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MADE EASY
Leading Institute for ESE, GATE & PSUs

ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-2

Section A : Geo-technical Engineering and Foundation Engineering [All topics]

Section B : Surveying and Geology [All topics]

Name : .....

Roll No :

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

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. 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.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE	
Question No.	Marks Obtained
Section-A	
Q.1	35
Q.2	46
Q.3	60
Q.4	—
Section-B	
Q.5	47
Q.6	
Q.7	44
Q.8	—
Total Marks Obtained	232

Signature of Evaluator: Sheroyab

Cross Checked by: .....

Keep it up. (accuracy is good)

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.

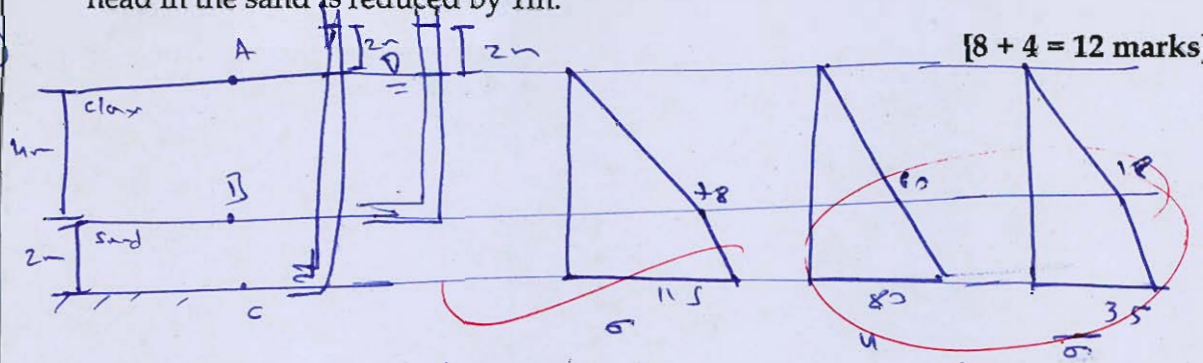
Section A : Geo-technical Engineering and Foundation Engineering

Q.1 (a) (i) A soil profile consists of a surface layer of clay 4m thick ($\gamma = 19.5\ kN/m^3$) and a sand layer 2 m thick ($\gamma = 18.5\ kN/m^3$) overlying an impermeable rock. The water table is at the ground surface. If the water level in a stand pipe driven into sand layer rises 2 m above the ground surface, draw the plot showing the variation of total stress (σ), pore water pressure (u) and effective stress ($\bar{\sigma}$) Take $\gamma_w = 10\ kN/m^3$.

(ii) Determine the increase in effective stress at the top of the rock when the artesian head in the sand is reduced by 1m.

[8 + 4 = 12 marks]

Soln (i)



Point	σ (kN/m^2)	u (kN/m^2)	$\bar{\sigma}$ (kN/m^2)
A	0	0	0
B	$19.5 \times 4 = 78$	$6 \times 10 = 60$	18
C	$78 + 2 \times 18.5 = 115$	$8 \times 10 = 80$	35

3+2

at the junction PWP and $\bar{\sigma}$ will change

(ii)

$\bar{\sigma}_{C_1} = 35\ kN/m^2$

$\bar{\sigma}_{C_2} = 115 - 7 \times 10 = 45\ kN/m^2$

$\Delta\bar{\sigma}_C = 10\ kN/m^2$ increase.

Q.1 (b) (i) The in-situ unit weight of a medium to coarse sand used as subgrade for a highway, was 16 kN/m^3. It was decided to improve the soil by mechanical stablization. When 5.5 kN of a mixture of dry sand and silt was added to 1m^3 of this subgrade, the volume was increased by 20 percent. How much reduction in porosity of the soil was achieved? Assume average specific gravity of soil solids G_S as 2.67. [Take γ_w = 9.8 kN/m^3]

(ii) Further 1.5 kN of clay at a moisture content of 10%. was added to the above mixture such that no further increase in the volume of the subgrade resulted. Determine the further reduction in porosity that this addition of clay brought about. Assume G_S of clay particles is 2.67.

[6 + 6 = 12 marks]

Sol^n

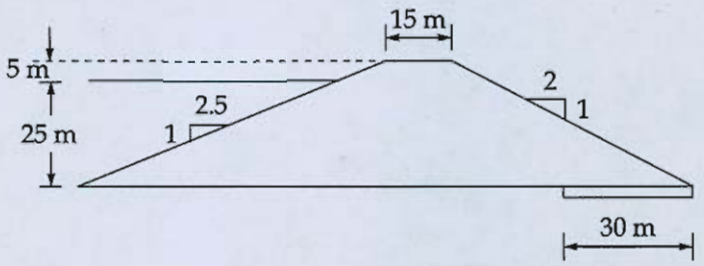
$\gamma_b = 16\ kN/m^3$, $\Delta W_s = 5.5\ kN$

$V_{T_1} = 1m^3$, $V_{T_2} = 1.2 \times 1 = 1.2m^3$

$\Delta\eta = ?$, $G = 2.67$, $\gamma_w = 9.8$

$\gamma_b = \frac{W_{T_1}}{V_{T_1}} \Rightarrow W_{T_1} = 16\ kN$

Q.1 (c) A homogenous earth dam is provided with a horizontal filter drain 30 m long at its toe, as shown in Figure. Determine the focal length.



Also determine the seepage discharge per unit length if the coefficient of permeability is 40 m/day.

[12 marks]

Soln

Base width = $15 + 30(2.5+2)$

$= 150\text{ m}$

$H = 25\text{ m}$

~~$d = 150 - 0.7$~~

$L = nH = 2.5 \times 25 = 62.5\text{ m}$

$d = 150 - 30 - 0.7 \times 62.5$

$= 76.25$

$S = \sqrt{d^2 + H^2} - d$

~~$= \sqrt{76^2 +$~~

$= \sqrt{76.25^2 + 25^2} - 76.25$

$= 3.994\text{ m}$

Seepage discharge $= 40\text{ m/d} \times 3.994\text{ m}$

$= 159.75\text{ m}^2\text{/d-m length}$

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Q.1 (d) In order to determine the field permeability of a free aquifer, pumping out test was performed and following observations were made:

Diameter of well = 20 cm, discharge from the well = 240 m^3/hr

RL of original water surface, before pumping started = 240.5 m

RL of water in well at constant pumping = 235.6 m

RL of impervious layer = 210 m

RL of water in observation well = 239.8 m

Radial distance of observation well from the tubewell = 50 m

Determine the permeability of aquifer. Also calculate:

(i) The error in coefficient of permeability if observations are not taken in the observation well, and the radius of influence is assumed to be 300 m.

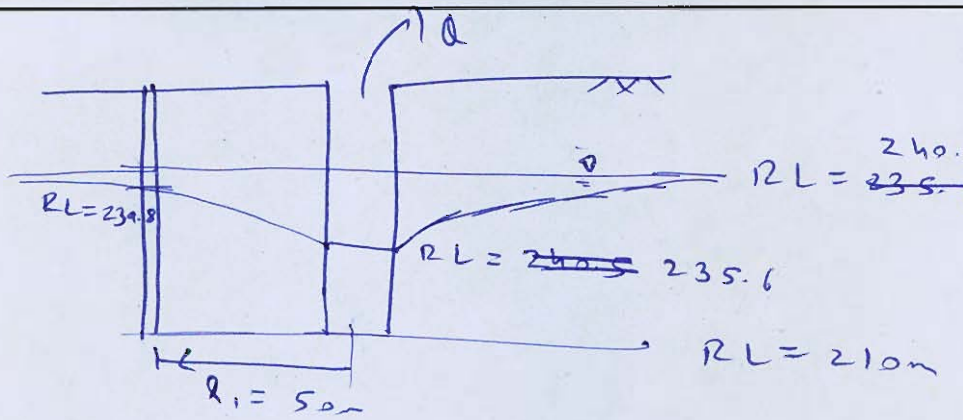
(ii) Actual radius of influence based on the observations of observation well.

