210/300

- Always write values with units
- ~~Do calculation~~ stepwise and clear.
- Improve Answer representation

Good

Accuracy O.K

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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	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	

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.

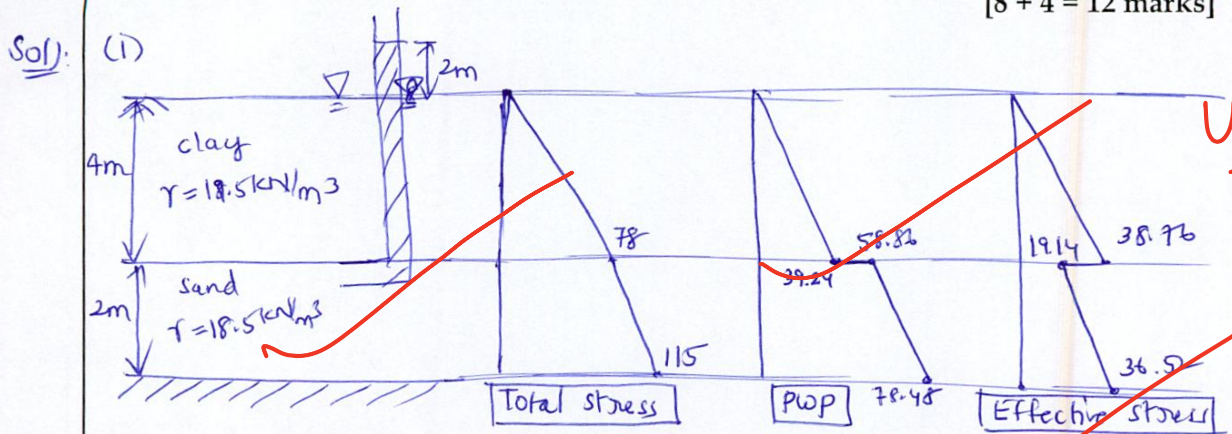
Section A : Geo-technical Engineering and Foundation Engineering

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]

Sol). (i)



Position	Total stress (σ)	PWP (u)	$\bar{\sigma} = \sigma - u$
z = 0	0	0	0
z = 4 (in the clay)	$19.5 \times 4 = 78\ kN/m$	$9.81 \times 4 = 39.24\ kN/m$	$38.76\ kN/m$
z = 4 (in the sand)	$78\ kN/m$	$9.81 \times 6 = 58.86$	$19.14\ kN/m$
z = 6	$78 + (18.5 \times 2) = 115$	$9.81 \times 8 = 78.48$	$36.52\ kN/m$

(ii) If head in sand is reduced by 1m

At the top of rock,

Total stress (σ) = $115\ kN/m$

Pore water pressure (u) = $9.81 \times 7 = 68.67\ kN/m$

Effective stress ($\bar{\sigma}$) = $115 - 68.67 = 46.33\ kN/m$

Increase in effective stress = $46.33 - 36.52$

$= 9.81\ kN/m$

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]

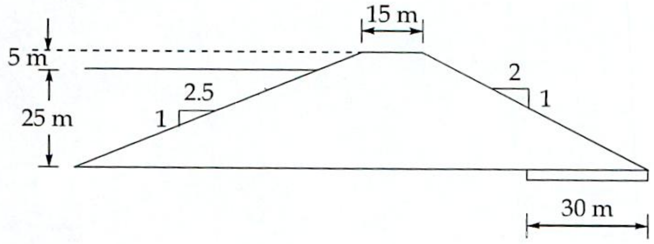
(ii) Further 1.5 kN of clay at a moisture content of 10%. was added to the above mixture such that no further increase in the volume of the subgrade resulted. Determine the further reduction in porosity that this addition of clay brought about. Assume G_S of clay particles is 2.67.

[6 + 6 = 12 marks]

Sol:

(i) Given: $G_s = 2.67$, $(\gamma_b)_1 =$

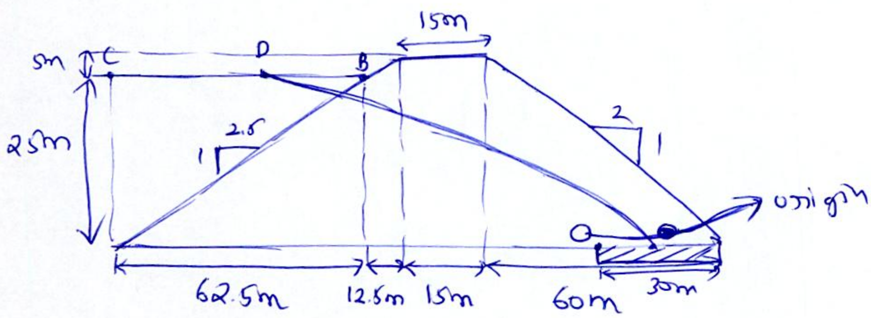
Q.1 (c) A homogenous earth dam is provided with a horizontal filter drain 30 m long at its toe, as shown in Figure. Determine the focal length.



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

[12 marks]

Sol).



