MADE EASY

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ESE 2022 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-3 : Strength of Materials [All Topics]

Transportation Engg.-1 + Surveying and Geology-1 [Part Syllabus]

Geo-Technical & Foundation Engg.-2 + Environmental Engg.-2 [Part Syllabus]

Name : .....

Roll No :

Test Centres	Student's Signature
Delhi ☐ Bhopal ☐ Jaipur ☐ Lucknow ☐ Pune ☐ Kolkata ☐ Bhubaneswar ☐ Patna ☐ 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	39
Q.2	51
Q.3	
Q.4	35
Section-B	
Q.5	30
Q.6	
Q.7	
Q.8	7
Total Marks Obtained	162

Signature of Evaluator ..... 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.

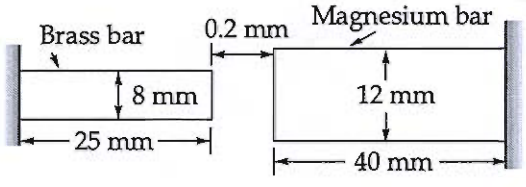
DO'S

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.

Section A

Q.1 (a) A bimetallic thermal control, made of a brass bar of 8 mm diameter and a magnesium bar of 12 mm diameter is as shown in figure. The bars are so arranged that the gap between their ends is 0.2 mm at room temperature. Find the temperature increase above the room temperature at which the two bars just come in contact. Also find the compressive stress induced in magnesium bar when the temperature is increased by 470°F above room temperature.

Take $\alpha_{brass} = 10 \times 10^{-6}$ per °F, $\alpha_{magnesium} = 15 \times 10^{-6}$ per °F, $E_{brass} = 100$ kN/mm^2, $E_{magnesium} = 40$ kN/mm^2.



[12 marks]

Ans We know $\Delta l = l \alpha \Delta T$

$\Rightarrow (l \alpha \Delta T)_{Brass} + (l \alpha \Delta T)_{mag} = 0.2\ mm$

$\Rightarrow (25 \times 10 \times 10^{-6} \times \Delta T) + (40 \times 15 \times 10^{-6} \times \Delta T) = 0.2\ mm$

$\boxed{\Delta T = 235.294\ ^\circ F}$

So temp need to be increased by $235.29^\circ f$

now, $\Delta T = 470^\circ f$

$$\left(l \alpha \Delta T - \frac{\sigma_b l}{E_b}\right) = l \alpha \Delta T - \frac{\sigma_m l}{E_m}$$

4

$\Rightarrow 0.1175 - \frac{\sigma_b \times 25}{4 \times 100\ \frac{kN}{mm^2}} = 0.282 - \frac{\sigma_m\ 40}{40\ \frac{kN}{mm^2}}$

$\sigma_m - \frac{\sigma_b}{4} = 0.282 - 0.1175$ ——— (1)

also $\sigma_b \times A_b = \sigma_m \times A_m$

$\Rightarrow \sigma_b \times (8)^2 = \sigma_m (12)^2 \Rightarrow \sigma_b = 2.25\ \sigma_m$

~~2.25 6m~~ $- \frac{6m}{4}$

$6m - \frac{2.25\,6m}{4} = 0.1645$

$6m = 0.376\ kN/mm^2$

Q.1 (b) (i) There are four alternate proposals for road plan in a district, the details are given as below. Identify with reason which proposal is best. Assume utility value of 1 and 5 per 300t of agricultural and industrial products served.

	Total road length (km)	Number of town and villages served with population range					Productivity in tonnes	
		< 2 K	2K – 5K	5K – 10K	10K – 20K	> 20 K	Agriculture	Industrial
P	800	8	16	30	22	6	150	90
Q	650	6	22	38	40	5	320	75
R	780	6	20	28	38	6	110	60
S	710	12	23	31	26	6	408	40

(ii) The speed of overtaking and overtaken vehicles are 80 kmph and 50 kmph, respectively, on a two way traffic road. The distance between overtaking vehicle and vehicle coming from opposite side is 475 m, when driver took decision of over-taking. The average acceleration during overtaking may be taken as 0.9 m/s^2 and length of wheel base of vehicle is 6 m. The distance between overtaking and overtaken vehicles before overtake is 20 m and 23 m, respectively. Calculate the distance between overtaking vehicle and vehicle coming from opposite direction after overtaking operation. Take design speed as 90 kmph.

[6 + 6 = 12 marks]

Agricult : utility 1 per 300 sqft of agricu
5 Per 300 sqft of industrial.

let utility for population $<2K \rightarrow 0.5$
$2K-5K \rightarrow 1$
$5K-10K \rightarrow 2$
$10K-20K \rightarrow 4$
$>20K \rightarrow 8$

total utility

$$P = (8\times0.5 + 16\times1 + 30\times2 + 22\times4 + 6\times8) + \left(\frac{1}{300}\times150\right) + \left(\frac{5}{300}\times90\right) = 218$$

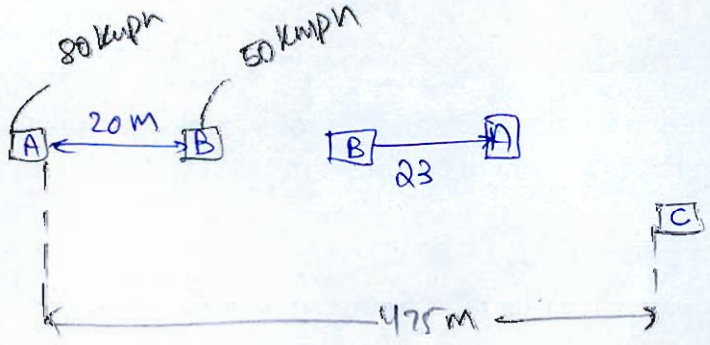
6

$Q = 303.31$ $R = 280.36$ $S = 245.026$

utility per km : $P = 0.272$ ✓
$Q = 0.406$ ✓
$R = 0.359$ ✓
$S = 0.345$ ✓

proposal Q is best. ✓

(ii)



$V_A = 80$ kmph
$V_B = 50$ kmph
$V_C = 90$ kmph (assuming)

$a = 0.4\ m/s^2$
$l = 6m$

here $d_1 = 0.278 V_B t_R = 27.8$ m

$d_2 = S_1 + 0.278 V_B T + S_2 = 178.803$ m

$d_3 = 0.278 V_C T = 244.44$ m

$T = \sqrt{\frac{2(S_1+S_2)}{a}} = 9.77$ sec

$t_R = 2$ sec for OSD

d_4

So 495 $= d_1 + d_2 + d_3 +$ (distan blw A and C)

$d_4 = 23.95$ m

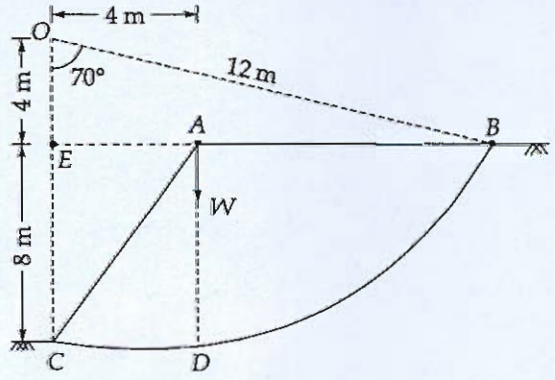
6

Q.1 (c) (i) Write a short note on design features affecting the soil sample disturbance.

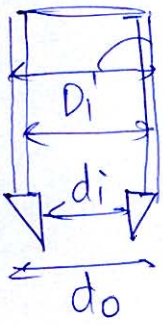
(ii) A slope has been excavated to a depth of 6 m in saturated clay, having the following properties:

$C_u = 60$ kN/m^2, $\phi_u = 0$ and unit weight = 20 kN/m^3.

Determine the factor of safety for trial failure surface as shown in figure.



[3 + 9 = 12 marks]

(i) 

internal dia ratio $= \frac{D_i - d_i}{d_i}$

external dia ratio $= \frac{d_o - D_o}{D_o}$

and Area ratio = ?

(1)

(ii) $C_u = 60\ kN/m^2$ $\phi_u = 0$ $\gamma = 20\ kN/m^3$

$FOS = \frac{\text{Shear Strength}}{\text{Stress Coming on Surface}} = \frac{C + \Sigma N \tan\phi}{\tau}$

wt of section $= \left\{\frac{70}{360} \times \pi (12)^2\right\} - \left(\frac{1}{2} \times 4 \times 11.313\right) - \frac{1}{2} \times 8 \times 4$

$= 49.33 \times 1 \times 20$

$W = 986.74\ kN/m$

resisting moment $= C \times l \times \gamma$

$= \frac{60}{kN/m^2} \times 1 \times \frac{70}{360} \times (2\pi\gamma) \times 12$

$= 10,555.75\ kN.m$

collapsing moment $= W \times 4$

$= 986.74 \times 4 = 3946.96\ kN.m$

$fos = \frac{10,555.75}{3946.96} = 2.674$

9

Q.1 (d) **(i)** What is the significance and application of BOD in sanitary engineering? Derive an expression for the BOD left after certain time.