[12 marks]

Soln

$d_w = 0.2m, \Rightarrow r_w = 0.1m$

$Q = 240\ m^3/hr$



$H_w = 240.5 - 210 = 30.5m$

$h_1 = 239.8 - 210 = 29.8m$, $l_1 = 50m$

$h_w = 235.6 - 210 = 25.6$, $l_w = 0.1m$

We know,

$$Q = \frac{\pi k (h_2^2 - h_1^2)}{\ln(R_2/r_1)} = \frac{\pi k (h_1^2 - h_w^2)}{\ln(r_1/r_w)}$$

$$240 m^3/hl = \frac{\pi k (29.8^2 - 25.6^2)}{\ln(50/0.1)}$$

$\Rightarrow$ ~~$k = 2.04m$~~ $2.04 m/d = k$

(i) $R = 300m$, ~~$h_2 = ?$~~ $H_w = 30.5$

$$Q = \frac{\pi k (H_w^2 - h_w^2)}{\ln(R/r_w)}$$

$\Rightarrow 240 m^3/hl = \frac{\pi k (30.5^2 - 25.6^2)}{\ln(\frac{300}{0.1})}$

$\Rightarrow k = 2.225 m/d$

$$\% \text{ error} = \frac{2.225 - 2.04}{2.04} \times 100$$

$$= 9.06\%$$

(ii)

$$Q = \frac{\pi k (H_w^2 - h_w^2)}{\ln(R/r_w)}$$

$$240\ m^3/d = \frac{\pi \times k (30.5^2 - 29.8^2)}{\ln(R/r_w)} \times 2.04$$

$$\Rightarrow \boxed{R = 154.35\ m}$$

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Q.1 (e) Explain about the following methods of soil stabilization:

(i) Chemical stabilization (ii) Stabilization by heating

(iii) Electrical stabilization

[4 + 4 + 4 = 12 marks]

Ans (i) Chemical Stabilization

Certain chemicals like lime, bitumen, cement etc are added to the soil to improve its properties. Due to this

1. Activity decreases
2. Swelling & shrinkage decrease
3. Strength increases.

(ii) Stabilization by heating

In this stabilization is carried by heating the soil to improve its properties.

(iii)

Electrical stabilization

AC current is passed through the soil due to which properties of soil are modified.

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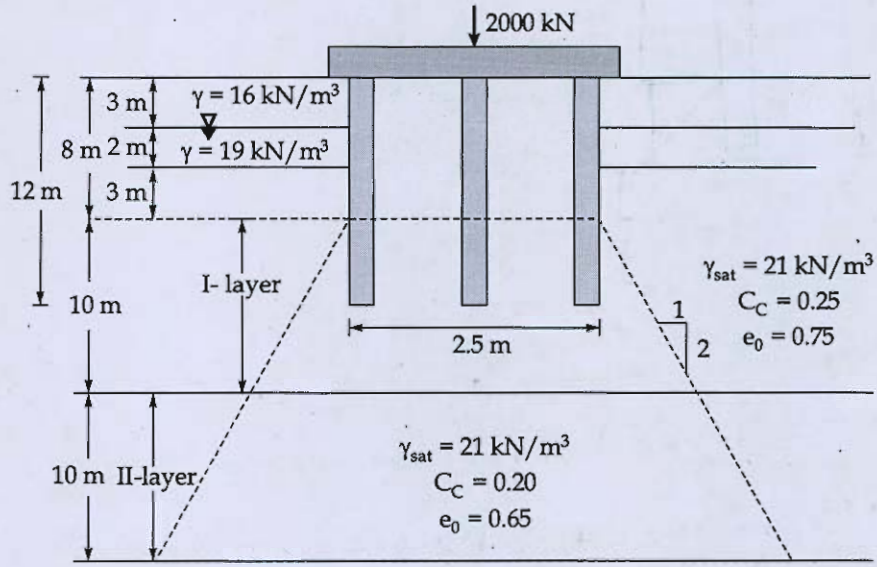
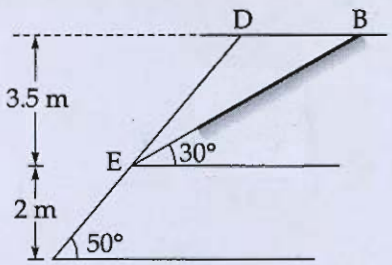
Q.2 (a) **(i)** A group of friction piles of 30 cm diameter is subjected to a net load of 2000 kN, as shown in the figure below. Estimate the consolidation settlement.
(Take, $\gamma_w = 10\ kN/m^3$)



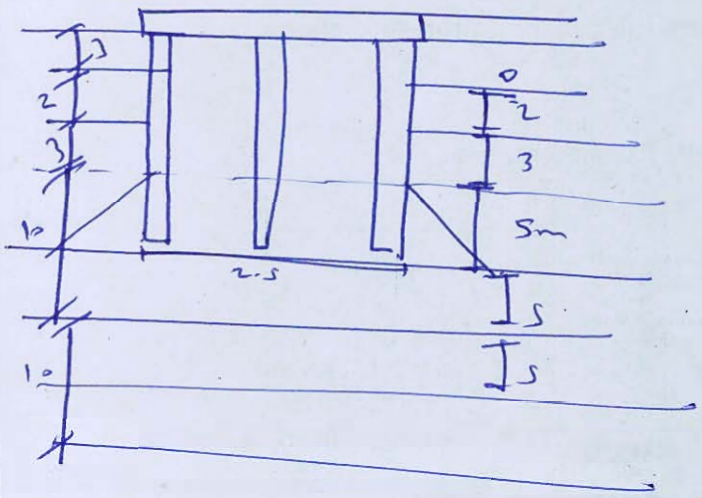
(ii) A soil mass *EBD* having $C = 8\ kN/m^2$, $\phi = 20°$ and $\gamma = 19\ KN/m^3$ is resting on an inclined impermeable clay layer, as shown in figure below. Determine the factor of safety against wedge failure along interface *EB*.



[10 + 10 = 20 marks]

Soln Acc to given figure

$H_1 = 10m$,



(1) For I st layer, $H_0 = 10{,}000\,mm$

$\bar{\sigma}_0 = 16\times 3 + 19\times 2 + 21\times 8 - 10\times 10$

$= 154\,kN/m^2$

$\Delta\bar{\sigma} = \dfrac{2000\,kN}{(2.5+5)^2} = 35.56\,kN/m^2$

$\Delta H_1 = \dfrac{H_0 C_c}{1+e_0}\log_{10}\left(\dfrac{\bar{\sigma}_0 + \Delta\sigma}{\bar{\sigma}_0}\right)$

$= \dfrac{10{,}000\times 0.25}{1.75}\log_{10}\left(\dfrac{154+35.56}{154}\right)$

$= 128.89\,mm$

(2) For II nd layer, $H_0 = 10{,}000$

$\bar{\sigma}_0 = 16\times 3 + 19\times 2 + 21\times 13 + 21\times 5 - 10\times 20$

$= 266\,kN/m^2$

$\Delta\bar{\sigma} = \dfrac{2000}{(2.5+15)^2} = 6.53\,kN/m^2$

$\Delta H_2 = \dfrac{H_0 C_c}{1+e_0}\log_{10}\left(\dfrac{\bar{\sigma}_0 + \Delta\sigma}{\bar{\sigma}_0}\right)$

$$\Delta H_2 = \frac{10,000 \times 0.2}{1.65} \log_{10}\left(\frac{264 + 6.53}{264}\right)$$

$$= 12.86 \text{ m}$$

Total settlement = 128.89 + 12.86

~~= 141.7~~ 141.75 m

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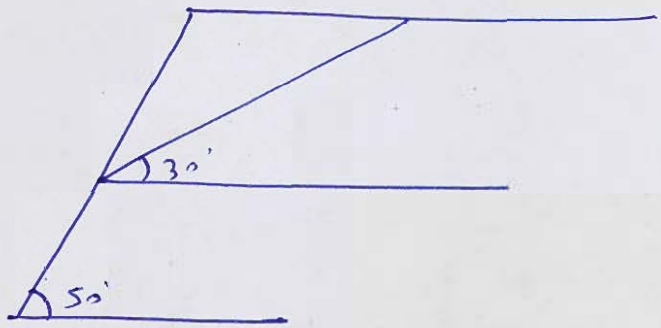
(11)



Q.2 (b) **(i)** Explain in brief about modified Proctor test.

