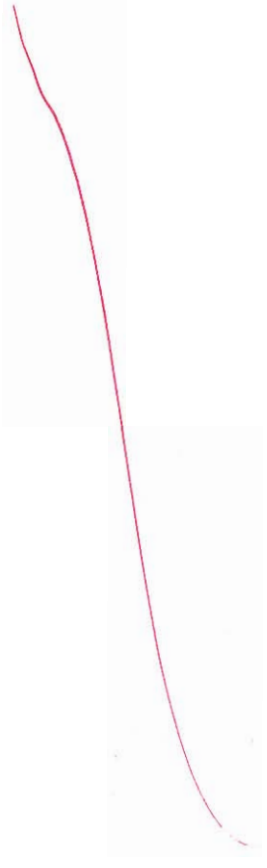
Determine:

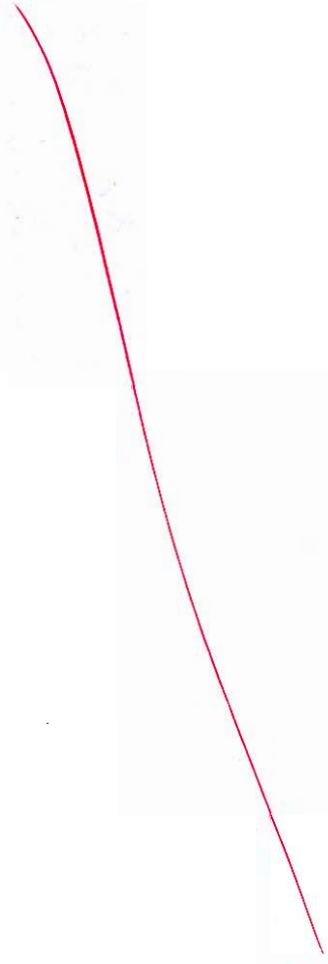
(i) the average delay to vehicles arriving between 0 - 120 sec.

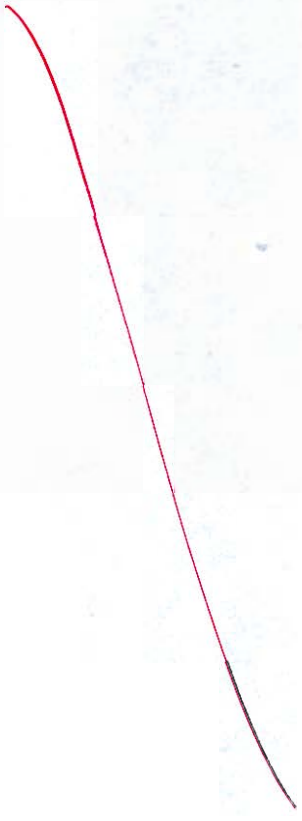
(ii) the average delay to vehicles arriving between 120 - 420 sec.

(iii) the average delay to vehicles arriving between 0 - 420 sec.

[20 marks]





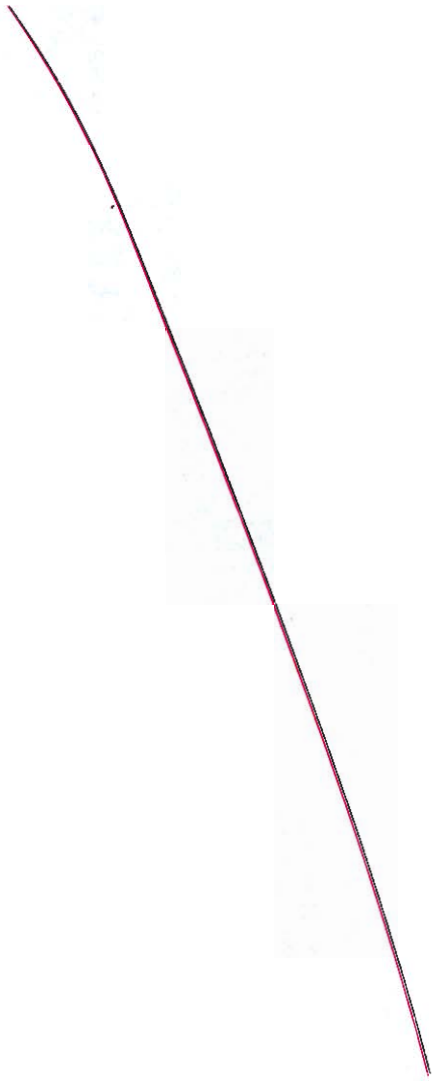


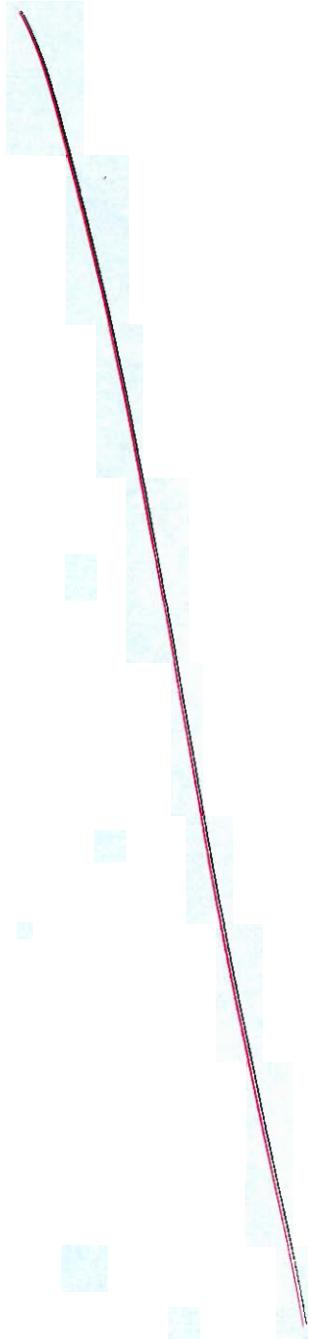
Q.4 (c) (i) Distinguish between:

1. Extrusive and intrusive rocks.
2. Acidic and basic rocks. **[8 marks]**

Q.4 (c) (ii) Discuss briefly about the phenomenon of weathering of rocks with agents associated with each phenomenon.

[12 marks]





Section B : Strength of Materials -1 + Environmental Engineering -1

Q.5 (a) A bar of cross section 10 mm × 10 mm is subjected to an axial pull of 15 kN. The lateral dimension of the bar is found to be changed to 9.9975 × 9.9975 mm^2. If the modulus of rigidity of the material is 8×10^4 N/mm^2, then determine the Poisson's ratio and modulus of elasticity of bar material. Also, find the change in volume of bar when the bar of length 3 meter is subjected to a hydrostatic pressure of 150 N/mm^2. **[12 marks]**

Sol:) i) Poisson ratio ⇒ $\left|\dfrac{\text{Lateral strain}}{\text{longitudnal strain}}\right|$

Axial stress, σ_x

$\Rightarrow \dfrac{15000}{100} \Rightarrow 150\ N/mm^2$.