(ii) The following observations were made on a 5% dilution of waste water:

Dissolved oxygen of water = 3.5 mg/*l*.

Dissolved oxygen of diluted sample after 5 days of incubation = 1.0 mg/*l*.

Dissolved oxygen of original sample = 0.4 mg/l.

Determine the ultimate BOD of the sample, if k_D = 0.15/day at base 10.

[8 + 4 = 12 marks]

(i) * BOD stands for biochemical oxygen demand.
* It measures the amount of oxygen required by microorganisms for decomposition of organic matter
* It indicates that if the ~~DO~~ Dissolved oxygen in water is lesser than saturated DO then the water is polluted.
* BOD bottle test is used to determine 5 day / 3 day BOD of a sample.

Application?

as $L_T = L_o e^{-k_D t}$

$L_T \rightarrow$ amount of oxygen yet to consume.

$BOD_T = L_o - L_o e^{-k_D t}$

$= L_o (1 - e^{-k_D t})$

$BOD_T \rightarrow$ amount of oxygen consumed

$L_o \rightarrow$ ultimate BOD

$K_D \rightarrow$ deoxygenation constant.

(2) Derivation?

(iii) $DF = \frac{5}{100}$

$DO = 3.5$ mg/L (water)

$DO_{mix} = 1$ mg/L (after 5 days)

$DO = 0.4$ mg/L (original)

DO_{mix} at $t = 0$

$= \frac{3.5 \times 95 + 0.4 \times 5}{100} = 3.345$ mg/L

$BOD_5 = \frac{DO_i - DO_f}{DF} = \frac{3.345 - 1}{0.05}$

$= 46.9$ mg/L

as $BOD_5 = L_o (1 - 10^{-k_D t})$ here base 10

$46.9 = L_o (1 - 10^{-0.15 \times 5})$

$L_o = 88.88$ mg/L

(3)

α

Q.1 (e) The principal stresses in a material are 50 MPa, 40 MPa and – 30 MPa. Calculate the following:

1. Total strain energy per unit volume.
2. Volumetric strain energy per unit volume.
3. Shear strain energy per unit volume.

Take E = 200 GPa and Poisson's ratio, $\mu = 0.3$ **[12 marks]**

$\sigma_{p1} = 50$ MPa $\quad \sigma_{p2} = 40$ MPa $\quad \sigma_{p3} = -30$ MPa

(1) Total strain energy per unit volume

$$U = \frac{1}{2E}\left[\sigma_{p1}^2 + \sigma_{p2}^2 + \sigma_{p3}^2 - 2\mu\left(\sigma_{p1}\sigma_{p2} + \sigma_{p2}\sigma_{p3} + \sigma_{p1}\sigma_{p3}\right)\right]$$

$= 0.0271$ MPa / volume

(2) ~~Volumetric~~ Shear strain energy | Distortion strain energy

$$= \frac{1}{12G}\left[(\sigma_{p1} - \sigma_{p2})^2 + (\sigma_{p1} - \sigma_{p3})^2 + (\sigma_{p3} - \sigma_{p2})^2\right]$$

$E = 2G(1+\mu) \Rightarrow G = 76.92$ GPa

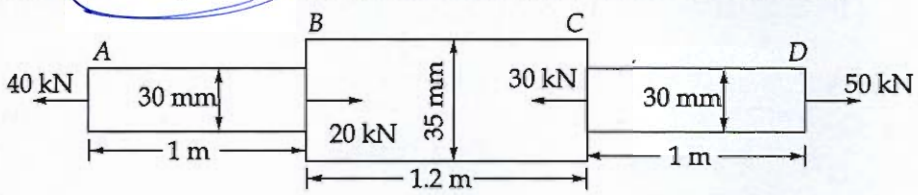
$U_{ss} = \frac{1}{12 \times 76.92} \times$ = 0.01235 MPa Volume

(3) Total strain energy = Volumetric strain energy + distortion/shear strain energy

Volumetric strain energy = 0.01474 MPa Volume

6

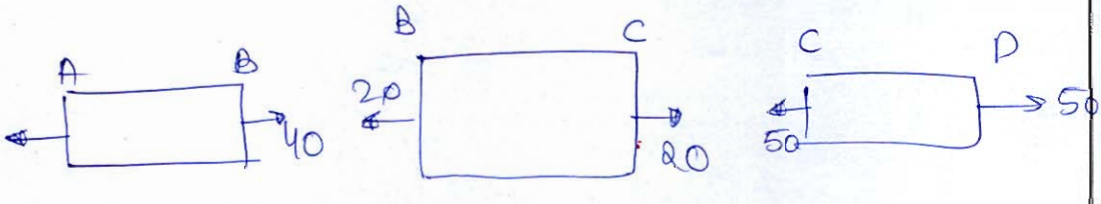
Q.2 (a) **(i)** A steel bar of variable section is subjected to forces as shown in figure. Taking $E = 210$ kN/mm^2, determine the total elongation of the bar.



(ii) If a tension test bar is found be taper from $(D + a)$ diameter to $(D - a)$ diameter, prove that the error involved in using the mean diameter to calculate the Young's modulus is $\left(\frac{10a}{D}\right)^2$ percent.

[10 + 10 = 20 marks]

(i)



$\delta_{AB} = \frac{PL}{AE} = \frac{40 \times 1000}{\frac{\pi}{4}(30)^2 \times 210} = 0.269$ mm

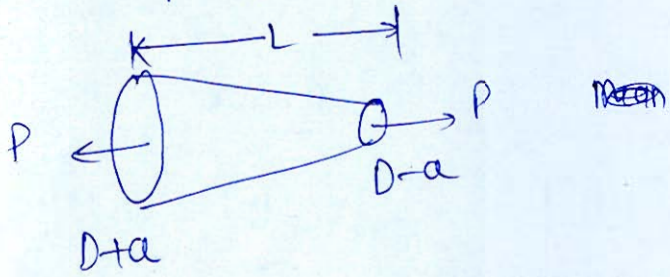
$\delta_{BC} = \frac{20 \times 1200}{\frac{\pi}{4}(35)^2 \times 210} = 0.118$ mm, $\delta_{CD} = \frac{50 \times 1000}{\frac{\pi}{4}(30)^2 \times 210} = 0.3368$ mm

So total elongation = $\delta_{AB} + \delta_{BC} + \delta_{CD}$

= 0.3685 mm ✗ 6

Using superposition principle.

(ii)



We know when varying diameter section is there then

$$\delta = \frac{PL}{\frac{\pi}{4}(D_1)(D_2)E}$$

$$\delta = \frac{PL}{\frac{\pi}{4}(D+a)(D-a)E_1} \quad \text{—— (1)}$$ ✓

When mean diameter is taken,

$$d_m = \frac{(D+a)+(D-a)}{2} = \frac{2D}{2} = D$$

$$\delta = \frac{PL}{AE} = \frac{PL}{\frac{\pi}{4}(D)^2 E_2}$$

$$\% \text{ error} = \frac{E_1 - E_2}{E_1} \times 100$$ ✓

$$= \frac{\frac{PL}{\frac{\pi}{4}(D^2-a^2)\delta} - \frac{PL}{\frac{\pi}{4}(D^2)\delta}}{\frac{PL}{\frac{\pi}{4}(D^2-a^2)\delta}}$$

$$= \frac{\frac{1}{D^2-a^2} - \frac{1}{D^2}}{\frac{1}{D^2-a^2}} \times 100$$

$$= \frac{D^2 - D^2 + a^2}{(D^2-a^2)D^2} \times 100 \times \frac{1}{D^2-a^2}$$

$$= \frac{a^2}{D^2} \times 100$$

$$= \left(\frac{10a}{D}\right)^2$$

here prove

10

Q.2 (b) A town with population of 1,50,000 produces solid waste at the rate of 750 g/ capita-day. The composition of solid waste produced is given below in the table.
The landfill is designed to serve for period of 20 years and height of land fill is restricted to 15 m. The ratio of compacted fill to compacted SW is 1.75. Estimate the area required for the landfill.

Component	Mass fraction	Normal compaction	Density (kg/m^3)
1. Food waste	0.0943	2.8	288
2. Paper	0.4317	5.0	81.7
3. Plastics	0.0181	6.7	64
4. Cardboard	0.0650	4.0	99.3
5. Textiles	0.0020	5.8	64
6. Rubber	0.0088	3.3	128
7. Leather	0.0150	3.3	160
8. Garden Trimming	0.1432	4.0	104
9. Wood	0.0350	3.3	240
10. Glass	0.0749	1.7	194
11. Tin cans	0.0520	5.6	88.1
12. Non-ferrous metal	0.0100	5.6	160
13. Ferrous metal	0.0400	2.9	320
14. Dirt, ashes	0.0100	1.2	480

[20 marks]

Population = 1, 50, 000 Solid w = 750g/c/d

T = 20 yrs h = 15 m

$\frac{\text{Compacted fill}}{\text{Compacted SW}} = 1.75$ A = ?