(ii) A sample of soil was prepared by mining dry soil with 10% by mass of water. Find the mass of this wet mixture required to produce a cylinder compacted specimen of 15 cm diameter and 12.5 cm deep and having 6% air content. Also find the void ratio and the dry density of the specimen if G = 2.68.

[10 + 10 = 20 marks]

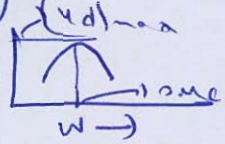
Ans (b) Modified proctor test

It is done to obtain the maximum dry density of the soil and the optimum moisture content of soil.

- In this test oven dried sample of soil is taken and about 10% water is added.
- Now it is compacted in 5 layers with 25 no. of blows in each layer with suitable hammer & from suitable height.
- Now the weight of soil is calculated & volume of soil is volume of mould.
- The water content is determined by oven dry test.

• Now, $\gamma_b = \frac{W_s}{V_T}$ & $\gamma_d = \frac{\gamma_b}{1+w}$

• The process is repeated at diff. moisture content. Then graph is plotted ⇒



(11) $w = 10\%$, $d = 15\,cm$, $L = 12.5\,cm$, $a_c = 6\%$, $G = 2.68$

$V_T = \frac{\pi}{4} \times 15^2 \times 12.5 = 2208.93\,cc$

We know, $S + a_c = 1$

$\Rightarrow S = 1 - 0.06 = 0.94$

$eS = wG$

$\Rightarrow e \times 0.94 = 0.1 \times 2.68 = 0.285$

$\gamma_d = \frac{\gamma_w G}{1+e} = \frac{9.81 \times 2.68}{1.285} = 20.46\,kN/m^3$

Vol. of solids $= \frac{V_T}{1+e} = \frac{2208.93}{1.285}$

$= 1719.01\,cc$

6+10

Now, $G = \frac{\text{Mass of solids}}{\text{vol of solids} \times \rho_w}$

$2.68 = \frac{M_s}{1719.01 \times 1\,gm/cc}$

$M_s = 4606.95\,gm$

Now, Mass of water $= 0.1 \times 4606.95$

$= 460.69\,gm$

Total mass of ~~soil~~ mixture required

$= 4606.95 + 460.69$

$= 5067.64\,gm$

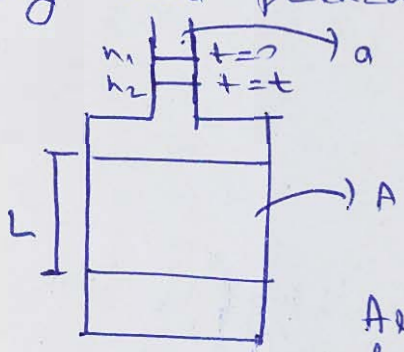
Q.2 (c) **(i)** Explain the process of determination of permeability of soil by falling head test.

(ii) A soil sample of height 6 cm and area of cross-section 100 cm^2 was subjected to a falling head permeability test. In a time interval of five minutes, the head dropped from 60 cm to 20 cm. If cross-sectional area of stand pipe is 2 cm^2, compute the coefficient of permeability of the soil sample. If the same sample is subjected to a constant head of 18 cm, calculate the discharge flowing through the sample.

[10 + 10 = 20 marks]

Soln

Falling head permeability test



Let k => permeability

We know,

$$\frac{\text{Vol. of water}}{\text{time}} = a \times \frac{dh}{dt}$$

Area of soil sample => A

& length = L

$$\frac{\text{Vol. of water}}{\text{time}} = \frac{-a\,dh}{dt} = k \times \frac{h}{L} \times A$$

$$\Rightarrow \frac{-a\,dh}{h} = \frac{k}{L} A\,dt$$

Let during time t water in standpipe of area fall from h_1 to h_2

$$\Rightarrow \int_0^{h_2} \frac{a\,dh}{dt} = \int_{@h}^{t} \frac{k\,h}{L} A$$

$$\Rightarrow -\int_{h_1}^{h_2} \frac{a\,dh}{h} = \int_0^t \frac{k}{L} A\,dt$$

$$\Rightarrow -a \ln\left(\frac{h_2}{h_1}\right) = \frac{k}{L} A t$$

$$\Rightarrow a \ln\left(\frac{h_1}{h_2}\right) = \frac{k}{L} A t$$

$$\Rightarrow \boxed{k = \frac{aL \ln(h_1/h_2)}{At}}$$

10+10

(ii) (a) $L = 6\,cm$, $A = 100\,cm^2$

$t = 5\,min$, $h_1 = 60\,cm$, $h_2 = 20\,cm$

$a = 2\,cm^2$, $k = ?$

$$k = \frac{aL \ln(h_1/h_2)}{At}$$

$$= \frac{2 \times 6 \times \ln(60/20)}{100 \times 5 \times 60} = 4.394 \times 10^{-4}\ cm/sec$$

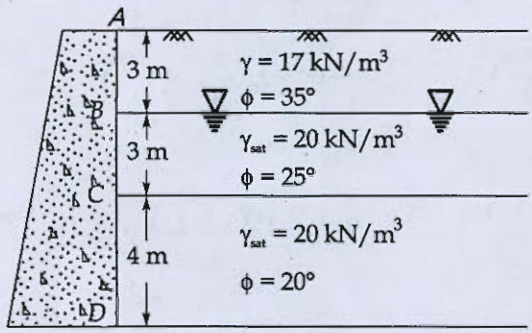
(b) For constant head $H = 18\,cm$

$$Q = kiA = k \times \frac{H}{L} \times A$$

$$= 4.394 \times 10^{-4}\ \frac{cm}{sec} \times \frac{18}{6} \times 100$$

$$= 0.1318\ cm^3/s$$

Q.3 (a) For the retaining wall as shown in figure below, plot the distribution of passive earth pressure and determine magnitude of total passive thrust and point of application of total passive thrust.