$\varepsilon_y = \dfrac{\sigma_y - \mu\sigma_x - \mu\sigma_z}{E}$

$\Rightarrow \varepsilon_y = \dfrac{-\mu 150}{2G(1+\mu)}$

$\Rightarrow \dfrac{-2.5\times10^{-3}}{10} = \dfrac{-\mu 150}{2\times8\times10^4(1+\mu)}$

$\Rightarrow$ $\mu = 0.3636$ ⇒ Poisson ratio.

ii) Modulus of elasticity $= 2G(1+\mu)$

$= 21.81 \times 10^4\ N/mm^2$.

$= 2.181 \times 10^5\ N/mm^2$.

(iii) Change in volume

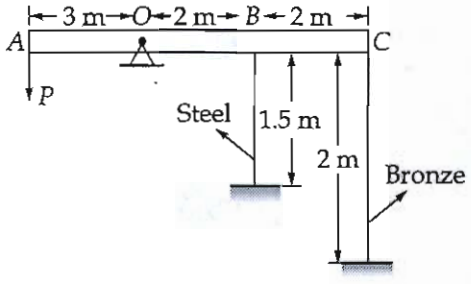
$$\Rightarrow \quad e_v = \frac{\Delta V}{V} = \frac{\sigma_1 + \sigma_2 + \sigma_3}{E}(1-2\mu)$$

10

$$\Rightarrow \quad \Delta V = \frac{3 \times 150}{21.81 \times 10^5}(1-2\times 0.3636) \times 3000 \times 10 \times 10 \ mm^3$$

$$\Delta V = 16.875 \ mm^3$$

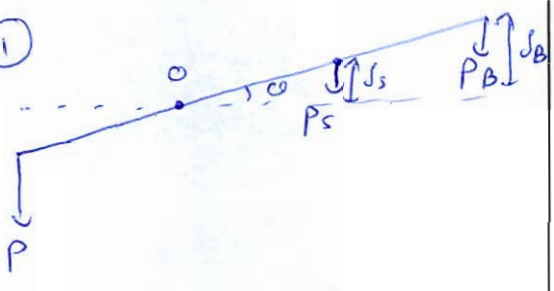
Q.5 (b) A rigid bar with negligible weight is hinged at O and attached to two vertical rods at B and C as shown in figure. Assuming the rods are initially stress free, what is the maximum load P that can be applied at A so that the maximum stresses in the steel and bronze rods do not exceed 160 MPa and 75 MPa respectively? Area of steel bar is 975 mm^2, area of bronze bar is 325 mm^2. Young's modulus of elasticity (E) for steel and bronze are 210 GPa and 85 GPa respectively.



[12 marks]

1.) $\Sigma M_O = 0$

$\Rightarrow 3P = 2P_S + 4P_B$ — (1)



& 2.) $\frac{\delta_S}{2} = \frac{\delta_B}{4}$

$\Rightarrow \frac{P_S \times 1.5}{2 \times 975 \times 210} = \frac{P_B \times 2}{4 \times 325 \times 85}$

$\Rightarrow P_S = 4.9411\, P_B$ — (2)

Using (1) & (2)

$P_S = 1.06779\, P$

& $P_B = 0.2161\, P$

Now, Assume steel reach 160 MPa first.

So, $P_S = 156$ kN

& $P_B = 31.571$ kN So $\sigma_B = 97.14$ MPa > 75 MPa.

So, Bronze fail first.

LD

Thus $\sigma_B = 75\ MPa$.

Check for second strength condition

So, $P_B = 24375\ N = 0.216\,P$

$= 24.375\ kN$

So, $P = 112.795\ kN$

↓

Max allowable P.

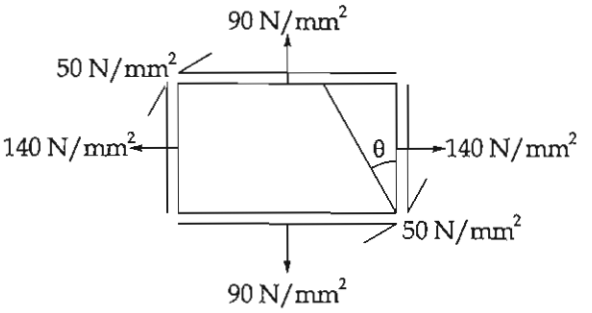
Q.5 (c) At a point in a bracket, the normal stresses on two mutually perpendicular planes are 140 N/mm^2 tensile and 90 N/mm^2 tensile. The shear stress across these planes is 50 N/mm^2. Using Mohr's circle of stress,

determine:

(i) the normal and shear stress on a plane for which $\theta = 30°$.

(ii) the magnitude of the principal stresses and the inclination of the planes on which principal stresses act.

Also, write the steps involved in solving (i) and (ii).



[12 marks]

Given :- $\sigma_x = 140$ MPa, $\sigma_y = 90$ MPa & $\tau_{xy} = -50$ MPa.

So, i) for $\theta = 30°$,

$$\sigma_{\theta=30°} \Rightarrow \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos 2\theta + \tau_{xy}\sin 2\theta$$

$$\sigma_{\theta=30°} \Rightarrow 84.198 \text{ MPa.}$$

& $$\tau_{\theta=30°} \Rightarrow -\left(\frac{\sigma_x - \sigma_y}{2}\right)\sin 2\theta + \tau_{xy}\cos 2\theta$$

$$\Rightarrow -46.65 \text{ MPa}$$

Steps on mohr circle

~~(ii) Magnitude of principal stress~~

i.) Centre of mohr circle $= \frac{\sigma_x + \sigma_y}{2}$

$= \frac{140 + 90}{2} = 115$ MPa

Centre $\Rightarrow (115, 0)$

Radius $\Rightarrow$ (R) $\sqrt{(140-115)^2 + 50^2}$

$\Rightarrow$ 55.901 MPa.

So $\sigma_{max} \Rightarrow 115 + 55.901 = 170.901$ MPa

$\sigma_{min} = 115 - 55.901 = 59.098$ MPa.

Now, $\alpha = \tan^{-1}\left(\frac{50}{25}\right)$

$= 63.4349^\circ$

$\Rightarrow 30^\circ$ angle on stress element will be 60° on circle..