Total wt of waste generate in 20 yrs $= 150000 \text{ c} \times \frac{750 \text{ g}}{\text{c.d}} \times 365 \times 20$

$= 821250$ ~~g~~ tonne

Component	weight.	Volume.	Compacted volume
1 Food waste	77443.8	288.902×10^3	96.036×10^3
2. Paper	354533	4339.5×10^3	867.9×10^3
3. plastic	14864.62	232.25	34.64
4. Cardboard	53381	537.57	134.4
5. textile	1642.5	25.664	4.42
6. Rubber	7227	56.46	17.109
7. Leather	12318.7	77	23.3
8. Garden trim	117603	1180.79	282.7 10^3
9. Wood	28743.7	119.765	36.292
10 glass	61511.6	317.07	186.51
11. tin cans	42705	484.73	86.55
12. Non-ferrous M	8212.5	5.132	0.9164
13. ferrous metal	32850	102.656	35.84
14 Dirt, ash	8212.5	17.109×10^3	14.25 10^3

Total compacted volume of waste

$= 1820.423 \times 10^3 \ m^3$

Compacted fill $= 1.75 \times 1820.42 \times 10^3$

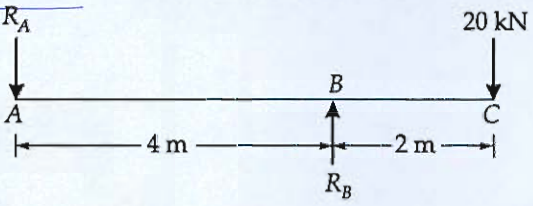
$= 3185740.25 \ m^3$

Area required $= \frac{3185740.25}{15}$

$= 212382.68 \ m^2$

20

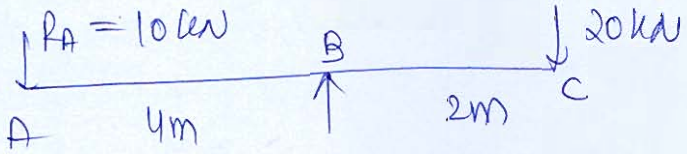
Q.2 (c) (i) An overhanging beam ABC is loaded as shown in figure. Find the equation of deflection curve and calculate deflection at C. Also determine maximum deflection between A and B. Take $E = 200$ GPa and $I = 24 \times 10^{-9}$ m^4.



(ii) Using moment area method, derive an expression for deflection at free end of a cantilever beam of length l subjected to a concentrated moment M at the free end.

[15 + 5 = 20 marks]

we know $EI\dfrac{d^2y}{dx^2} = M_x$



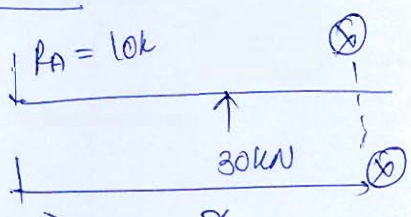
$R_B = 30$ kN

let $\Sigma M_A = 0$, $\quad R_B(4) = 20 \times 6$

$R_B = 30$ kN

$\Sigma F_y = 0 \qquad R_A = 10$ kN

using Macaulay method.



$M_x = -10 \times x + 30(x-4)$

So $EI\dfrac{d^2y}{dx^2} = -10x + 30(x-4)$

Integrating

$EI\dfrac{dy}{dx} = \dfrac{-10x^2}{2} + C_1 + \dfrac{30(x-4)^2}{2}$

$EIy = \dfrac{-10x^3}{6} + C_1x + C_2 + \dfrac{30(x-4)^3}{6}$

using bound condition at $x=0,\ y=0$

$\Rightarrow \quad 0 = 0 + 0 + C_2 \quad \Rightarrow \quad C_2 = 0$

at $x = 4 \quad y = 0$

$$0 = -\frac{10(4)^3}{6} + C_1(4) + 0 \quad \Rightarrow C_1 = \frac{10 \times 4^2}{6}$$

$$C_1 = 26.66$$

so $$y = \frac{1}{EI}\left\{ \underbrace{\frac{-10x^3}{6} + 26.66x}_{\text{Valid b/w } 0 \le x \le 6} + \underbrace{\frac{30(x-4)^3}{6}}_{\text{Valid b/w } 4 \le x \le 6} \right\}$$

for max deflection: $\frac{dy}{dx} = 0$

$$0 = \frac{-10x^2}{2} + 26.66$$

$$x^2 = \frac{26.66 \times 2}{10} \Rightarrow x = 2.309 \text{ from A}$$

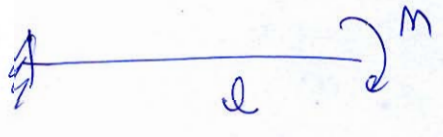
deflection at $C = ?$

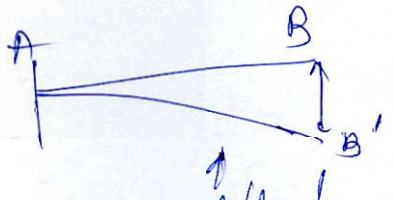
10

$$y = \frac{1}{EI} \times \{-20.517 + 26.66 \times 2.309\}$$

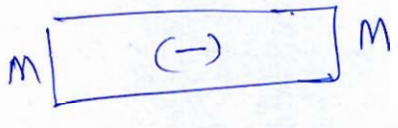
$$\boxed{y_{max} = \frac{41.04}{EI}} = ? \text{ (solve complete)}$$

(ii)

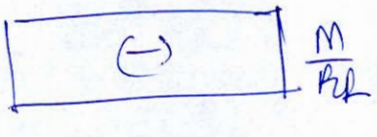




BMD:



$\frac{M}{EI}$ digram:



5

$BB' =$ using Mohr II theorem

(Area b/w A and B) × ($\bar{x}$ from B)

$$\boxed{BB' = \frac{Ml}{EI} \times \frac{l}{2} = \frac{Ml^2}{2EI}}$$

Q.3 (a) A piece of material is subjected to tensile stresses of p_1 and p_2 at right angles to each other ($p_1 > p_2$).

Find the plane across which the resultant stress is most inclined to the normal. Find the value of this inclination and the resultant stress when $p_1 = 60\ \text{N/mm}^2$ and $p_2 = 40\ \text{N/mm}^2$ (both tensile).

[20 marks]

Q.3 (b) (i) Explain in detail, how waste water gets treated in a facultative pond. Draw a neat sketch of facultative pond.

(ii) Waste water flow from a community averages 4000 m^3/d at a temperature of 26°C during summer. The BOD_5 of waste water is 350 mg/L and reaction coefficient k is 0.24 day^{-1} at 20°C. Three facultative ponds are provided to treat the waste water in series having depth of 1.8 m each. Determine the area of each pond, if overall efficiency required is 92%.

[12 + 8 = 20 marks]

Q.3 (c) Explain briefly the properties of summit curve and it's possible types.
Derive an expression for finding reduced level for vertical point of tangency for a summit curve. Also prove that the vertical point of intersection exists at mid of length of summit curve.

[20 marks]

Q.4 (a) A retaining wall of 8 m height has backfill soil in 3 different layers. Top 1 m and bottom-most 3 m layer of clay has their unconfined compressive strengths equal to 50 kN/m^2 and 75 kN/m^2, respectively. The void ratio of top and bottom-most clay is 0.7 and 0.5 respectively. Middle 4 m sand layer has void ratio of 0.45 and when tested in tri-axial test the following results were found:

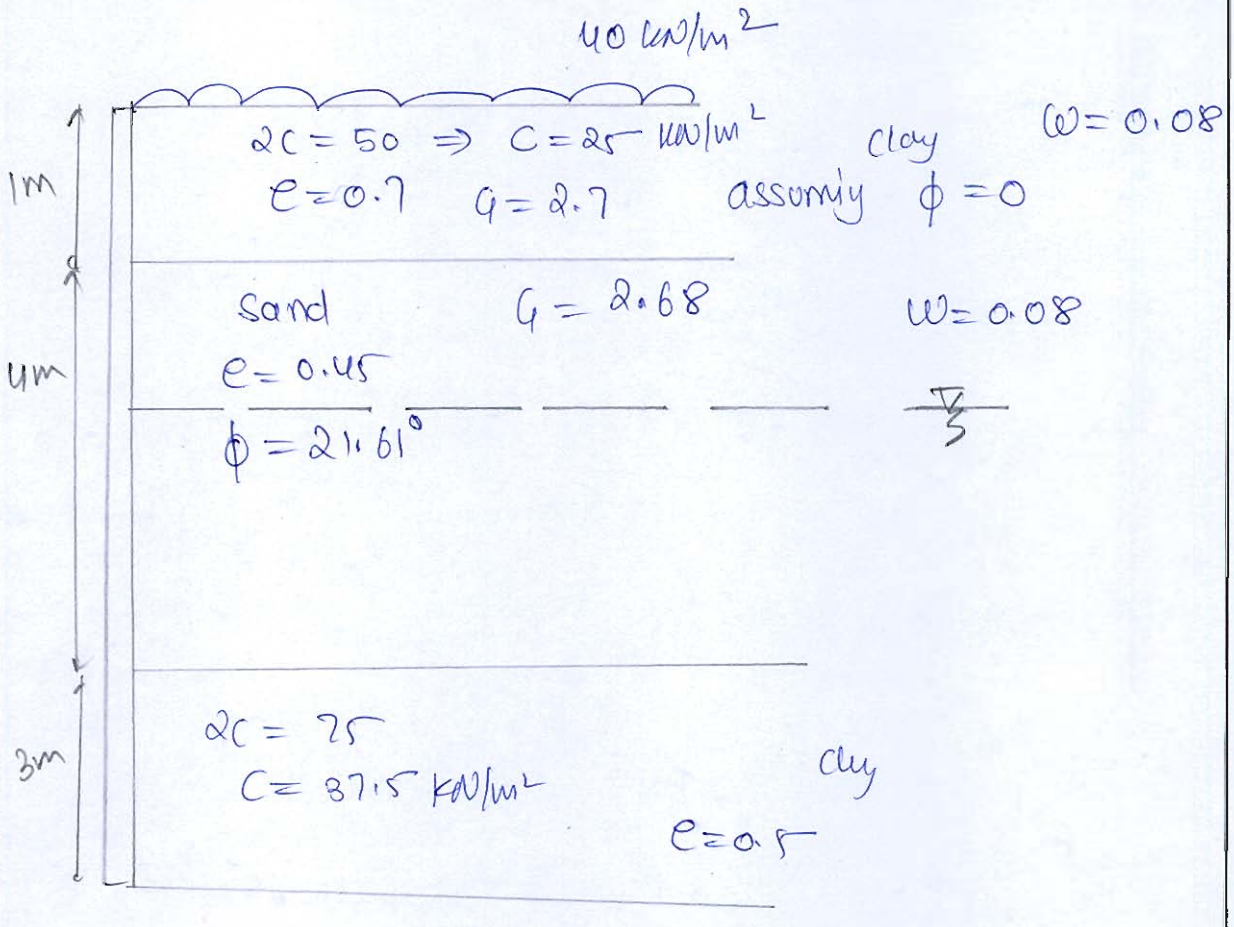
Confining pressure = 300 kN/m^2

Deviator pressure = 350 kN/m^2

Calculate position of total active earth pressure force from bottom of wall, if water table exists 3 m from top of wall and surcharge of 40 kN/m^2 is applied at ground level.

[Take $G_{clay} = 2.7$, $G_{sand} = 2.68$, $w_{clay\ above\ WT} = 8\%$, $w_{sand\ above\ WT} = 8\%$]

[20 marks]



as $\sigma_1 = \sigma_3 \tan^2\left(45 + \frac{\phi}{2}\right) + 2C \tan\left(45 + \frac{\phi}{2}\right)$ (2C → 0)

for sand $C = 0$

$\Rightarrow (300 + 350) = 300 \tan^2\left(45 + \frac{\phi}{2}\right)$

$\boxed{\phi = 21.61°}$

Clay : $\gamma_b = \frac{\gamma_w (G+Se)}{1+e}$ $\quad es = wG$

$= \frac{9.81(2.7+2.7\times0.08)}{1+0.7}$

$\gamma_b = 16.82$

$\gamma_{sat} = \frac{9.81(2.7+0.7)}{1.7} = 19.62 \text{ kN/m}^3$

Sand: $\gamma_b = \frac{9.81(2.68+0.08\times2.68)}{1+0.45}$

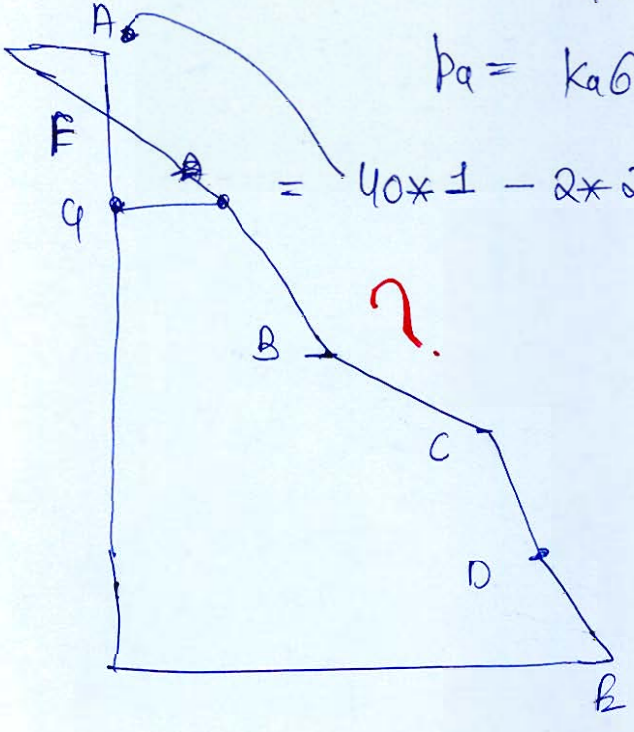
$= 19.58 \text{ kN/m}^3$

$\gamma_{sat} = \frac{9.81(2.68+0.45)}{1.45} = 21.17 \text{ kN/m}^3$

active earth cau, $K_a = \frac{1-\sin\phi}{1+\sin\phi} =$

$p_a = K_a \sigma_v - 2c\sqrt{K_a}$

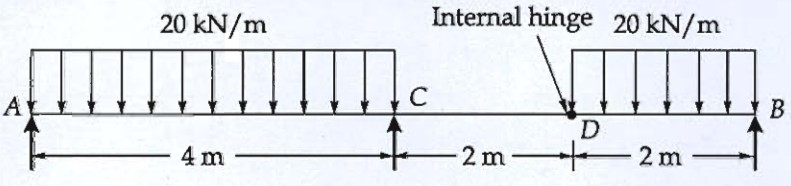
$= 40\times1 - 2\times25 = 40-50 = -10$



7.

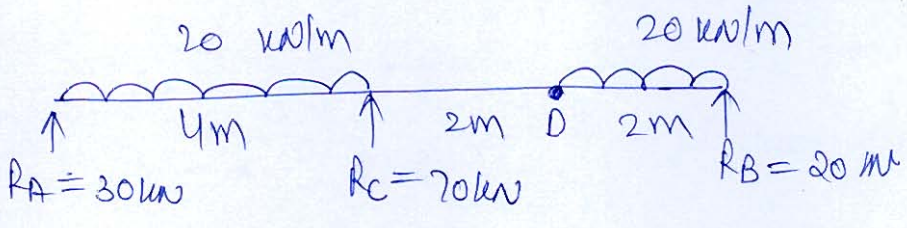
5

Q.4 (b) Draw shear force and bending moment diagram for the beam loaded as shown in figure.



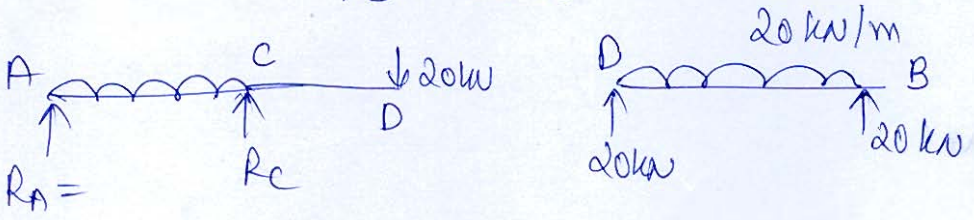
[20 marks]

Ans



$\Sigma M_D = 0 \qquad R_B(2) = 20 \times 2 \times \frac{2}{2}$

$R_B = 20kN$

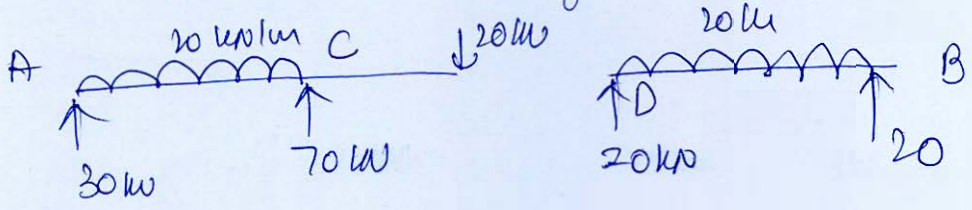


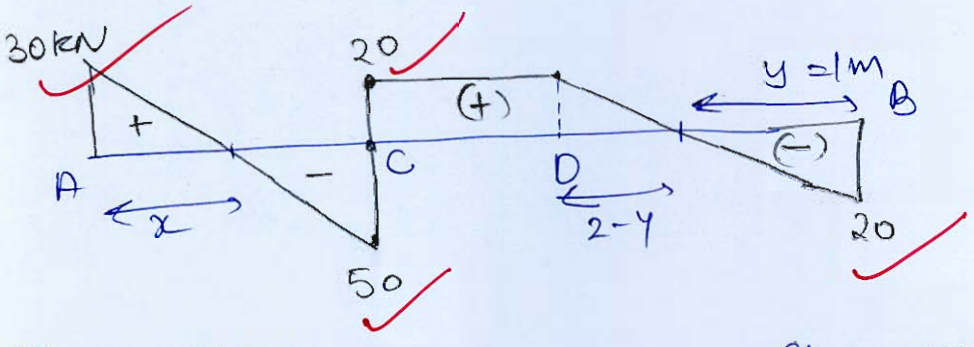
$\Sigma M_C = 0 \qquad R_C(4) = 20 \times 6 + 20 \times 4 \times 2$