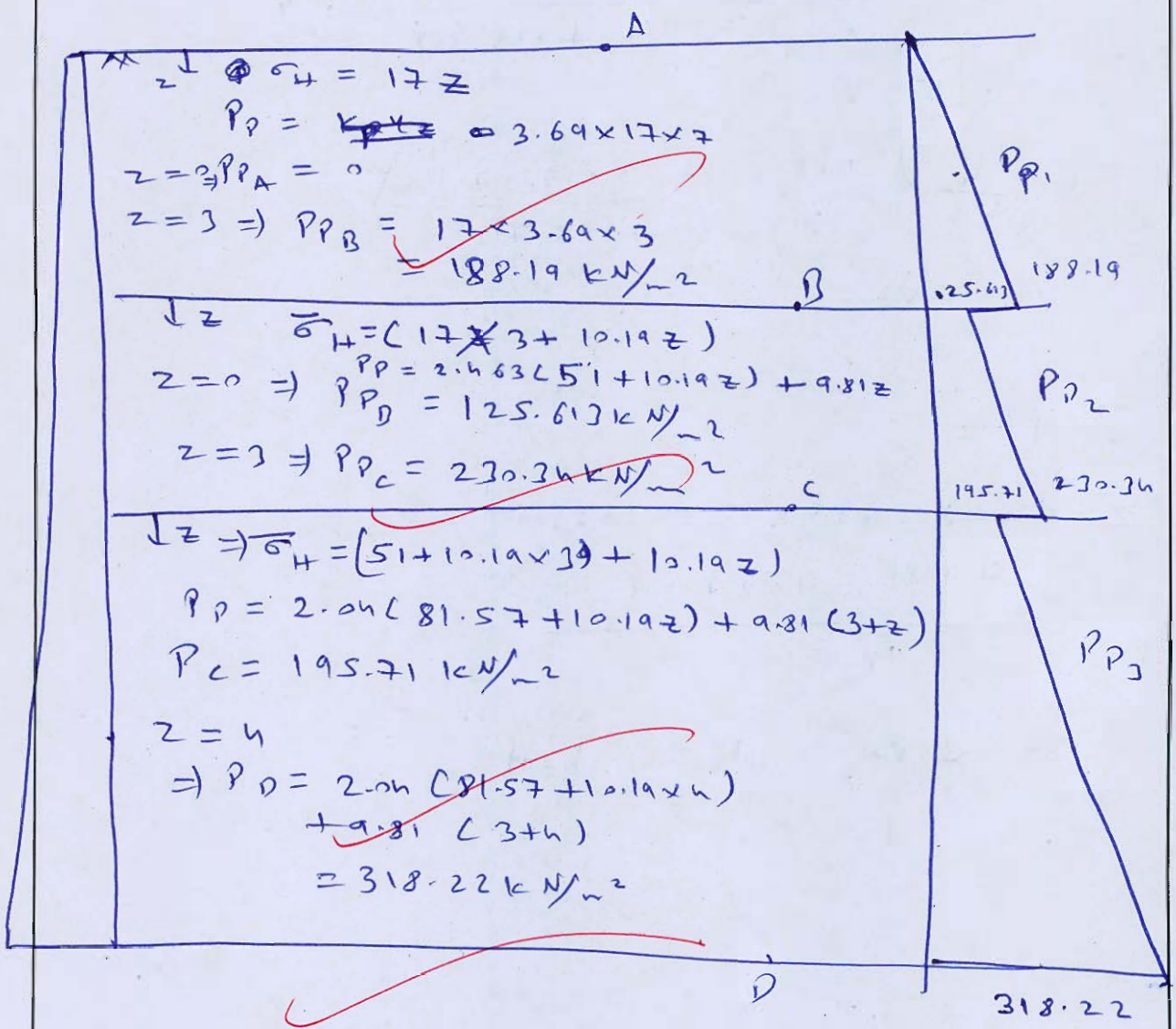
[20 marks]

Soln

$K_{P_1} = \frac{1+\sin 35}{1-\sin 35} = 3.69$

$K_{P_2} = \frac{1+\sin 25}{1-\sin 25} = 2.463$

$K_{P_3} = \frac{1+\sin 20}{1-\sin 20} = 2.04$



$P_{P_1} = \frac{1}{2} \times 3 \times 188.19 = 282.285$

$P_{P_2} = \frac{1}{2} \times 3 \times (125.613 + 230.34) = 533.92$

$P_{P_3} = \frac{1}{2} \times 4 \times (195.71 + 318.22) = 1027.86$

Total passive E.P.

$= 1844.065 \text{ kN/m}$

z_1 from bottom $= 7 + 3/3 = 8 \text{ m}$

$$z_2 = 4 + \frac{3}{3}\left\{\frac{230.34 + 2 \times 125.613}{230.34 + 125.613}\right\}$$

$= 5.35 \text{ m}$

$$z_3 = \frac{4}{3}\left\{\frac{318.22 + 2 \times 195.71}{318.22 + 195.71}\right\}$$

$= 1.8 \text{ m}$.

20

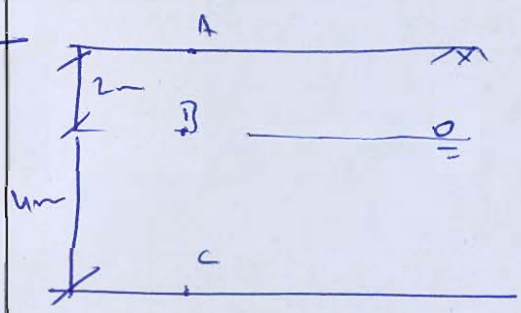
$$\bar{z} = \frac{282.285 \times 8 + 533.92 \times 5.35 + 1.8 \times 1027.86}{1844.065}$$

$= 3.8 \text{ m}$ from bottom

Q.3 (b) Sketch the variation of total stress, effective stress and pore water pressure up to a depth of 6 m below ground level, with the following data:
The water table is 2 m below ground level. The dry density of the soil is 17.66 kN/m^3, specific gravity is 2.65. What would be the change in these stresses, if water table drops by 1.0 m? [Assume after lowering of water table soil is saturated by capillary effect].

[20 marks]

Soln



$\gamma_d = 17.66\ kN/m^3$

$G = 2.65$

$\gamma_d = \dfrac{\gamma_w G}{1+e}$

$17.66 = \dfrac{9.81 \times 2.65}{1+e}$

$\Rightarrow e = 0.472$

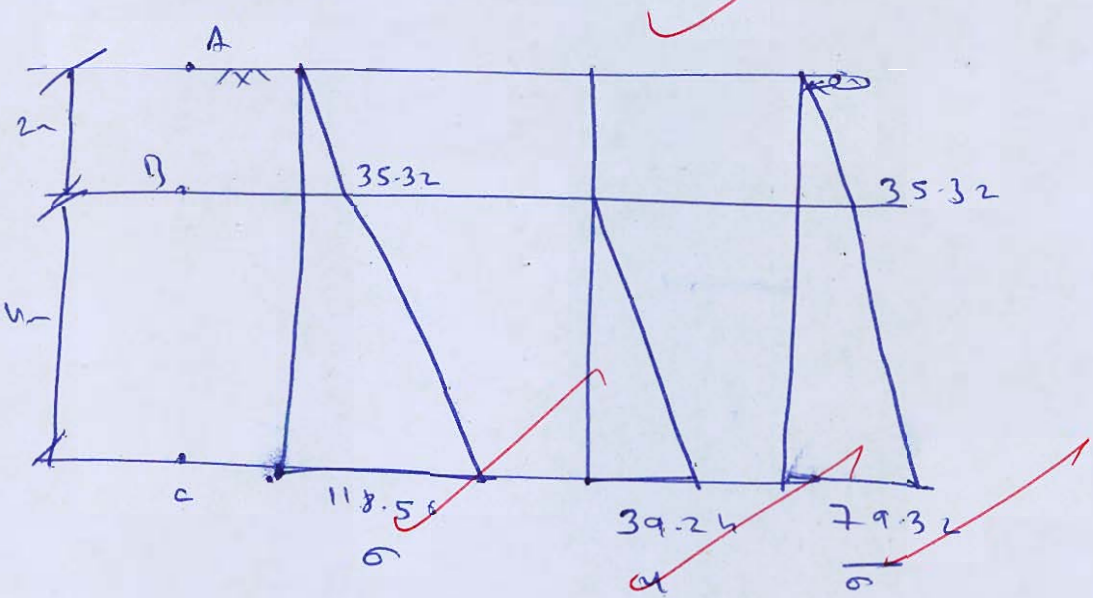
Assuming soil above water table to be dry