So, $\beta = 180 - 60 - 63.435 = 56.565^\circ$

So, σ at $\theta = 30^\circ = 115 - R\cos\beta \Rightarrow 84.198$ MPa

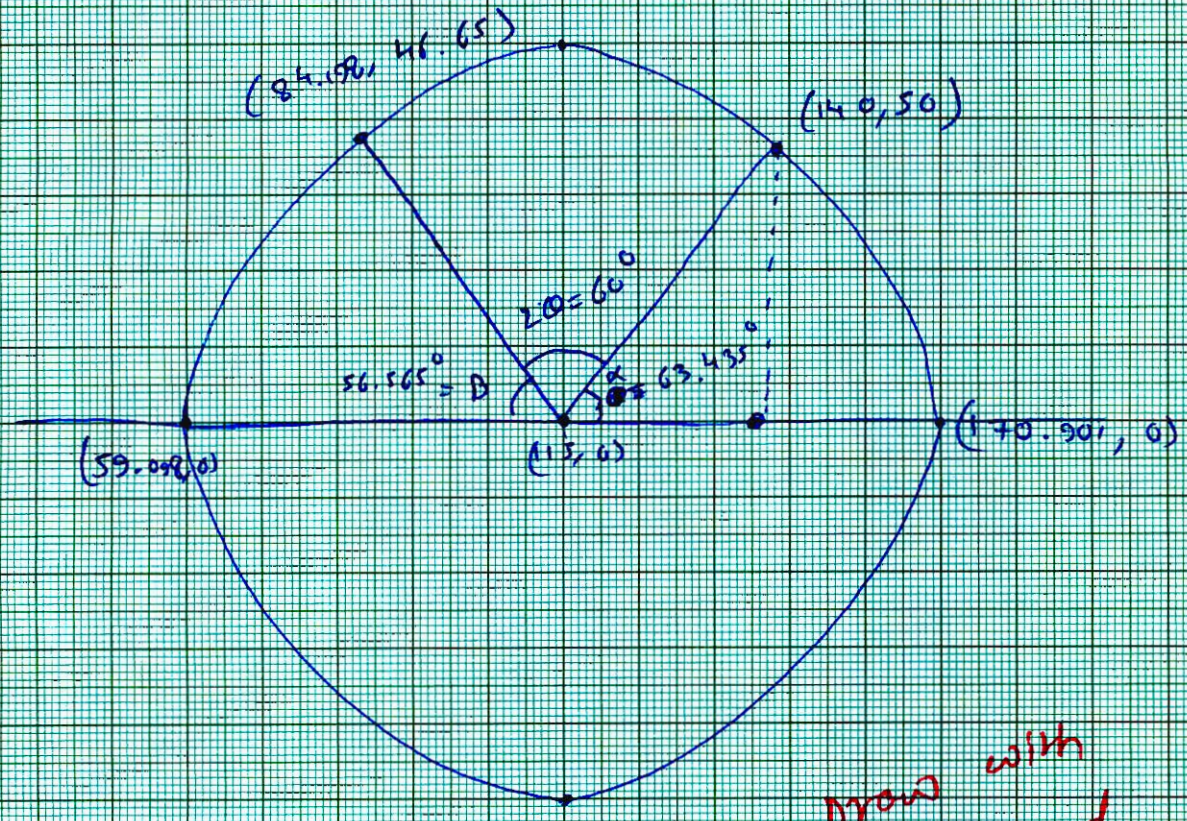
& τ at $\theta = 30^\circ \Rightarrow R\sin\beta \Rightarrow 46.65$ MPa.

Inclination of max $\sigma \Rightarrow \alpha = 63.435^\circ$ on

Inclination of min $\sigma \Rightarrow \beta + 60 = 116.565^\circ$ Mohr circle

So, for element angles will be half of their value i.e $\Rightarrow \frac{\alpha}{2} = 31.7175^\circ$

& 58.2825°.



Draw with pencil and instruments.

2

Date :
Page No. :

Q.5 (d) A filter consists of a 1 m depth of uniform sand with a diameter of 0.4 mm and shape factor of 0.85. The porosity of bed is 0.4 and specific gravity of sand is 2.65. Filtration rate is to be kept as 5 m/hr. Determine the head loss through filter using Karman-Cozney equation. (Take Dynamic viscosity of water as 1.001×10^{-3} N-s/m^2).

[12 marks]

Q.5 (e) What are the air-pollution-control devices available for control of particulate contaminants? Briefly explain the working principles of these devices along with the size range of particulate matter that each type of device is capable of removing efficiently.

[12 marks]

Device available

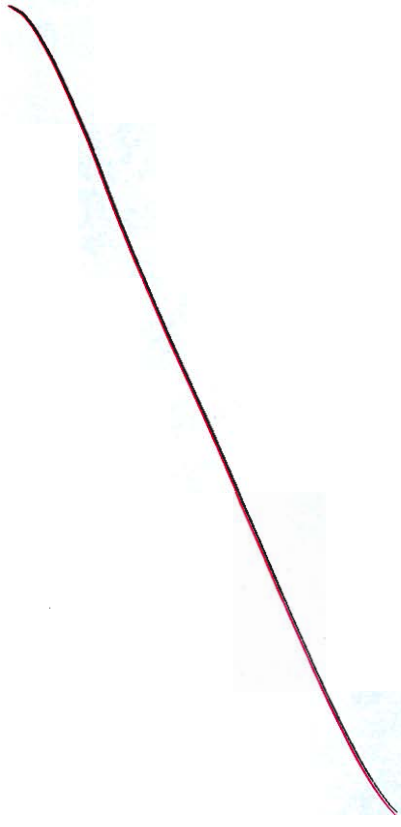
1.) Fabric filter ⇒ $\geq 1\ \mu m$

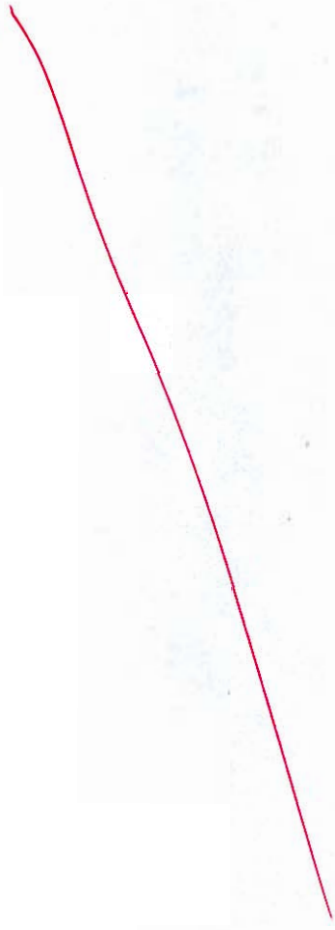
2.) Cyclone precipitator

3.) Electrostatic precipitator ⇒ $< 1\ \mu m$

4.) Gravity settling Chamber. ⇒ $> 50\ \mu m$

2





Q.6 (a) Explain alkalinity in raw water. What are the common sources of alkalinity in raw water? How is it measured? A 100 ml sample of water is titrated with 0.02 N H_2SO_4. The initial pH is 9.5 and 6.2 ml of acid is required to reach the pH of 8.3. An additional 9.8 ml of acid is required to reach the pH of 4.5. Determine the species of alkalinity present and concentration of each species.

[20 marks]

Sol:) Alkalinity is defined as the presence of hydroxyl ions, carbonate ion or bicarbonate ion in raw water.

3

- Common source of alkalinity in raw water as basic material, products containing carbonates, bicarbonates etc.

→ It is measured using titration on sample raw water.

Now, 6.2 ml corresponds to 6.2 mg of alkanility as $CaCO_3$.

alkanility in 100 ml, so for OH^- & $\frac{1}{2} CO_3^{2-}$, so concentration of OH^- & $\frac{1}{2}CO_3^{2-}$ is 62 mg/l.

So, $[OH^-] + \frac{1}{2}[CO_3^{2-}] = 62$

& $[OH^-]$ initially $\Rightarrow 10^{-4.5} \times 10^3 \times 50$

$\Rightarrow 1.58$ mg/l.

So, $[OH^-] \Rightarrow 1.581$ mg/l.