$R_C = 70 kN$

$R_A = 30 kN$

Now SFD → Shear force diagram





$SF_A = 30\ kN$

Sign convention
SF: L → R
upward → +ve

(left) $SF_C = 30 - 20\times4 = -50\ kN$

(right) $SF_C = -50 + 70 = +20\ kN$

$SF_D = +20\ kN$

$SF_B = +20 - 20\times2 = -20\ kN$

~~$SF_B = -20 + 20$~~

~~Bending Moment~~

$$\frac{30}{x} = \frac{50}{4-x}$$

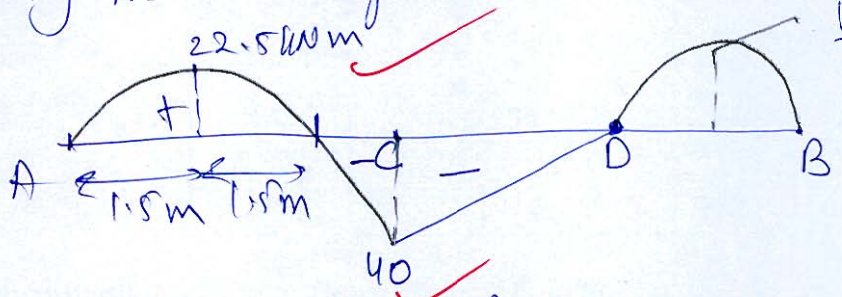
$$80x = 30\times4$$

$$\boxed{x = 1.5\ m}$$

$$\frac{20}{2-y} = \frac{20}{y}$$

$$\boxed{y = 1\ m}$$

Bending moment diagram



$\frac{wl^2}{8} = \frac{20 \times 4}{8} \times 2 = 10 \text{ kN m}$

b/w A and C, $M_x = R_A x - w \cdot x \cdot \frac{x}{2}$

$M_A = 0$

$M_C = 30 \times 4 - 20 \times 4 \times 2 = -40 \text{ kN.m}$

at $x = 1.5\text{m}$

$M = 30 \times 1.5 - 20 \times 1.5 \times \frac{1.5}{2} = 22.5 \text{ kN.m}$

at $y = 1\text{m}$ from B

$M = 20 \times 1 - 20 \times 1 \times \frac{1}{2} = \underline{10 \text{ kN.m}}$

Point of contraflexure : Zero bending moment

$0 = 30x - 10.x^2$

$10x^2 = 30x$

$\boxed{x = 3\text{m}}$

20

Q.4 (c) **(i)** From the traverse data given below, check whether the traverse closes or not. If not, then balance the traverse using Bowditch's rule.

Line	AB	BC	CD	DA
Length (m)	310.5	340.8	405.2	279.2
Bearing	S45°E	N50°30′E	N54°15′W	S33°18′W

(ii) A steel tape was exactly 30 m long at 20°C when supported throughout its length under a pull of 8 kg. A line was measured with pull of 15 kg applied to the tape at a mean temperature of 13°C and was found 800 m long. The cross-sectional area of the tape is 0.03 cm^2, total weight of tape is 0.65 kg. Calculate true length of line if the tape was supported during measurement at every 15 m. Measurements were taken at rising ground of 1 in 300 situated at 800 m above MSL.

Take $\alpha_{steel} = 11 \times 10^{-6}/°C$, $E_{steel} = 2.1 \times 10^6$ kg/cm^2 and radius of Earth, $R = 6370$ km.

[12 + 8 = 20 marks]

(i)

Line	length	(FB, θ)	(l cosθ) latitude	l sinθ Departure
AB	310.5	135°	−219.55	219.55
BC	340.8	50°30′	216.77	262.97
CD	405.2	305°45′	236.73	−328.84
DA	279.2	213°18′	−233.35	−153.287
Σ =	1335.7m		Σ = 0.592	Σ = 0.392

for close traverse : Σ latitude = 0

Σ departure = 0

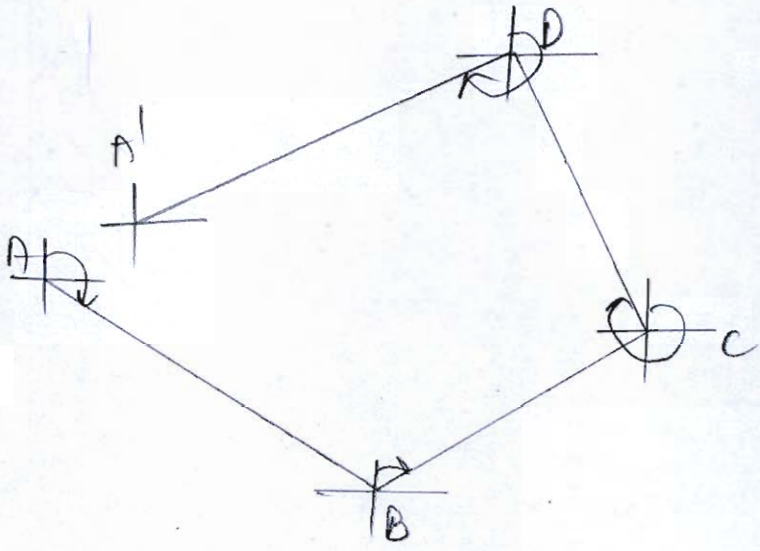
here $\Sigma L = 0.592$

$\Sigma D = 0.3928$

So not closed

$$C_L = -\left|\frac{l}{\Sigma l}\right| e_L \quad , \quad C_D = -\left|\frac{l}{\Sigma l}\right| e_D$$

Always solve survey question's values upto 3 decimal



10

Using Bowditch

Line	Correction	Corrected Latitude	Correction	Corrected departure
AB	−0.1376	−219.687	−0.0913	219.458
BC	−0.151	216.619	−0.100	162.87
CD	−0.1795	286.55	−0.119	−328.959
DA	−0.1237	−233.473	−0.082	153.369

$\Sigma L = 0.009 \approx 0$

$\Sigma D = 0$

(ii) $l = 30m \rightarrow T = 20^\circ C$ (no sag)

$P_0 = 8\ kg$

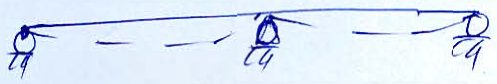
$P_m = 15\ kg$, $T = 13^\circ C$ $\rightarrow L' = 800m$

$A = 0.03\ cm^2$

$W = 0.65\ kg$

due to temp: Corr^n, $C_T = l \alpha \Delta T$

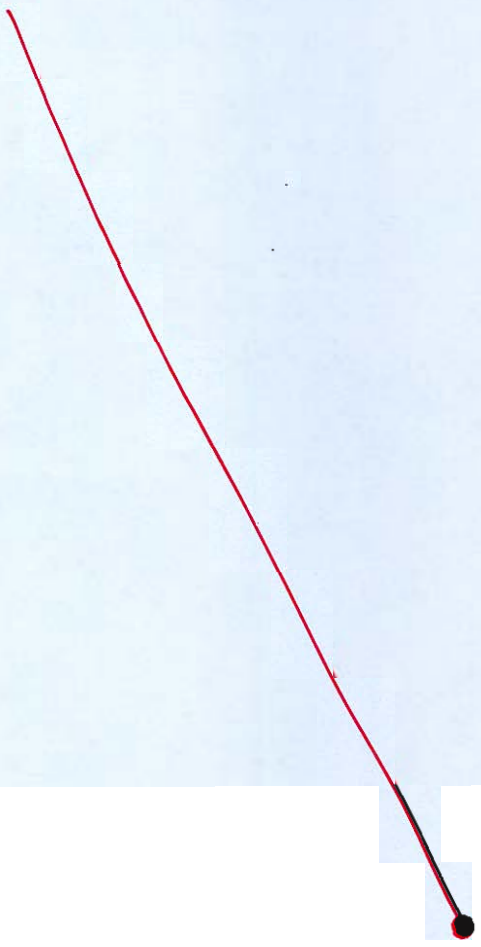
due to pull, correction, $C_p = \frac{(P_m - P_o)L}{AE}$



due to temp $\Rightarrow$ $C_T = 0.0616\ m$

$C_p =$ ——

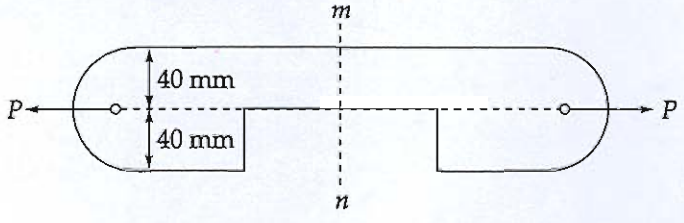
0



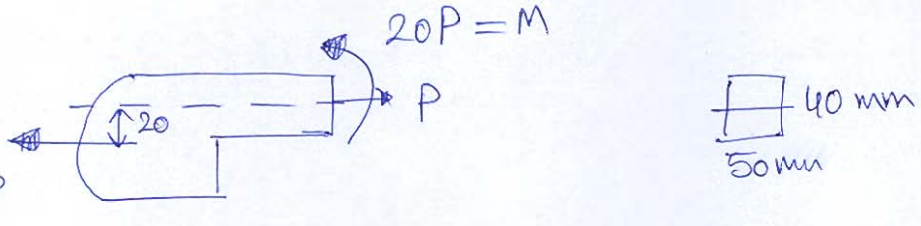
Section B

Q.5 (a) To reduce interference, a link in a machine is designed so that its cross-sectional area in the centre of the section is reduced by one-half as shown in the figure below. The thickness of the link is 50 mm. Given that, $P = 40$ kN.