$\gamma_{sat} = \dfrac{\gamma_w (G+e)}{1+e}$

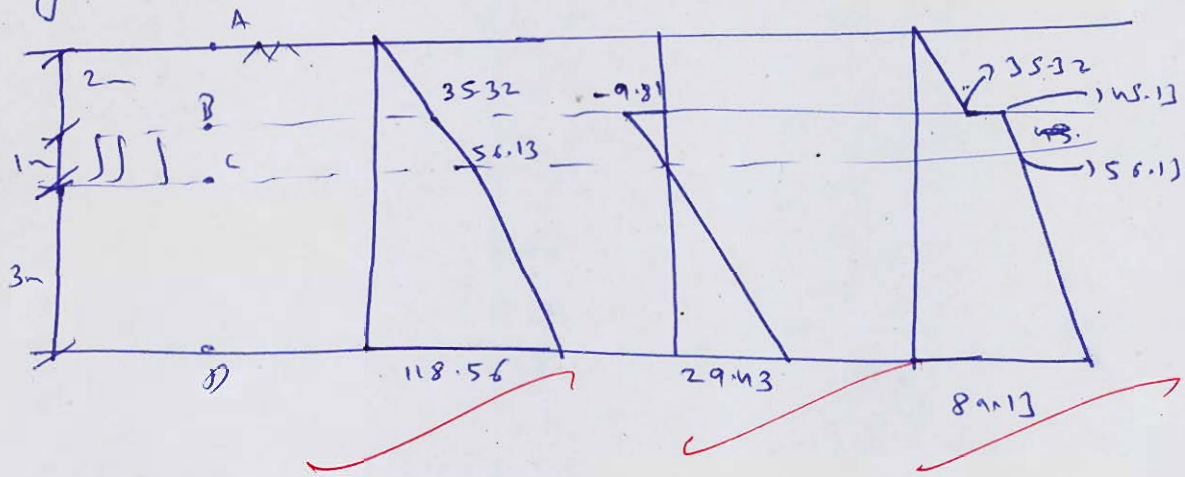
$= \dfrac{9.81\,(2.65 + 0.472)}{1.472}$

$= 20.81\ kN/m^3$

Point	σ	u	$\bar{\sigma} = \sigma - u$
A	$17.66 \times 0 = 0$	0	0
B	$17.66 \times 2 = 35.32$	0	35.32
C	$35.32 + 4 \times 20.81 = 118.56$	$4 \times 9.81 = 39.24$	79.32



If water table drops by 1m



Point	σ	u		$\bar{\sigma}$
A	0	0		0
B	$17.66 \times 2 = 35.32$	0	Just above	35.32
		-9.81	Just below	45.13
C	$17.66 + 20.81 \times 1 = 56.13$	0		56.13
D	$56.13 + 20.81 \times 3 = 118.56$	29.43		89.13

20

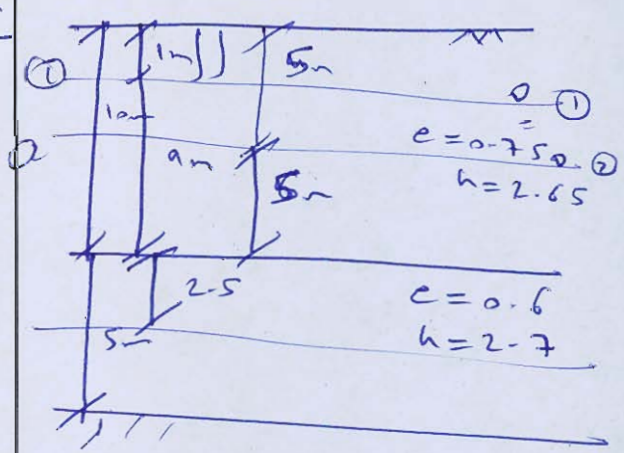
Q.3 (c) A light weight building stands or a 10 m thick stratum of sand. Beneath the sand stratum, a clay layer of 5 m thick exists. The clay layer is underlain by a rock stratum. The water table lies at a depth of 1.0 m below ground surface and the sand above the water table is saturated with capillary rise. The sand has a void ratio of 0.75 and specific gravity 2.65. During dry season, water is pumped out from the sand stratum till the water table is lowered by 4.0 m and sand above water table becomes dry.

Calculate the number of days when the building settles by 25 mm. Ignore settlement during pumping operation.

Take properties of clay as: Void ratio = 0.60, Specific gravity = 2.70, Liquid limit = 40%, Coefficient of consolidation = 6×10^{-3} cm^2/s.

[20 marks]

Soln



$$(\gamma_{sat})_{sand} = \frac{\gamma_w (h+e)}{1+e}$$

$$= \frac{9.81 (2.65+0.75)}{1.75}$$

$$= 19.06 \text{ kN/m}^3$$

$$(\gamma_d)_{sand} = \frac{9.81 \times 2.65}{1.75}$$

$$= 14.85 \text{ kN/m}^3$$

$$(\gamma_{sat})_{clay} = \frac{9.81 (2.7+0.6)}{1.6}$$

$$= 20.23 \text{ kN/m}^3$$

(1) $\bar{\sigma_o} = 19.06 \times 10 + 2.5 \times 20.23 - 11.5 \times 9.81$

$= 128.36 \text{ kN/m}^2$

(2) When u.T. is lowered by h m

$\bar{\sigma_1} = 5 \times 14.85 + 5 \times 19.06 + 2.5 \times 20.23 - 7.5 \times 9.81 = 146.55 \text{ kN/m}^2$

(3) $H_o = 5000\text{mm}$, $C_c = 0.009(h_o - 10)$

$= 0.27$

$\Delta H = \frac{H_o C_c}{1+e_o} \log_{10}\left(\frac{\bar{\sigma_1}}{\bar{\sigma_o}}\right)$

$= \frac{5000 \times 0.27}{1.6} \log_{10}\left(\frac{146.55}{128.36}\right)$

$= 48.56\text{mm}$

(4) For 25mm settlement

$U = \frac{25}{48.56} = 0.5147 < 0.6$

$T_v = \frac{\pi}{4} \times 0.5147^2 = 0.208$

$T_v = C_v \times \frac{t}{d^2}$ (20)

$0.208 = \frac{6 \times 10^{-3} \times 10^{-4}}{s} m^2 \times \frac{t}{(5)^2}$

$\Rightarrow t = 100.31 \text{ days}$

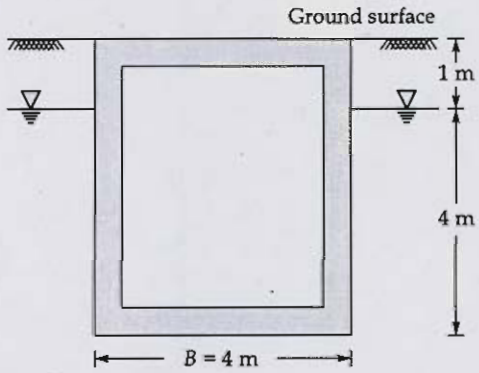
Q.4 (a) **(i)** A square footing of (2.5 m × 2.5 m) size has been founded at 1.2 m below the ground level in a cohesive soil having a bulk density of 1.8 t/m^3 and an unconfined compressive strength of 5.5 t/m^2. Determine the ultimate and safe bearing capacity of the footing for a FOS of 2.54 by

1. Terzaghi's Theory
2. Skempton's Theory

(ii) What are the various methods of estimation of pile load carrying capacity? Explain them in brief.

[12 + 8 = 20 marks]

Q.4 (b) A concrete hollow box culvert is shown below:



(i) Determine the minimum wall thickness of the box culvert to prevent uplift using a factor of safety of 1.2. The ground water can rise to the ground surface. The unit weight of concrete is 24 kN/m^3. Assume the worst-case scenario.