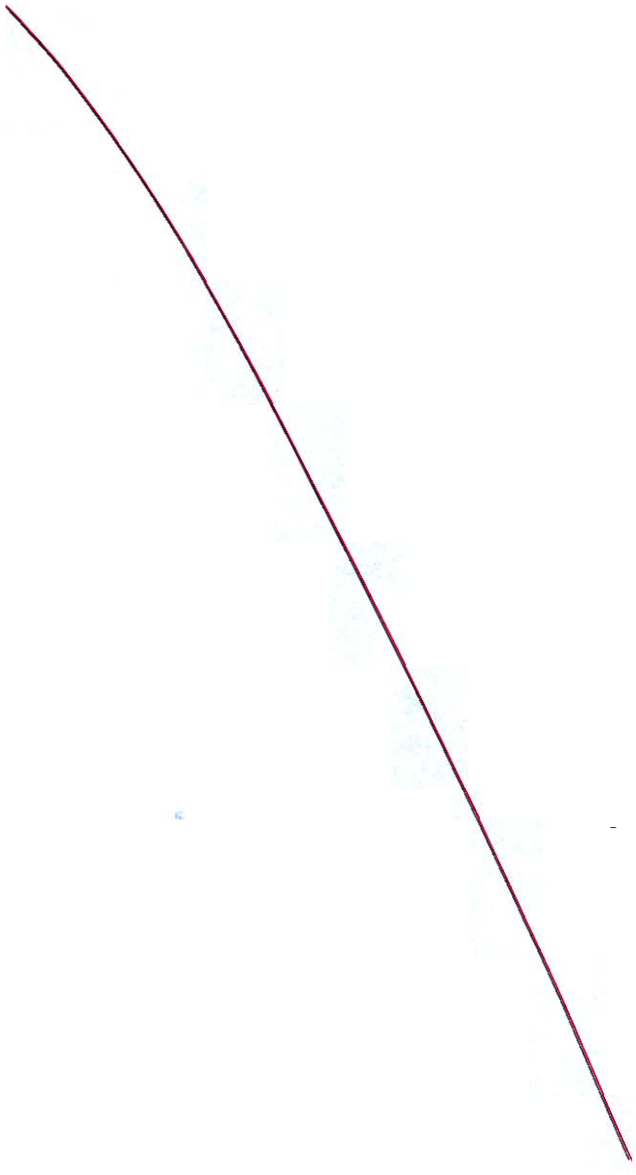
& $[CO_3^{2-}] \Rightarrow 120.837$ mg/l

10

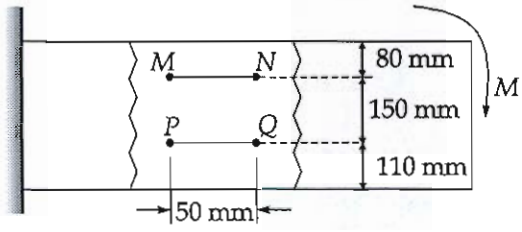
& $\frac{1}{2}[CO_3]^{2-} + [HCO_3]^- = 98$

So, $[HCO_3]^- = 37.581$ mg/l.

Species present $\Rightarrow [OH^-]$, $[HCO_3]$ & $[CO_3^{2-}]$.



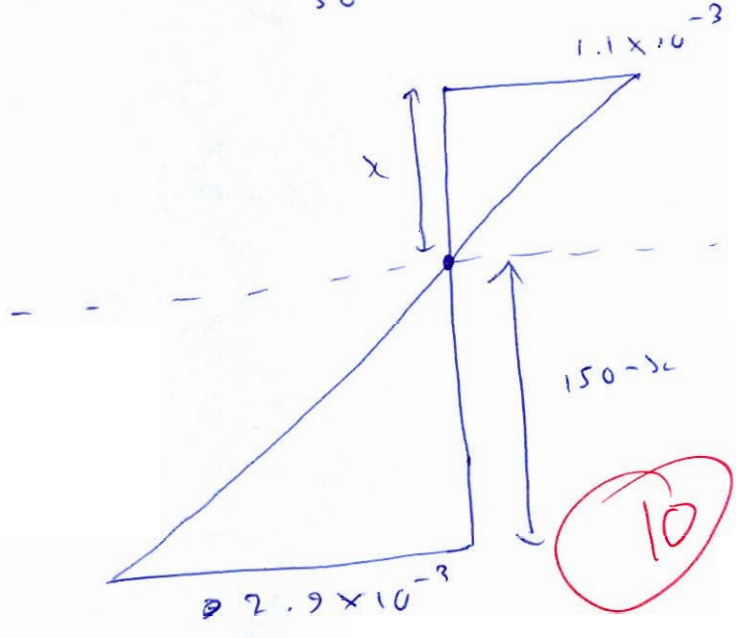
Q.6 (b) (i) A beam is subjected to end couples as shown below. In the laboratory, it is observed that fibres at layer MN are longer by 0.055 mm and fibres at layer PQ shorter by 0.145 mm in 50 mm gauge length. Determine the depth of neutral axis from top fibre and flexural stress at top and bottom fibres.
(Take $E = 2.1 \times 10^5$ N/mm^2)



[10 marks]

i.) Strain in $MN = \frac{0.055}{50} = 1.1 \times 10^{-3}$

Strain in $PQ = \frac{-0.145}{50} = -2.9 \times 10^{-3}$



Now,

$$\frac{1.1 \times 10^{-3}}{x} = \frac{2.9 \times 10^{-3}}{150 - x}$$

$x = 41.25$ mm

So, Neutral axis is at $80 + x$

$\Rightarrow$ 121.25 mm from top

Now, strain at top $\Rightarrow \frac{1.1\times10^{-3}}{41.25}\times 121.25$

$\Rightarrow 3.233\times10^{-3}$

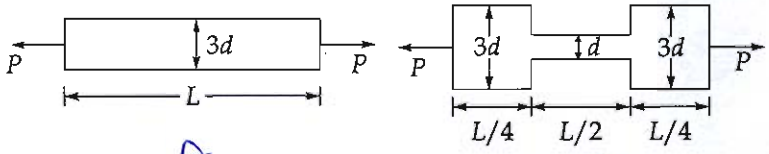
Top flexural stress $\Rightarrow E\epsilon \Rightarrow 679$ MPa (Tensile)

Strain at bottom $= \frac{2.9\times10^{-3}}{108.75}\times 208.75$

$\Rightarrow 5.833\times10^{-3}$

Bottom flexural stress $\Rightarrow E\epsilon = 1225$ MPa.

Q.6 (b) **(ii)** Two bars of same material and same length are subjected to equal gradually applied tensile loads. One bar is $3d$ in diameter throughout and the other has diameter d over the middle half of its length and the remainder length having diameter $3d$ as shown in figure. Determine the ratio of strain energies of two bars.



[10 marks]

i) Energy in A $\Rightarrow \frac{P^2L}{2AE}$

$\Rightarrow \frac{P^2L}{2\times\frac{\pi}{4}(3d)^2E}$

$\Rightarrow \frac{2}{9}\frac{P^2L}{\pi d^2E}$

ii) Strain energy in B $\Rightarrow \frac{P^2}{2E}\left[\frac{L}{4\frac{\pi}{4}(3d)^2}+\frac{L}{2\frac{\pi}{4}d^2}+\frac{L}{4\frac{\pi}{4}(3d)^2}\right.$

$$\Rightarrow \frac{1}{2}\frac{U}{}\frac{P^2L}{\pi d^2 E}$$

So, Ratio of strain energy of A & B $\Rightarrow$ 2/9 / 10/9

10

$= 1/5$

Ratio of A & B $\Rightarrow$ 1 : 5

Q.6 (c) **(i)** What are the factors that affect bactericidal efficiency of chlorine?