1. Determine the maximum and minimum values of the normal stress acting on section m-n.
2. Sketch the stress distribution in section *m-n*.



[12 marks]



Direct Normal stress $= \frac{P}{A} = \frac{40 \times 10^3}{50 \times 40} = 20 \frac{N}{mm^2}$

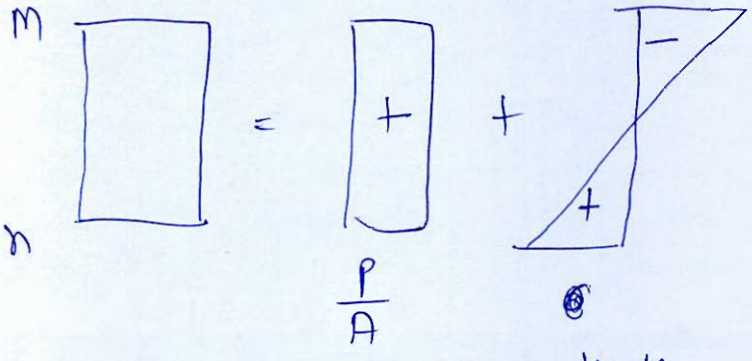
Bending normal stress

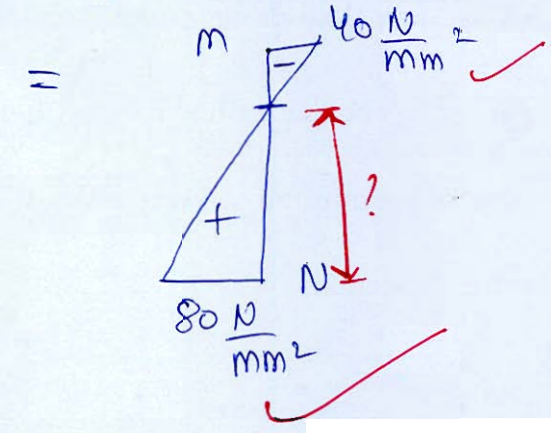
$$\sigma = \frac{My}{I} = \frac{40 \times 20 \times 10^3 \times 20}{\frac{50(40)^3}{12}} = 60 \frac{N}{mm^2}$$

Comp at top
Tensile at bottom

$\sigma_{N\,max} = 20 + 60 = 80 \frac{N}{mm^2}$ tensile at bottom

$\sigma_{N\,min} = 20 - 60 = -40 \frac{N}{mm^2}$ Comp at top





8

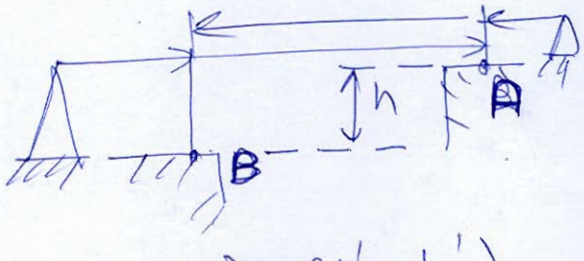
Q.5 (b) **(i)** The following records refer to an operation involving reciprocal levelling:

Staff at	Instrument at		Remarks
	A	*B*	Distance AB = 1200 m
A	1.155 m	0.985 m	RL_A = 525.725 m
B	2.655 m	2.385 m	

Find the RL of *B* and the rate and direction of collimation error. Assume that the radius of Earth is 6370 km.

(ii) A closed traverse is having five stations viz. *A*, *B*, *C*, *D* and *E* taken in anticlockwise order, in the form of a regular pentagon. If *FB* of the *AB* is 30°, then find *FB* of all the other sides.

[8 + 4 = 12 marks]



$AB = 1200\ m$

$RL_A = 525.725\ m$

$$h = \frac{(h_A - h_B) + (h'_A - h'_B)}{2}$$

$$= 1.45\ m$$

MV: $h_B = 2.055$ m

TV: $h_B = h_A + h = 1.155 + 1.45$

$= 2.605$ m ✓

error = $E_{cd} + E_{refraction} + E_{curvature}$

hor $E_{ref} + E_{curv} = 0.0673\, d^2$

$= 0.0673 (1.2)^2$

$= 0.0969$ m ✓ error due to refraction and curvature at each

$\Rightarrow (2.605 - 2.655) = E_{cd} + 0.0969$

$E_{cd} = -0.1469$ ✗ (4)

means line of sight shifted downward

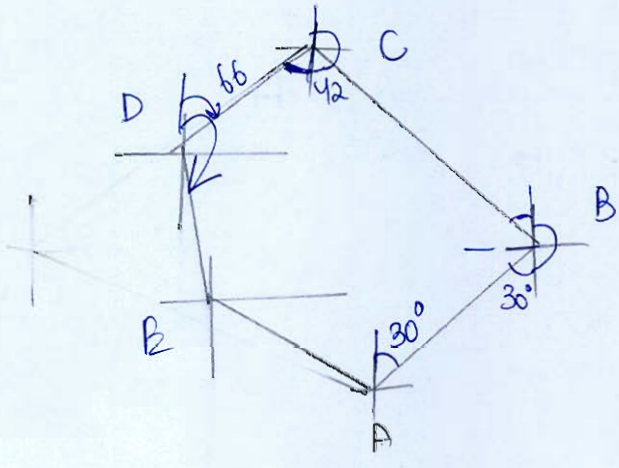
RL of B = RL of A ~~±~~ ~~correction~~ h + ~~±~~ Correction due to Curv + Ref

$= 525.725 + 1.45 + (-0.0969)$

$= $ ~~527.078~~

$= 524.1781$ m ✗

(ii)



regular pentagon ⇒ interior angle sum = $(n-2)180$

$= 3 \times 180$

$= 540$

each angle $= \frac{540}{5}$

$= 108$

AB

AB → 30

BC = $30 + 180 + 108 = 318^0$ ✓

CD = $180 - 42 = 138^0$ ✗

DE = $(108 + 138) = 246^0$ ✗

EA = $66^0 + 108 = 174^0$ ✗

(1)

Q.5 (c) (i) Write a short note on Vibro-Flotation.

(ii) A square footing is required to carry a net load of 1000 kN. Determine the size of footing, if depth of the foundation is 1.8 m and assume a factor of safety of 3. The soil is sandy with N = 13. Water table is very deep. Use Tang's Equation. Net ultimate bearing capacity for square or circular footing as is given by:

$$q_{nf} = 0.33\, N^2 B R_{wr} + (100 + N^2)\, D_f .\, R_{wq}$$

where

$R_{w\gamma}$ = Reduction factor for high water table for N_γ term

$$R_{w\gamma} = \left(0.5 + \frac{0.5b}{B}\right) \le 1$$

b = Depth of water table below the base of the footing.

R_{wq} = Reduction factor for high water table for N_q term

$$R_{wq} = \left(1 - \frac{0.5a}{D_f}\right) \le 1$$

a = Height of water table above the base of the footing.

[5 + 7 = 12 marks]

Q.5 (d) **(i)** Explain the term refuse and briefly explain its composition.

(ii) Explain in detail the process of composting.

[4 + 8 = 12 marks]

(i) Refuse is any substance which is of no use to the uses and is discarded.

Broadly it can be classified into biodegradable and non-biodegradable.

It basically constitutes

(a) food waste
(b) paper
(c) plastics
(d) cardboard
(e) textile
(f) leather
(g) Rubber
(h) Garden trimmings
(i) wood
(j) glass

Garbage
ashes
Rubbish

1

(ii) * Composting is the process in which biodegradable solid waste is decomposed either in Aerobic condition (presence of oxygen → plenty) or anaerobic condition.

* In composting Nitrogen to carbon ratio is maintained for effective working.

* following factors affect the composting process

(1) PH → PH of waste should not be too high or too low so that microorganism decomposing the organic matter can work effectively.

Also during the fermentation stage PH get lowered which is also needed to be take care of.