(ii) If the weight of the culvert is restricted so that uplift can occur, suggest one possible method to prevent uplift. [Take γ_w = 9.81 kN/m^3]

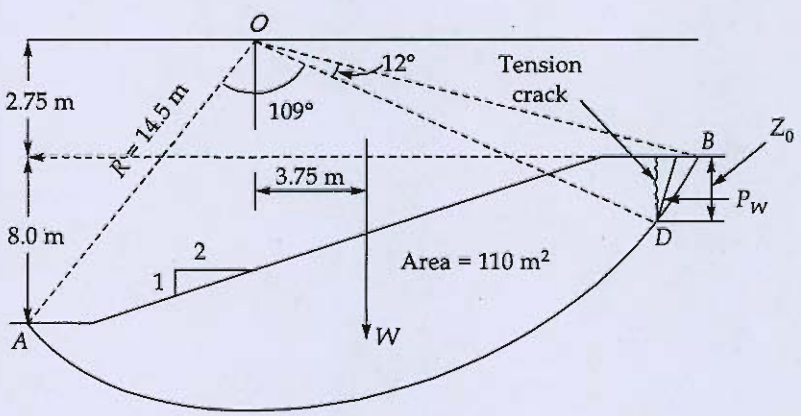
[14 + 6 = 20 marks]

Q.4 (c) The below figure shows the cross-section of a cutting in a homogenous, saturated clay soil inclined at a slope of 2 horizontal to 1 vertical with a height of 8.0 m. Bulk unit weight of soil is 18 kN/m^3 and undrained cohesion is 27 kN/m^2 ($\phi_u = 0°$). What is the factor of safety against immediate shear failure along the slip circle as shown below for various cases:

(i) Ignoring tension crack.

(ii) Allowing tension crack but without water (Area of sliding mass of tension crack = 1.5 m^2, centroid of remaining area from O = 3.6 m)

(iii) Allowing the tension crack with water.



[20 marks]

Section B : Surveying and Geology

Q.5 (a) A levelling staff is held vertical at distances of 100 m and 300 m and horizontal sights are 0.99 and 3.00 m, respectively. Find the constants of the instrument.
The instrument is set up at station *A* and the staff is held vertical at a point *B*. With the telescope inclined at an angle of depression of 10° to the horizontal, the readings on the staff are 2,670, 1.835, 1.000 m. Calculate the R.L. of *B* and its horizontal distance from *A*. The H.I is 1.42 m and R.L. of station *A* is 450.5 m.

[12 marks]

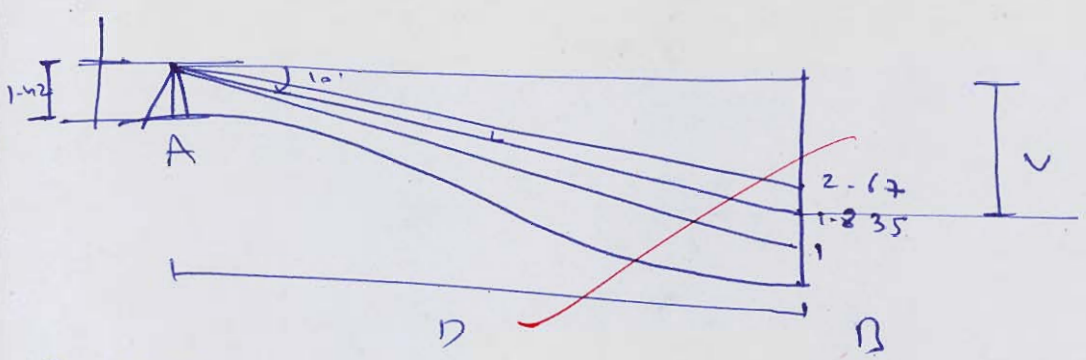
Soln We know, $D = Ks + C$

$100 = K \times 0.99 + C$ — (i)

$300 = K \times 3 + C$ — (ii)

(ii) − (i) ⇒ $200 = (3 - 0.99)K$

$\Rightarrow K = 99.5$ & $C = 1.49$



$S = 2.67 - 1 = 1.67$

$L = Ks\cos\theta + C = 99.5 \times 1.67 \cos 10 + 1.49$

$= 165.13\text{m}$

$D = L\cos\theta = 162.62\text{m}$

12

$V = L\sin\theta = 165.13 \sin 10 = 28.67\text{m}$

$RL_B = RL_A + 1.42 - V - 1.835$

$RL_B = 450.5 + 1.42 - 28.67 - 1.835$

$RL_B = 421.415$

Q.5 (b) (i) Describe the properties used for interpretation of remote sensing information.

(ii) What are the sources of errors in GIS? Name only four.

[6 + 6 = 12 marks]

Ans

Remote sensing is the process of obtaining the information about an object without coming in contact with the object

- In this electromagnetic waves are used to obtain the necessary details about the object.
- Properties of object like

Absorption
Reflection
Reflection

are used to determine information

6

Q.5 (c) (i) Describe with the help of sketches the various characteristics of contours.

(ii) Find the radius of curvature of the bubble tube and the value of each 2 mm division from the following average reading of the ends of the bubble and of a staff 80 m away.

	I	*II*
Staff reading	1.680	1.602
Eye-piece end of bubble	20	10
Object glass end of bubble	10	20

[6 + 6 = 12 marks]

Soln (i) Characteristics of contours

(1) Equally spaced contours represent uniform slope.

(2) Closely spaced contours represent steep slope whereas widely spaced contours represent gentle slope.

(3) Contours are always closed.

(4) Closed contours with values increasing inside represent hill.

(5) Closed contours with values decreasing inside represent valley.

(6) Two contours cannot intersect except in case of vertical cliff.

(7) Contours intersect ridge & valley lines perpendicularly.

(11)

$l = 2nm, \quad D = 80m, \quad S = 1.68 - 1.602$

$= 0.078m$

$n = \frac{(20-10) + (20-10)}{2} = 10$

We know,

$\theta = \frac{nl}{R} = \frac{S}{D}$

$\Rightarrow \frac{10 \times 2 \times 10^{-3}}{R} = \frac{0.078}{80}$

~~$\Rightarrow R = 20.21m$~~ $\boxed{R = 20.51m}$

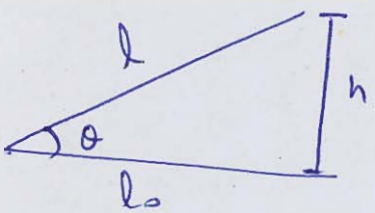
4+6

Q.5 (d) Derive the expression for the tape correction on the sloping ground.

A 30 m chain is used to measured a line along a gradient of 1 : 15. Later it was detected that chain was misaligned by 0.9 m while the measurement was made. Determine the horizontal distance measured if the length measured along the slope was 90 m.

[12 marks]

Soln



$l_0 \Rightarrow$ TV

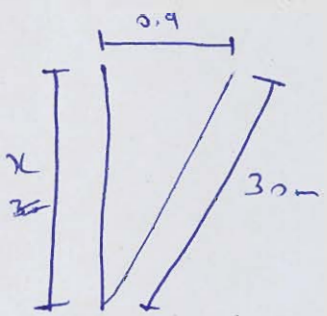
$l =$ M.V.