[8 marks]

i) Factors affecting efficiency of chlorine:-

1. PH of the water.
2. Turbidity of water.
3. Chlorine demand of water.
4. Presence of ammonia in water.
5. Temperature of water.
6. Quality of water.
7. Dissolved impurities in water.

4

Q.6 (c) (ii) Compute the quantity of 85% lime and 90% pure soda required to soften 3 million litres of raw water containing alkalinity of 250 mg/l as $CaCO_3$, hardness as $CaCl_2$ equal to 60 mg/l and $MgSO_4$ as 80 mg/l.

[12 marks]

i) a) Lime removes all carbonate hardness.

b) NCH present of Mg is converted to NCH of Ca by lime.

& c) Soda removes all the NCH initially present of Ca or converted by from Mg.

So. ~~i) CH = Min {TH, Alk}~~

Total CH = Min {TH, Alk}

Since NCH is present

CH = 250 mg/l. = Alk.

So, CH ⇒
in 3 million litre water ⇒ 750 kg
as $CaCO_3$

1 mole lime removes 100 mg of $CaCO_3$ CH.

So, No. of moles of lime req ⇒ $\frac{750 \times 1000}{100 \times 0.85}$

⇒ $\frac{7500}{0.85}$

= 8823.529 moles

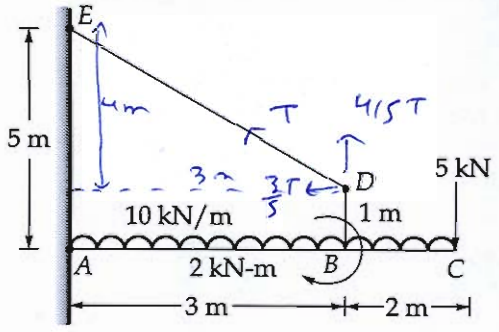
So, lime required ⇒ $8823.529 \times 56 \times 10^{-3}$

= 494.11 kg. of lime.

& Soda required ⇒ $\left(\frac{60}{111} + \frac{80}{120}\right) \times 10^{-3} \times 3 \times 10^{6} \times 142 \times 10^{-3}$ / 0.9

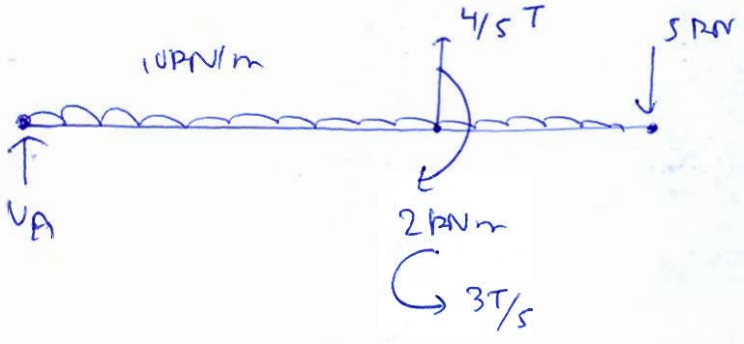
⇒ 571.41 kg of Soda

Q.7 (a) The beam *ABC* as shown in figure is hinged to the wall at *A*. A vertical bracket *BD* is firmly fixed to the beam at *B* and a tie *DE* is hinged to the bracket at *D* and to the wall at *E*. Draw shear force and bending moment diagrams for the beam *ABC*, when it carries an uniformly distributed load of 10 kN/m run over whole length of 5 m, a point load of 5 kN at C and a clockwise moment of magnitude 2 kN-m at *B*. Also calculate the maximum bending moment and locate the point of contraflexure also.



Assume T in DE

[20 marks]



Now, $\Sigma M_A = 0$

$$\Rightarrow 10 \times 5 \times \frac{5}{2} + 2 + 5 \times 5 - \frac{3T}{5} - \frac{4}{5}T \times 3 = 0$$

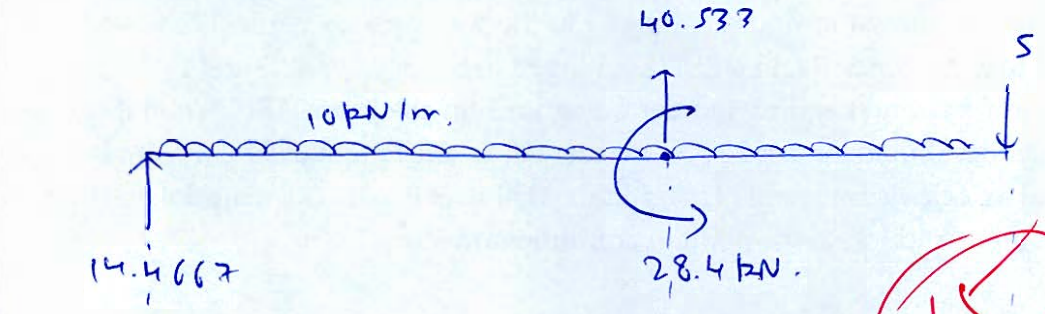
$$\Rightarrow 152 = 3T$$

$$T = 50.66 \text{ kN}$$

So, $4/5\,T = 40.533$ & $\frac{3}{5}T = 30.4$ kN.

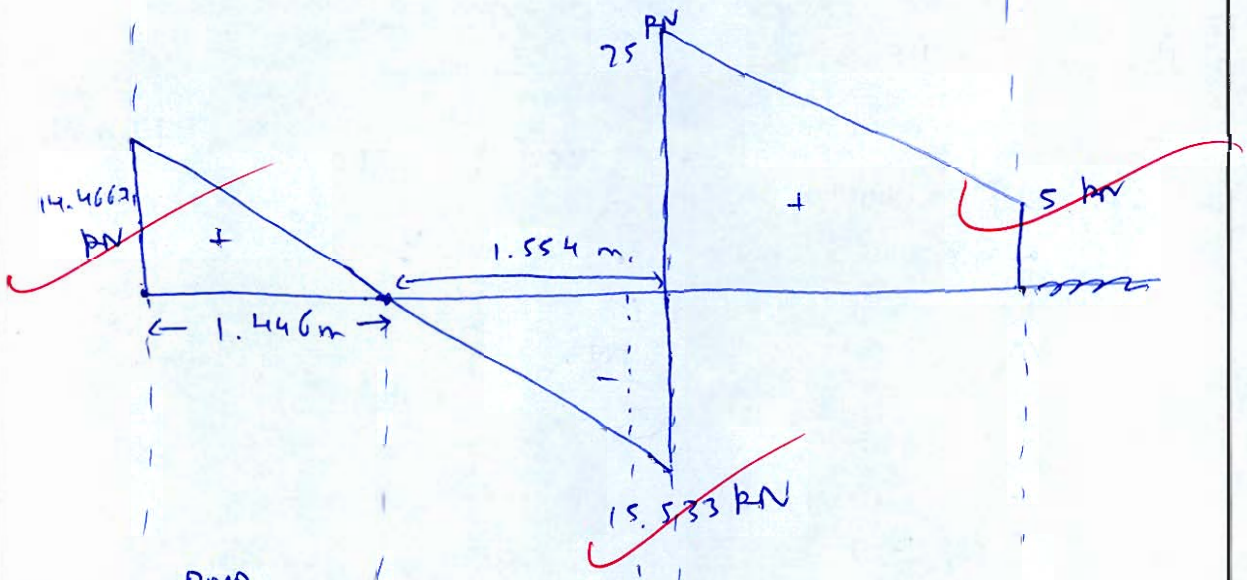
So, ~~Actual loading~~ & $V_A = 14.4667$ kN.