(2) temp → temp should not be too high so that M/O can get killed or too low that reaction doesn't take place.

More are some M/O which works in higher temp range (~~Mesophilic~~ thermophilic bacteria).

(3) Oxygen → based on supply of oxygen composting is classified into

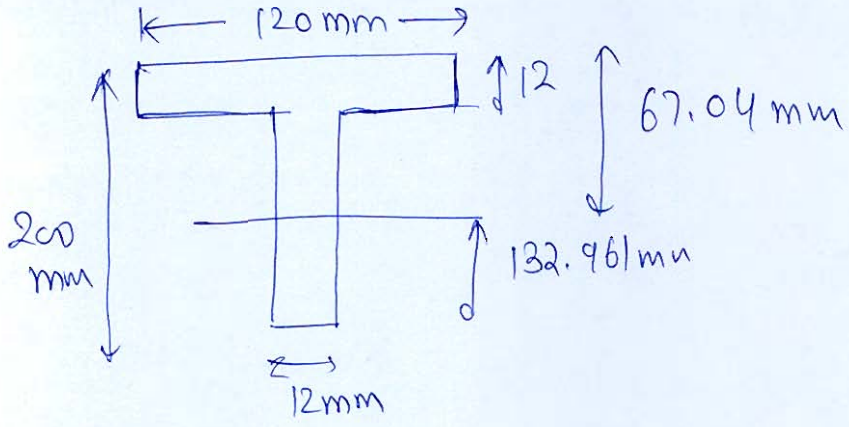
Aerobic → takes lesses time

Anaerobic → take longer time, also causes odour nuisance.

6

Q.5 (e) The cross-section of a joist is a T-section, 120 mm × 200 mm × 12 mm, with 120 mm side horizontal. Sketch the shear stress distribution and hence find the maximum shear stress if it has to resist a shear force of 200 kN.

[12 marks]



NA = Neutral axis

$$\bar{y} = \frac{A_1y_1 + A_2y_2}{A_1 + A_2} \quad \text{94}$$

$$= \frac{(120\times12)\ast + 188\times12 \ast 94}{(120\times12 + 188\times12)}$$

$$= 132.961$$

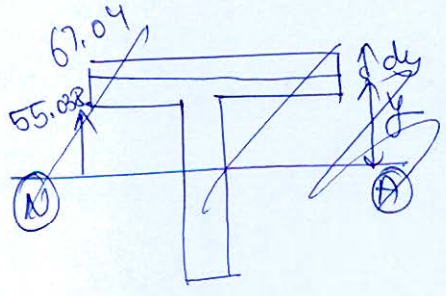
mention from bottom

$$I = \frac{(120\times12^3)}{12} + (120\times12)(67.04-\frac{12}{2})^2 + \frac{12(188)^3}{12} + 12\times188 \times (38.961)^2$$

$$I = 15451738 \text{ mm}^4$$

We know, Shear stress, $\tau = \frac{VQ}{It}$

where ~~$Q = A\bar{y}$~~



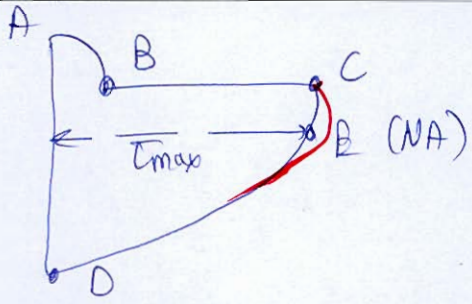
In flange

$$d\tau = \frac{V(dA\bar{y})}{It}$$

$dA = dy \ast b$

$\bar{y} = y + \frac{dy}{2}$ ≈ y

$$\int_{55.08}^{67.04} d\tau = \int \frac{V(b.dy\times y)}{I\ b}$$



Shear stress distribution.

$\tau_A = \tau_D = 0$

$\tau_B = \frac{200 \times 10^3 \times (120 \times 12)(61.04)}{15451738 \times 120}$

$\tau_B = 9.48\ N/mm^2$

$\tau_C = 9.48 \times \frac{120}{12} = 94.8\ N/mm^2$

$\tau_{NA} = \frac{200 \times \left(\frac{132.96^2}{2} \times 12\right)}{15451738 \times 12}$

$= 114.41\ N/mm^2$

10

Q.6 (a) **(i)** A hollow steel shaft 5 m long is to transmit 180 kW of power at 120 rpm. The total angle of twist is not to be exceeded 2° for this length and the allowable shear stress is 50 N/mm^2. Determine the inside and outside diameter of the shaft, taking modulus of rigidity, $G = 0.8 \times 10^5$ MPa.

(ii) A 2 m long pin ended column of square cross-section is to be made of wood. Assume modulus of elasticity, E = 14 GPa, permissible Euler's stress, σ_c = 12 MPa, and using a factor of safety of 2.5 in computing the Euler's critical load for buckling. Determine the size of the cross-section if the column is to safely support 100 kN load. [Round off your answer to next higher multiple of five]

[12 + 8 = 20 marks]

Q.6 (b) (i) Discuss in detail about the types of shear failures of soil and draw their load settlement curve.

(ii) An anchorage bulk head 6m high retains sand on both sides. The anchor rods are 1 m below the top and depth of embedment is 1.8 m. Determine FOS against failure. Angle of internal friction of sand is 30° and sand is submerged throughout with a unit weight of 11 kN/m^3.

[12 + 8 = 20 marks]

Q.6 (c) (i) A copper tube 1.2 m long, has 80 mm internal diameter and 2 mm wall thickness. It has closed ends, and is filled with water under pressure. What will be the alteration of pressure if an additional 10 cubic centimeter of water is pumped into the tube. Neglect the distortion of end plates. Take modulus of elasticity of copper = 1.02×10^5 N/mm^2 and Poisson's ratio = 0.3. Assume bulk modulus for water to be 2.1×10^3 N/mm^2.

(ii) A close-coiled helical spring, made of 12 mm diameter steel rod, has 12 complete turns over a mean diameter of 100 mm. Determine

(a) increase in the number of turns, and bending stress induced, if it is subjected to an axial twist of 16 Nm.

(b) torsional stiffness of the spring.

Assume, modulus of elasticity of steel is 2×10^5 N/mm^2.

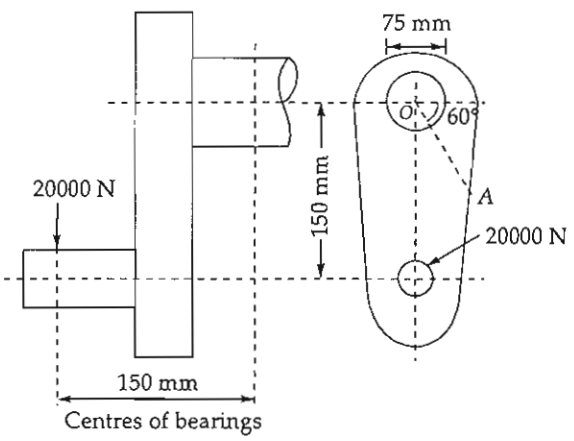
[10 + 10 = 20 marks]

Q.7 (a) (i) A uniform bar of cross-section area, A and flexural stiffness EI is heated so that its temperature varies linearly from $\frac{t}{2}$ at one end to t at the other end. One end is pin jointed to a rigid foundation. The other end is pin jointed so that it can slide in the length of the bar (L), the thermal expansion of which is resisted by a compression spring of stiffness k. If there is no load in the spring when $t = 0$, obtain an expression for the stress in the bar when it is heated and show that it buckles in flexure when

$$t = \frac{4\pi^2 I}{3\alpha L^2 A}\left(1+\frac{EA}{kL}\right)$$

where, α = Coefficient of linear thermal expansion

(ii) Two views of an overhung crank are shown in figure below. A force of 20000 N is being applied to the crank pin in the direction shown and at a distance of 150 mm from the centre of the adjacent bearing. The crankshaft is of solid section of 75 mm diameter. Calculate the maximum principal stress and maximum shear stress in the section of the shaft at the centre of the bearing.



[10 + 10 = 20 marks]

Q.7 (b) **(i)** What is self cleansing velocity? Explain its importance.

(ii) Design a sewer running at depth of $\frac{2}{3}$ of diameter to carry discharge of 600 lps.

Take $n = 0.012$ and invert slope of $\frac{1}{750}$.

(iii) Define and explain hydraulically equivalent section connected to sewer designs.

[5 + 10 + 5 = 20 marks]

(i) self cleansing is the velocity at which silting of particles does not occurs and at which particles which are silted get scoursed off.

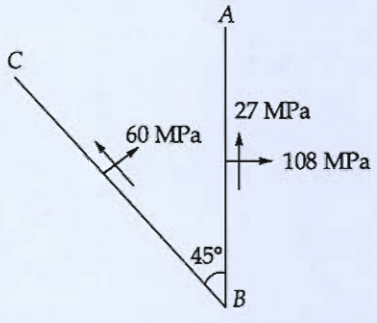
$$V_s = 4\sqrt{cd(G_s - 1)}$$

It is important because if the velocity is too low particles will get settle down and pipe will get clogged

but if it is too high then the scouring will occurs.