$C = TV - MV$

$= l_0 - l$

$= l\cos\theta - l$

$$C = -l(1-\cos\theta)$$



Actual dist. measured by chain

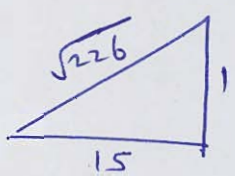
$= \sqrt{30^2 - 0.9^2}$

$= 29.986\ m$

For 90 m $\longrightarrow \dfrac{90}{30} \times 29.986$

$= 89.959\ m$

Horizontal distance $= l_0\cos\theta$

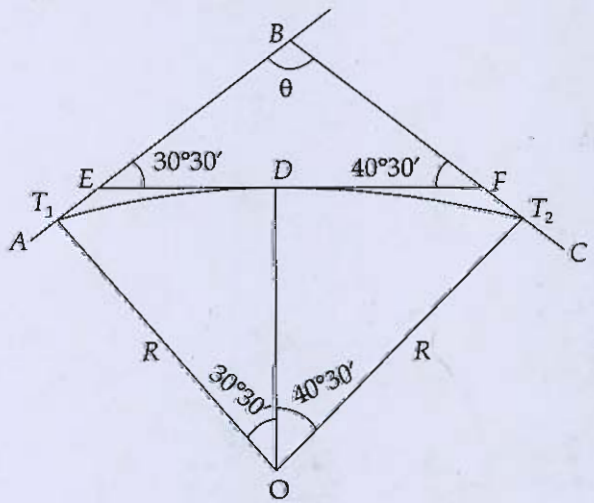


$= \dfrac{15}{\sqrt{226}} \times 89.959$

$= 89.759\ m$

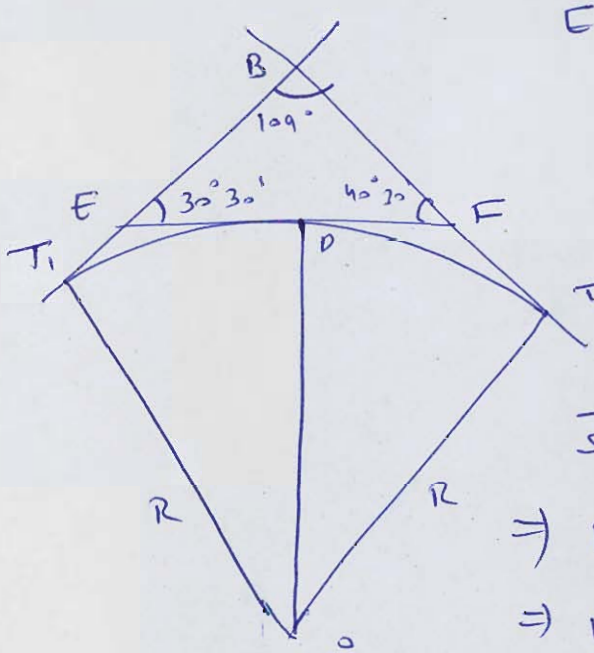
7

Q.5 (e) Two straight lines AB and BC intersect at B, the chainage of B being 1500.00 m. Another line EF intersect AB and BC such that $\angle BEF = 30°30'$ and $\angle BFE = 40°30'$. The length EF is 175 m. Find the radius of the curve which will be tangential to AB, EF and BC. Also calculate the chainages of the tangent points.



[12 marks]

Soln



$EF = 175m$

$\theta = 180^\circ - 30^\circ 30' - 40^\circ 30'$

$= 109^\circ$

Using sine law

$$\frac{EF}{\sin 109} = \frac{BE}{\sin(40^\circ 30')} = \frac{BF}{\sin(30^\circ 30')}$$

$\Rightarrow BE = 120.2m$

$\Rightarrow BF = 93.94m$

Now,

$EF = E\theta + DF = T_1E + T_2F$

$\Rightarrow 175 = R\tan\left(\frac{30^\circ 30'}{2}\right) + R\tan\left(\frac{40^\circ 30'}{2}\right)$

$\Rightarrow$ ~~$R = 233.81m$~~ $R = 272.77m$

Now, $T_1E = \frac{272.77}{233.81} \tan\left(\frac{30^\circ 30'}{2}\right) = 74.36m$

$T_2F = \frac{272.77}{233.81} \tan\left(\frac{40^\circ 30'}{2}\right) = 86.25$

$= 10.64m$

Chainage at B = 1500m

Chainage at T_1 = 1500 − 120.2 − 74.36m

= 1305.44

$L_C = L_{C_1} + L_{C_2} = \frac{2\pi R}{360} \times \Delta_1 + \frac{2\pi R}{360} \times \Delta_2$

$= \frac{2\pi \times 272.77}{360}(30^\circ 30' + 40^\circ 30')$

$L_C = 338.01m$

Chainage at T_2 = 1305.44 + 338.01

= 1643.45 m

12

Q.6 (a) (i) Write short notes on:

1. Photogrammetry
2. Map vs Aerial photographs.

(ii) The following staff readings were taken with a level, the instrument having been shifted after the 4th, 7th and 10th readings. The RL of the starting benchmark (A) is 123.450 m. The third reading was taken with an inverted staff on point *B*, and the 4th, 7th and 10th readings were taken on points *C*, *D* and *E*. The last reading was taken on benchmark *F*. The readings (in m) are:

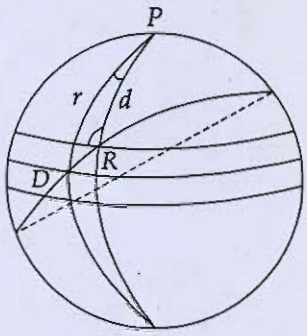
2.650, 3.740, (–2.830)(B), 4.270(C), 4.640, 0.380, 0.960(D), 1.640; 2.840, 3.480(E), 4.680 and 4.260(F).

1. Tabulate the readings in the form of a level-book page. Reduce the readings and apply the usual checks.
2. Calculate the R.L's of *B*, *C*, *D*, *E* and *F*. Use height of collimation method.

[8 + 12 = 20 marks]

Q.6 (b) **(i)** Explain the following terms : *(a)* Equinoctial points and *(b)* Right ascesion.

(ii) Find the shortest distance between a station (29°52′N, 77°54′E) at Roorkee and to a station (28°34′N, 77°06′E) at Delhi. Determine the azimuth of the line along which the direction of the shortest distance to be set out starting from Roorkee.



[4 + 16 = 20 marks]

Q.6 (c) P, Q, R and S are four stations whose coordinates are as given below:

Station	Easting (m)	Northing (m)
P	1000	1000
Q	1180.94	1075.18
R	1021.98	1215.62
S	939.70	1102.36

Another station X is to be fixed at the intersection of the lines PR and QS. What are the coordinates of X?

[20 marks]

Q.7 (a) An area of 150 km × 15 km is to be surveyed using aerial photogrammetry. Determine the total number of photographs required to cover the whole area with the following details:

Size of photograph = 23 cm × 23 cm
Average scale of photograph = 1 : 25000
Average elevation of terrain = 335 m
Longitudinal overlap = 65%
Side overlap = 28%
Ground speed of aircraft = 270 km/hr
Focal length of camera = 200 mm
Least count of intervalometer = 0.5 sec

[20 marks]

Soln No. of photographs ~~is~~ required in 1 strip

$$= \frac{150 \times 10^5 \text{ cm}}{23 \text{ cm} \times 25000 (1 - 0.65)} + 1$$

$$= 75.53 \simeq 76 \text{ photographs}$$

No. of strips required =

$$= \frac{15 \times 10^5}{23 \times 25000 \ (1 - 0.28)} + 1$$

$$= 4.62 \simeq 5$$

(12)

Total no. of photographs required

$$= N_1 \times N_2 = 76 \times 5 = 380$$

ground distance need to be adjusted

Q.7 (b) **(i)** The following latitudes and departures were obtained for a closed traverse *ABCDEFA* survey:

Line	Latitude (m)	Departure (m)
AB	0.00	183.79
BC	128.72	98.05
CD	177.76	–140.85
DE	–76.66	–154.44
EF	–177.09	0.00
FA	–52.43	13.08

Adjust the traverse by Bowditch's method and compute corrected latitudes and departures of all the traverse lines. Also calculate the bearing of *CD*.