So, Actual loading.

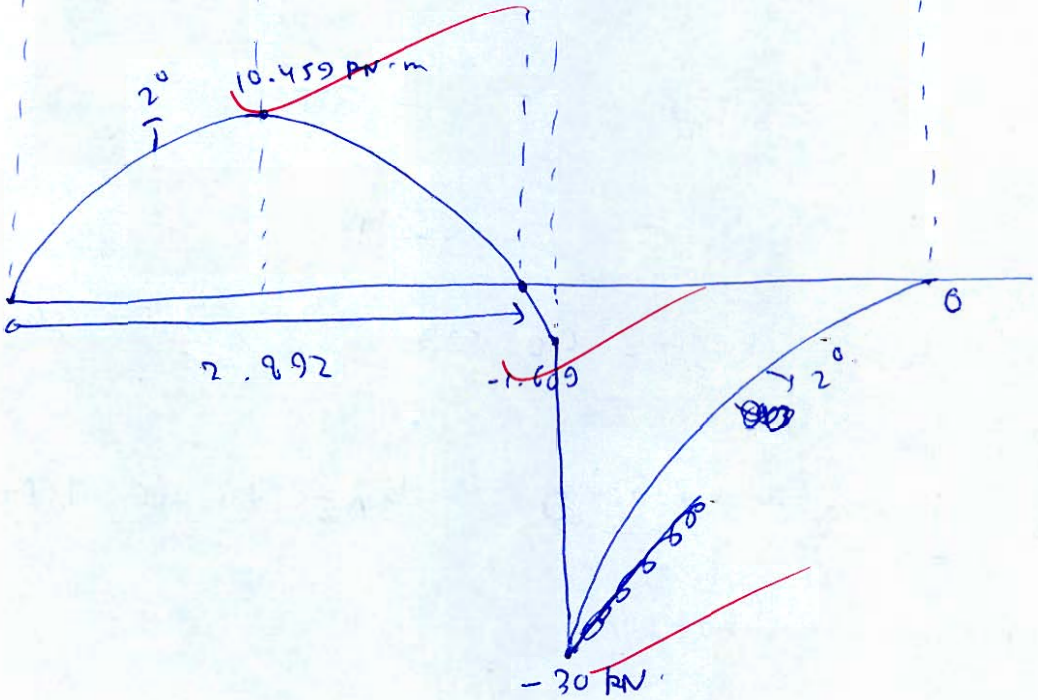


15

So, Shear force diagram.



Now, BMD.



Max +ve bending moment = 10.45 kN-m

Max -ve bending moment = -30 kN-m

Point of contraflexure = 2.892 m from A

Show equations with section cut for each beam section.

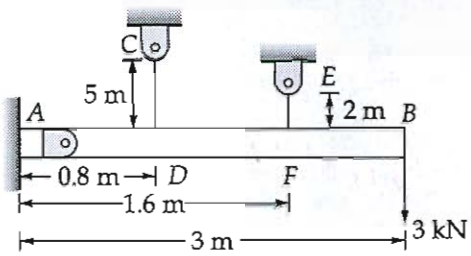
Q.7 (b) A rigid bar *AB* of length 3 m is hinged to a support at *A* and supported by two vertical steel wires attached at point C and *E* as shown in figure. Wire *CD* is 5 m long and 12 mm in diameter and wire *EF* is 2 m long and 3 mm in diameter.

Determine:

(i) the stresses in each wire, if a load of 3 kN is applied at *B*.

(ii) the downward displacement at end *B* of the bar.

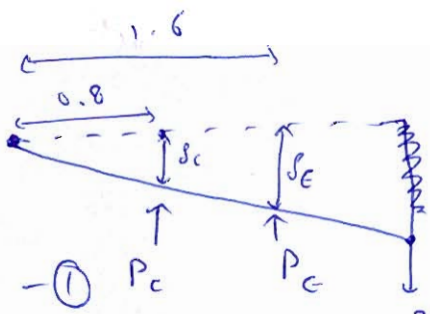
(Take $E = 2.1 \times 10^5$ N/mm^2)



[20 marks]

$\Sigma M_A = 0$

$0.8 P_C + 1.6 P_E = 9$ — (1)



&

$$\frac{\delta_C}{0.8} = \frac{\delta_E}{1.6}$$

$$\Rightarrow \delta_E = 2\delta_C$$

$$\Rightarrow \frac{P_E \times 2}{\frac{\pi}{4} 3^2 \times E} = \frac{2 \times P_C \times 5}{\frac{\pi}{4} \times 12^2 \times E}$$

$$\Rightarrow P_E = 0.3125 P_C \quad -(2)$$

Using (1) & (2).

$P_C = 6.923$ kN & $P_E = 2.1634$ kN

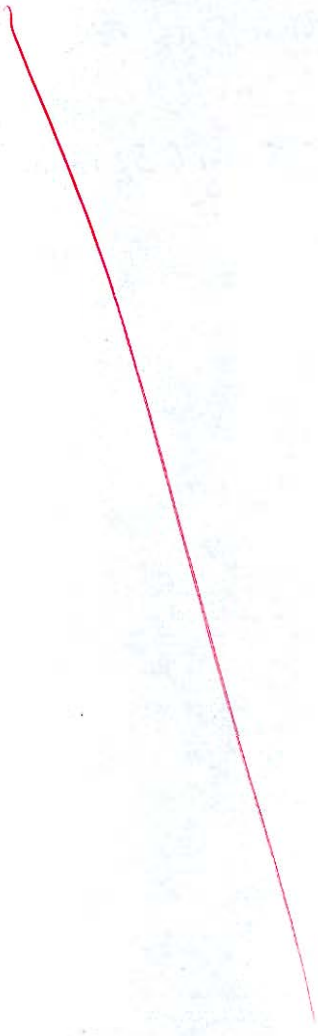
So, $\sigma_C = 61.212$ MPa & $\sigma_E = 306.058$ MPa

Q ii) $\delta_B = \frac{3}{0.8} \times \delta_C$

$\Rightarrow \frac{3}{0.8} \times \frac{P_c L_c}{A_c E}$

$\Rightarrow \frac{3}{0.8} \times \frac{6.923 \times 1000 \times 5000}{\frac{\pi}{4} \times 12^2 \times 2.1 \times 10^5}$

$\delta_B = 5.465 \text{ mm}$



Q.7 (c) (i) Define lapse rate. Explain environmental and adiabatic lapse rate in detail.