(ii)

Q.7 (c) (i) Figure below shows the normal and tangential stresses on two planes. Determine the principal stresses.



(ii) Enumerate various prominent theories of failure, with their graphical representation.

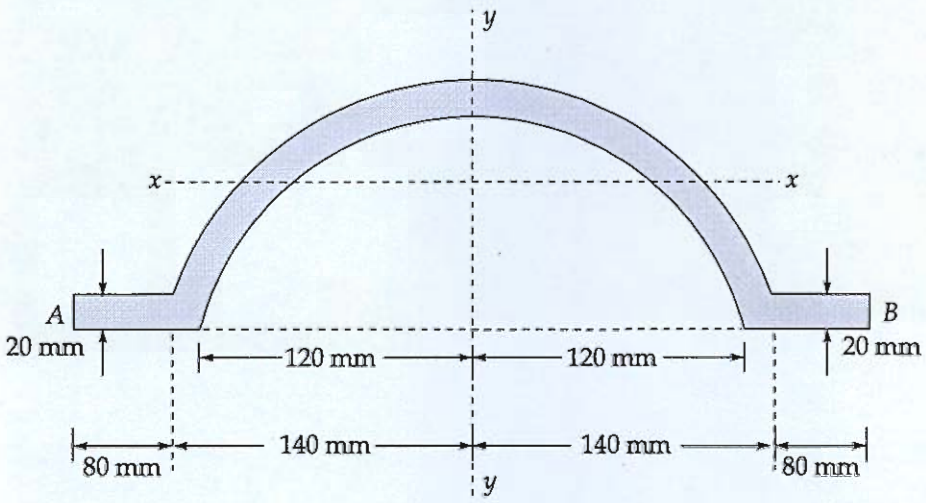
[14 + 6 = 20 marks]

Q.8 (a) **(i)** Show that the maximum bending stress in a beam of rectangular section of depth d is given by

$$f_{max} = \frac{Md}{6nI}(2n+1)$$

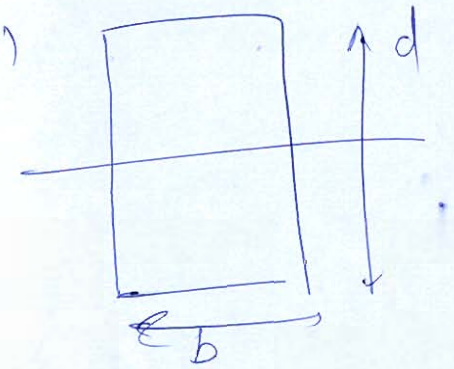
Here, stress-strain relationship is observed as $f^n = E \times \in$, where n is a constant which depends on the properties of the material.

(ii) Figure below shows the section of a steel beam in the shape of an inverted semi-circular channel with flanges. Determine the position of the centroid from the base of the beam and the second moment of the area of the section about the base and also about the centroidal axis parallel to the base.



[14 + 6 = 20 marks]

(i)



from Eulr eq

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

here $\sigma^n = E * \varepsilon$

D

Q.8 (b) (i) A square mass concrete footing supporting an ultimate load of 5000 kN extends from ground level to 4 m deep into clay stratum. The unit weight of concrete and soil are 25 kN/m^3 and 21 kN/m^3 respectively. Shear strength and adhesion of clay are 0.10 N/mm^2 and 25 kN/m^2 respectively. The adhesion may be supposed to act over a depth of 2 m from the bottom of foundation. Calculate size of footing required against a factor of safety of 4.5. Take cohesion of clay as 120 kN/m^2.

(ii) A 30 cm diameter pile of length 10 m was subjected to pile load test and the following results were obtained:

Load (kN)	0	500	1000	1500	2000	2500
Settlement during loading (cm)	0	0.90	1.70	2.50	4.00	6.50
Settlement during unloading (cm)	3.5	4.00	4.70	5.50	6.20	6.50

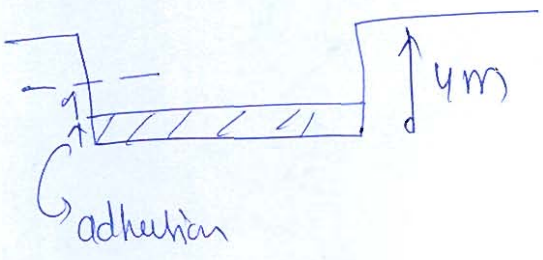
Calculate the allowable load on pile.

[12 + 8 =20 marks]

(i) $P = 5000$ kN

$\gamma_c = 25$ kN/m^3

$\gamma_{soil} = 21$ kN/m^3



$\tau = 0.10$ N/mm^2

let $\alpha = 25$ kN/m^3

FOS = 4.5

$C = 120$ kN/m^2

$$q_u = cN_c + qN_q + \frac{1}{2}B\gamma N_\gamma \quad \text{(adhesion)}$$

$$q_u = 120 * 5.7 * 21 * 4 + (25 * 2 * B \times 4)$$

$$\frac{5000 \text{ kN}}{B^2 \text{ m}^2} = 4.5\{768 + 200B\}$$

$B = 3.34$ m ×

but $\tau = 0.10$ N/mm^2

let $B = 5$ m, $\tau = 0.2$ failed

Do not write in this margin

At $B = 7.5m$ $T = 0.08 \not>$ $\tau_{sm} = 20 t/cm^2$

so provide $B = 7.5m$

(ii) allowable load

= 50% of max load at which 10% of D settlem occur

here $D = 30 cm$

10% = 3cm

Q.8 (c) (i) Derive an expression to calculate the set back distance for a single lane road if sight distance is more than length of curve.

(ii) A vertical is curve formed by joining upward gradient of 1% and another upward gradient of 4%. Design the length of valley curve to satisfy both comfort condition and headlight sight distance condition, if design speed of road is 80 kmph. [Take $f = 0.35$]

(iii) Explain stability of vehicle against the effect of overturning and transverse skidding.

[7 + 7 + 6 = 20 marks]

(ii) $\eta_1 = 1\%$. $\eta_2 = +4\%$.

$N = |1 - 4| = 3\%$

Comfort criteria: $L_v = 2\sqrt{\frac{NV^3}{C}}$ let $C = 0.6$

$L_v = 2\sqrt{\frac{0.03 * (0.278 \times 80)^3}{0.6}}$

$= 46.40\ m$

Headlight sight distance criteria:

$HSD = SSD = 0.278\, V t_r + \frac{V^2}{254 f}$

$= 127.59\ m$

let $L_v > SSD$

$L_v = \frac{NS^2}{1.5 + 0.035S} = 81.86 \neq 127.59\ m$

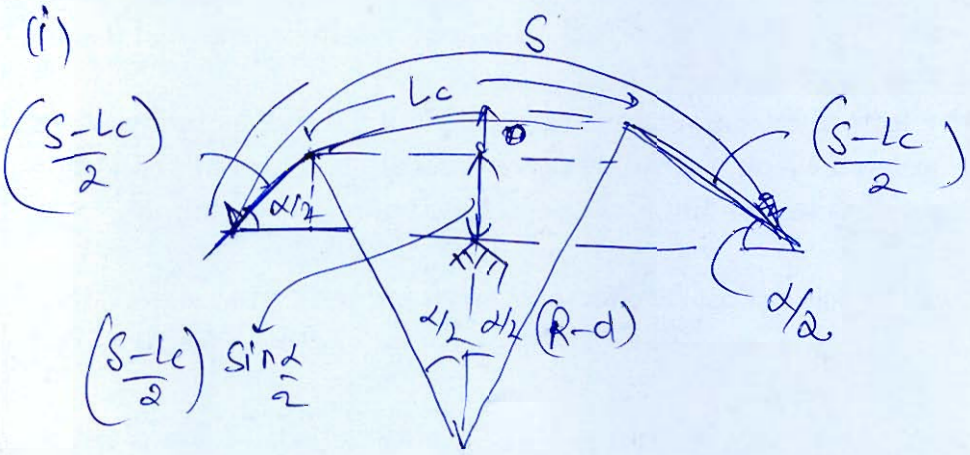
7

So, $L_v = 2S - \frac{1.5 + 0.035S}{N}$

$= 56.43\ m$

So $\boxed{L_v = 56.43\ m}$

(i)

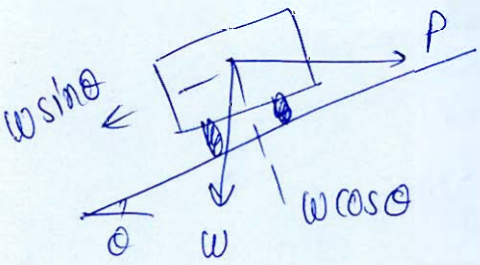


$$m = R - (R-d)\cos\frac{\alpha}{2} + \left(\frac{S-Lc}{2}\right)\sin\frac{\alpha}{2}$$

L_c = length circular cone

S = sight distance

(ii)



Space for Rough Work

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