(ii) A steel tape was exactly 30 m long at 20°C when supported throughout its length under a pull of 10 kg. A line was measured with this tape under a pull of 15 kg and at a mean temperature of 32°C and found to be 780 m long. The cross-sectional area of the tape = 0.03 cm^2, and its total weight = 0.693 kg α for steel = 11×10^{-6} per °C and E for steel = 2.1×10^6 kg/cm^2. Compute the true length of the line if the tape was supported during measurement.

1. At every 30 m
2. At every 15 m.

[10 + 10 = 20 marks]

Soln

Line	L	D	Length	C_L	Corrected Lat	Corrected Lat
AB	0	183.79	183.79	-0.0619	0.0619	-0.0619
BC	128.72	98.05	161.81	-0.0545	128.774	128.665
CD	177.76	-140.85	141.48	-0.0475	177.807	177.712
DE	-76.66	-154.44	172.42	-0.058	-76.602	-76.718
EF	-177.09	0	177.09	-0.0596	-177.03	-177.149
FA	-52.43	13.08	54.04	-0.0182	-52.411	-52.448
			$\Sigma = 890.63$		$\Sigma =$	$\Sigma = 0$

$\Sigma Lat = 0.3 = e_L$

$\Sigma Dep = -0.37 = e_D$

Closing error $= \sqrt{e_L^2 + e_D^2} = 0.476$

Sample calculation

Using Bow ditch mtd,

For AB,

Length $= L_{AB} = \sqrt{0^2 + 183.792} = 183.79$

$\Sigma Length = 890.63$

$C_L = -\left(\frac{L_{AB}}{\Sigma L}\right) \times e_L$

$= -\left(\frac{183.79}{890.63}\right) \times (0.3) = -0.0619$

$C_D = -\left(\frac{L_{AB}}{\Sigma D}\right) \times C_D$

$= -\left(\frac{183.79}{890.63}\right) \times (-0.37) = 0.0764$

Line	D	C_D	Corrected D C_D
AB	193.79	0.076n	183.861
BC	18.05	0.066n	98.709
CD	-140.85	0.0588	-140.7912
DE	-154.44	0.0717	-154.368
EF	0	0.0715	0.0715
FA	13.09	0.0224	13.1024
			$\Sigma \neq 0$

⇒) Bearing of CD

$\theta = \tan^{-1}\left(\frac{D}{L}\right) = \tan^{-1}\left(\frac{140.85}{212.76}\right)$

$= 38.39°$

$\theta = 180 + 38.39 = 218.39$

16

(ii)

~~L~~ = 30m, $T_s = 20^\circ C$, $P_s = 10\ kg$

$T_m = 32\ kg$ $P_m = 15\ kg$

$L = 780m$, $A = 0.03\ cm^2$, $W = 0.693\ kg$

$\alpha = 11 \times 10^{-6}/^\circ C$, $E = 2.1 \times 10^6\ kg/cm^2$

(a) Coll^n due to temp.

$= L \alpha (T_m - T_o)$

$= 780 \times 11 \times 10^{-6} (32 - 20)$

$= 102.9mm$

(b) Coll^n due to pull

$= \frac{(P_m - P_s) L}{A E}$

$= \frac{(15-10) \times 780}{0.03 \times 2.1 \times 10^6} = 61.9\ mm$

(c) Collcation due to sy

$= \frac{W^2 L}{24 P_m^2}$

$= \frac{-0.693^2 \times 780}{24 \times 15^2} = -69.36\ mm$

8

Total collcation = 95.44 mm

(d) For every 30m support

$\Rightarrow$ Collcation = 95.44mm

True length = $780 - \frac{95.44}{100}$

$= 779.904m$

Q.7 (c) (i) Explain the objectives of triangulation surveys and explain the criteria for selection of layout of triangles. Also, explain the terms well conditioned triangles and strength of figure.

(ii) The following are the observed values of an angle and their weightage :

Angle	Weightage
30° 24′ 20″	2
30° 24′ 18″	2
30° 24′ 19″	3

Find :

1. Probable error of single observation of unit weight.
2. Probable error of weighted arithmetic mean.
3. Probable error of single observation of weight 3.

[8 + 12 = 20 marks]

Ans (i) Well conditioned triangles :-

- The triangles whose angles are greater than 30° & less than 120°
- Intervisibility b/w stations is good.

Objective of triangulation :-

To obtain the necessary data about an area the area is divided into a series of triangles

- If the length & direction of one line & and the other two angles are precisely known than the length & direction of other two lines can be precisely calculated. This is principle of triangulation.

(ii)

Mean, $= \overline{x} = 30° 24' 1a'$

$$\overline{x} = \frac{2 \times 30° 24' 20'' + 30° 24' 18'' \times 2 + 3 \times 30° 24' 19''}{2+2+3}$$

$$= 30° 24' 1a'$$

$$\Sigma W_n (x_i - \overline{x}_i)^2 = 2 \times (30° 24' 20'' - 30° 24' 1a'')^2 + 2 (30° 24' 18'' - 30° 24' 1a'')^2 + 3 (30° 24' 19'' - 30° 24' 1a'')^2$$

$$= 2'' + 2 \times 1 + 0 = 4''$$

(1) Probable error in single observation of unit wt.

$$= \pm 0.6745 \sqrt{\frac{\Sigma W_n (x_i - \overline{x}_n)^2}{n-1}}$$

$$= \pm 0.6745 \sqrt{\frac{4''}{7-1}}$$

$$= 0° 0' 39.04''$$

6+8

(2) Probable error in mean

$$= \pm 0.6745 \sqrt{\frac{\Sigma W_n (x_i - \overline{x}_n)^2}{\Sigma W \times (n-1)}}$$

$$= 0° 0' 12.49''$$

avoid silly mistakes

(3) Probable error in single observation of weight 3 $= \pm 0.6745 \sqrt{\frac{\Sigma 3 W_n (x_i - \overline{x}_n)^2}{3 W_0 (n-1)}}$

$$= 0° 0' 19.09''$$

Q.8 (a) **(i)** Explain the following terms in the context of surveying: (a) Least count (b) Closing error (c) Arithmetic check (d) Local attraction (e) Whole to the part.

(ii) The following forebearings and backbearings were observed in traversing with a compass:

Line	Forebearing	Backbearing
PQ	S 37°30′E	N37°30′W
QR	S 43°15′W	N44°15′E
RS	N 73°00′W	S72°15′E
ST	N 12°45′E	S13°15′W
TP	N 60°00′E	S59°00′W

Calculate the interior angles and correct them for observational errors.

[10 + 10 = 20 marks]

Q.8 (b) Two sets of tacheometric readings were taken from an instrument station A (RL of A = 100 m) to a staff station B as shown below.

Instruments	P	Q
Multiplying constant	100	95
Additive constant	0.30	0.45
Height of instrument	1.40 m	1.45 m
Staff held	Vertical	Normal

Instruments	Instruments station	Staff station	Vertical angle	Stadia readings
P	A	B	5°44′	1.090, 1.440, 1.795
Q	A	B	5°44′	?

Determine:

(i) The distance between instrument station and staff station.

(ii) The R.L. of staff station B.

(iii) Stadia readings with instrument Q.

[20 marks]

Soln

Q.8 (c) (i) Define relief displacement. Also, derive the expression for relief displacement on a vertical photograph with a neat sketch.

(ii) Briefly discuss about the temporary adjustments made in a theodolite.

(iii) Define compensating error, positive cumulative error and negative cumulative error with respect to chaining.

Also mention the source for the above errors.

[6 + 6 + 8 = 20 marks]

■■■■

Space for Rough Work

Space for Rough Work

$$w = \frac{w_w}{w_s} = \frac{w_w}{w_s}$$

$$w_1 = w_2$$

$$w_1 \times (w_s) = w$$

CO_2	~~H_2O~~ Air
~~H_2O~~	~~CO_2~~

$$Q = kiA$$

$$k \times \frac{h}{L} \times A = a \times \frac{dh}{dt}$$