[6 marks]

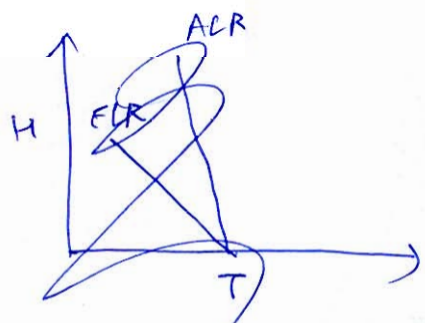
i) Lapse rate is the rate of change of temperature with respect to height.

- Environmental lapse rate is the rate of change of temperature wrt height for air.

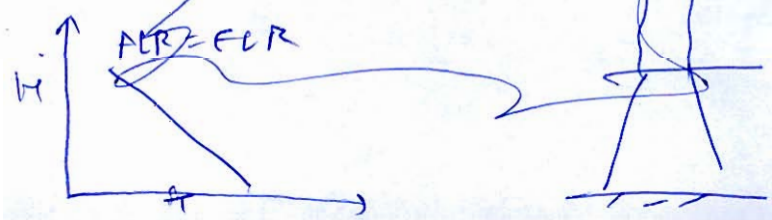
(3)

- Adiabatic lapse Rate is rate of change of temp. wrt height for pollutant particle.

~~ii) a) cooling plume (ELR > ALR) [Unstable / Super adiabatic]~~

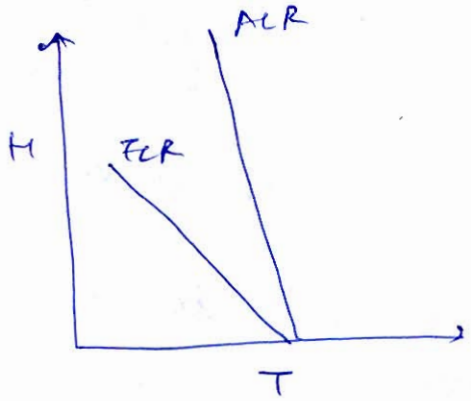


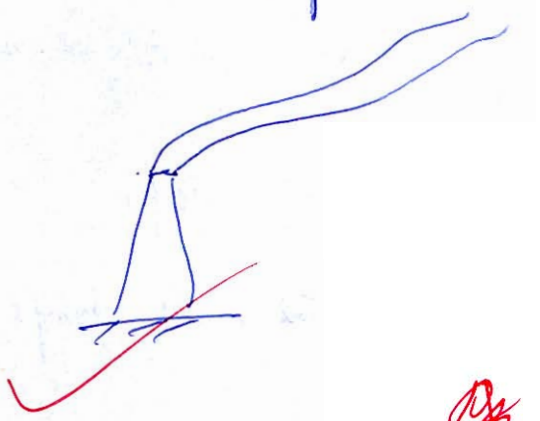
b) Neutral plume (ELR=ALR)



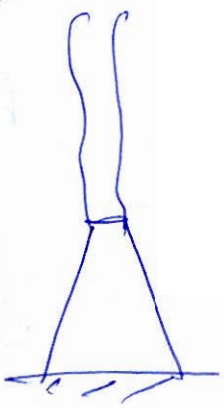
Q.7 (c) **(ii)** Explain the behavior of various types of plume coming out from a stack. **[14 marks]**

i) Looping plume (ELR > ALR) → Unstable / Superadiabatic

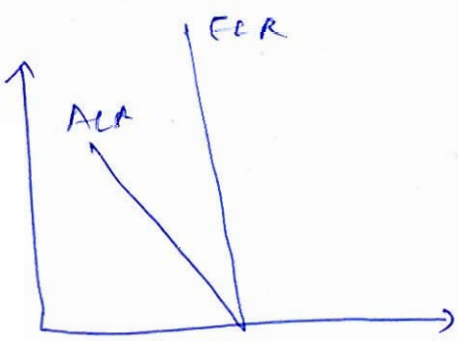


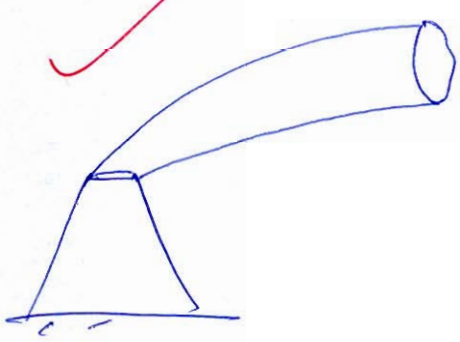


ii) Neutral plume (ELR = ALR)

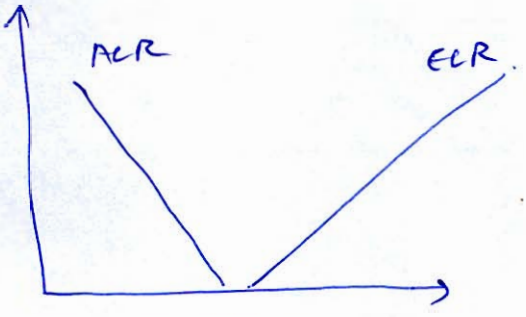


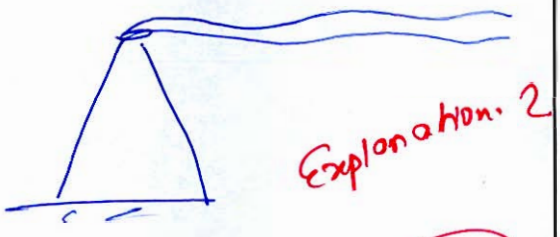
iii) Coning plume (ELR < ALR) → stable





iv.) Fanning plume → (Inversion)

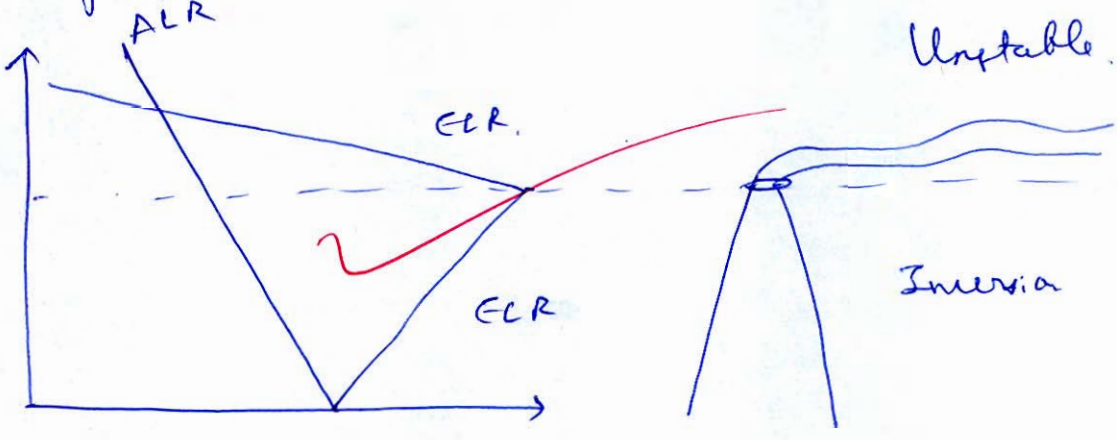




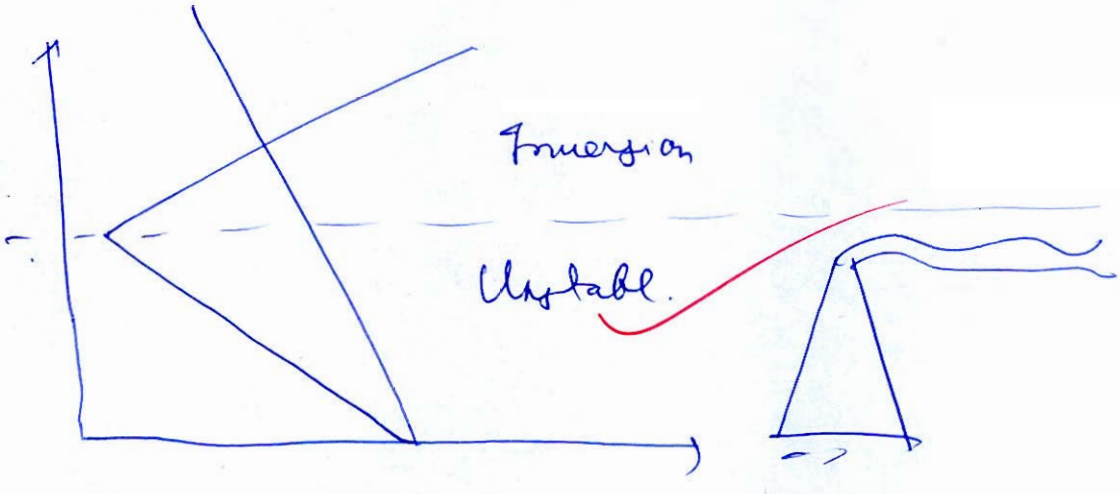
Explanation. 2

0+2

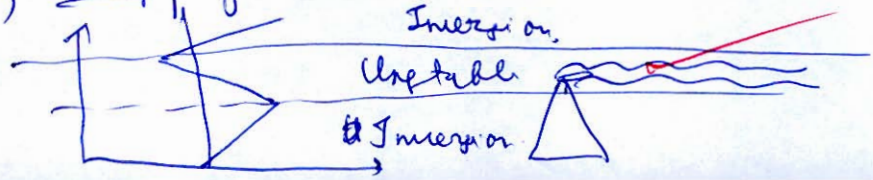
v.) Lofting plume (Best).



vi.) Fumigating plume (Worst)



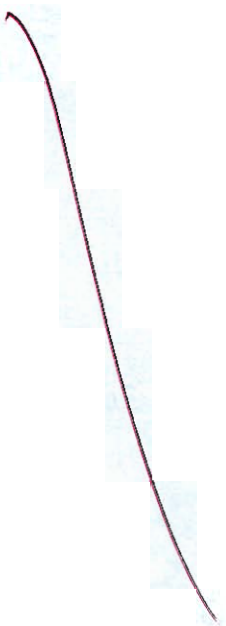
vii.) Trapping plume



Q.8 (a) (i) Assuming the geometric rate of growth of population of a town, calculate the population of town in year 2021 with the help of following census records of population:

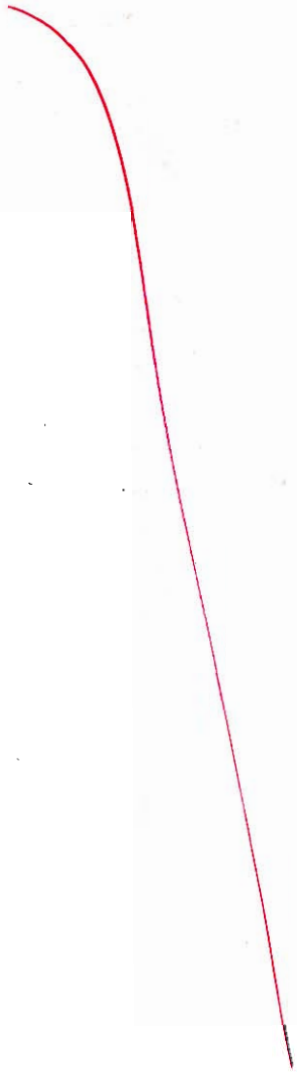
Years	1981	1991	2001	2011
Population (in thousands)	104	126	161	219

[8 marks]



.8 (a) (ii) What are the some of the factors that affect per capita water demand of a city?

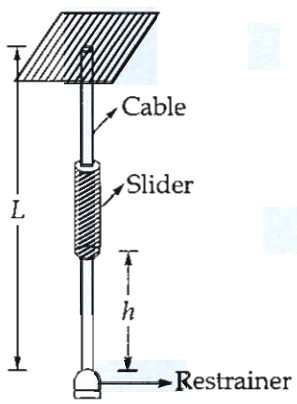
[12 marks]



Q.8 (b) (i) A 12 long beam of uniform section carries a uniformly distributed load of 18 kN/m over the whole length. If the beam is freely supported at the left end, find the position of second support so that the maximum bending moment for the beam shall be as small as possible. Also, find the maximum bending moment for this case.

(ii) A cable with a restrainer at the bottom hangs vertically from its upper end as shown in figure. The cable has cross sectional area of 50 mm^2 and modulus of elasticity $E = 130$ GPa. A slider of mass $m = 40$ kg drops from a height of $h = 1.2$ m on to the restrainer. If the allowable stress in the cable under an impact load is 700 MPa, then, what is the minimum permissible length L of the cable?

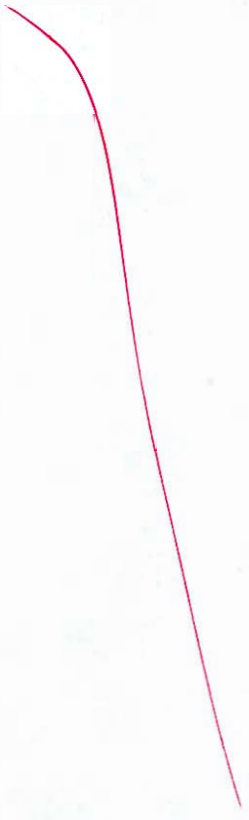
(Take $g = 9.81\ m/s^2$)

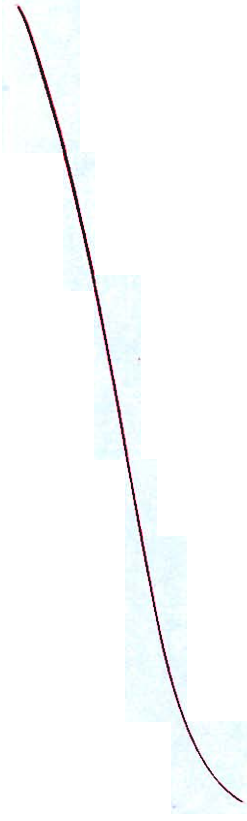


[14 + 6 marks]

8 (c) (i) Explain stages involved in process of EIA of a project in India.

[12 marks]





8 (c) (ii) Write a short note on effects of air pollutants on human health.

[8 marks]

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Space for Rough Work

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Space for Rough Work