We know that, BD = 0.3 BC

$\Rightarrow BD = 0.3 \times 62.5 = 18.75\,m$

Equation of top flow line

$$\sqrt{x^2+y^2} = x+s$$

'D' is on the top flow line & co-ordinates are

$(x, y) = (76.25, 25)$

$\Rightarrow \sqrt{76.25^2+25^2} = 76.25+s$

$\Rightarrow s \simeq 4$

(12)

Now, seepage discharge (q) = ks

$= 40\,m/day \times 4\,m$

$\Rightarrow$ **q = 160 m³/day**

Do not write in this margin

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:

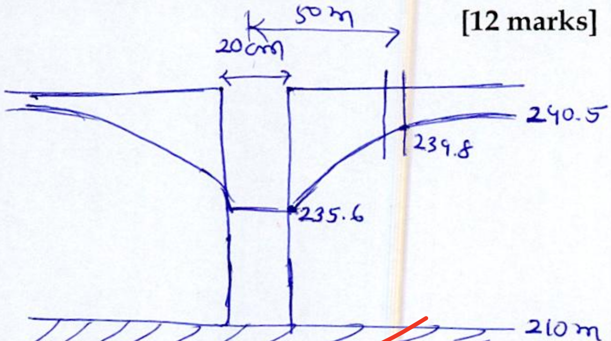
(i) The error in coefficient of permeability if observations are not taken in the observation well, and the radius of influence is assumed to be 300 m.

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

[12 marks]

Sol: For unconfined aquifer

$$Q = \frac{\pi K (h_2^2 - h_1^2)}{\ln(r_2/r_1)}$$



Here $r_1 = r = \frac{20}{2 \times 100} = 0.1 m$

$r_2 = 50 m$

$h_1 =$ ~~240.5~~ $235.6 - 210 = 25.6$

$h_2 = 239.8 - 210 = 29.8\,m$

$Q = 240\ m^3/hr$

$$\Rightarrow 240 = \frac{\pi \times k \times [29.8^2 - 25.6^2]}{\ln\left[\frac{50}{0.1}\right]}$$

$\Rightarrow \boxed{k = 2.04\ m/hr}$

4

Incomplete solution

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

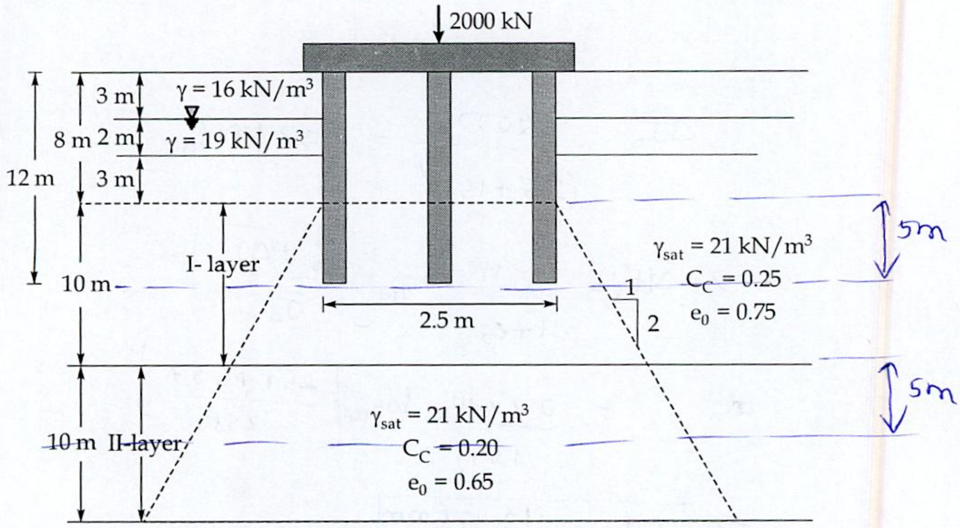
(i) Chemical stabilization (ii) Stabilization by heating

(iii) Electrical stabilization

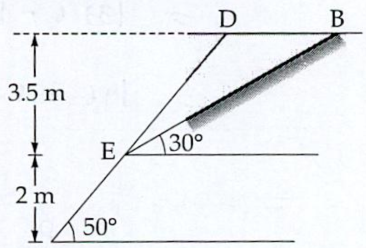
[4 + 4 + 4 = 12 marks]

Do not write in this margin

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]

Sol:

(i) For layer - I:

$\bar{\sigma}_0$ (At the middle) $= [16\times3] + [(19-10)\times5] + [(21-10)\times5]$

$= 148\ kN/m^2$

$$\Delta\bar{\sigma}_0 = \frac{2000\ kN}{(2.5+5)^2} = 35.56\ kN/m^2$$

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

$$= \frac{0.25\times10}{1+0.75}\log_{10}\left[\frac{148+35.56}{148}\right]$$

$\Rightarrow$ $\boxed{\Delta H_1 = 133.6\ mm}$

For II-layer:

$\bar{\sigma}_o$ (at the middle) $= 148 + ((21-10)\times 5) + ((21-10)\times 5)$

$= 258 \ kN/m^2$

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

$$\Rightarrow \Delta H_2 = \frac{C_c H}{1+e_o}\log_{10}\left[\frac{\bar{\sigma}_o + \Delta\bar{\sigma}_o}{\bar{\sigma}_o}\right]$$

$$= \frac{0.2\times 10}{1.65}\log_{10}\left[\frac{258+6.53}{258}\right]$$

$$\Rightarrow \boxed{\Delta H_2 = 13.158 \ mm}$$

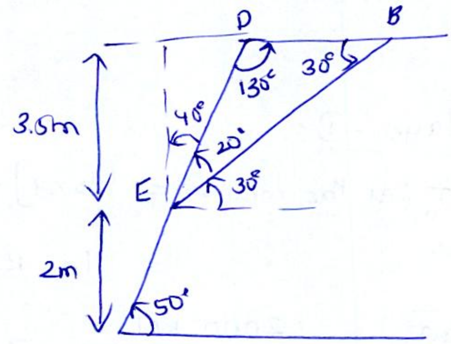
Now, Total Consolidation settlement $= \Delta H_1 + \Delta H_2$

$= 133.6 + 13.158$

$= 146.758 \ mm$

10

(ii) We have to find the soil mass DBE



From ΔDBE,

$$\frac{DB}{\sin 20^\circ} = \frac{DE}{\sin 30^\circ}$$

$$DE = \frac{3.5}{\cos 40} = 4.57 \ m$$

$$\Rightarrow \boxed{DB = 4.57\times\frac{\sin 20^\circ}{\sin 30^\circ} = 3.13 \ m}$$

Now, weight of mass DBE per unit length

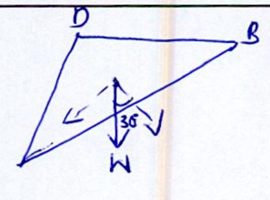
$= \left(\frac{1}{2}\times 3.13\times 3.5\right)\times 1\times 19$

$= 104.0725 \ kN/m$

Now, Actuating force = $W \sin 30°$

$= \frac{104.0725}{2}$

$= 52.036$ kN/m



Resisting force (or shear strength)

$= c L_{EB} + (W \cos 30°) \tan 20°$

Now, $\frac{EB}{\sin 130°} = \frac{DB}{\sin 20°}$

$\Rightarrow$ $EB = 3.13 \times \frac{\sin 130°}{\sin 20°} = 7.01$ m

$\Rightarrow$ Resisting force $= (8 \times 7.01) + (104.0725 \times \cos 30° \times \tan 20°)$

$= 88.884$ kN/m

Now, Factor of safety $= \frac{\text{Resisting force}}{\text{Actuating force}}$

$= \frac{88.884}{52.036}$

$= 1.708$

Hence, factor of safety against wedge failure along interface EB is **1.708**

10

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]

(ii) Given: Water content = 10%.

Volume of cylinder = $\pi r^2 h$

$= \pi \times \left(\frac{15}{2}\right)^2 \times 12.5$

Volume of cylinder = 2208.93 cm^3

Air content of specimen (a_c) = 6% ⇒ $S + a_c = 1$

⇒ $S = 94\%$

Now, $\gamma_b = \frac{\gamma_w(G_s + w_c G_s)}{1+e}$

$e = \frac{w_c G_s}{S} = \frac{0.1 \times 2.68}{0.94} = 0.285$

⇒ $\gamma_d = \frac{\gamma_w G_s}{1+e} = \frac{9.81 \times 2.68}{1.285} = 20.46$ kN/m³

$\gamma_b = \gamma_d(1 + w_c) = 20.46(1.1) = 22.5$ kN/m³

For $V = 2208.93$ cm³ $= 2.208 \times 10^{-3}$ m³

Mass required = $2.208 \times 10^{-3} \times 22.5 = 49.7$ N

Hence mass required to produce cylindrical

Specimen = $\frac{49.7}{9.81}$ = 5.07 kg

(10)

Void ratio (e) = 0.285

Dry density (γ_d) = 20.46 kN/m3

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

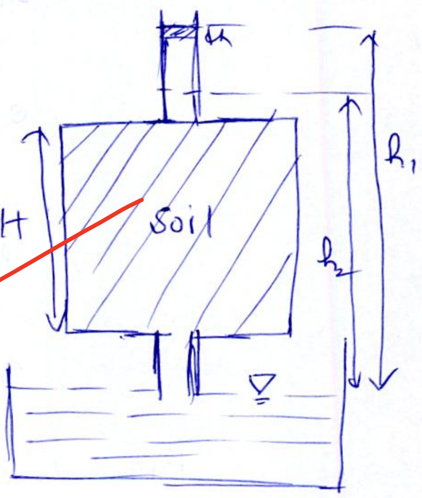
(ii) A soil sample of height 6 cm and area of cross-section 100 cm^2 was subjected to a falling head permeability test. In a time interval of five minutes, the head dropped from 60 cm to 20 cm. If cross-sectional area of stand pipe is 2 cm^2, compute the coefficient of permeability of the soil sample.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

[10 + 10 = 20 marks]

Sol): (i) Falling head test:

* It is generally done for fine soil, which is having low permeability

Let's consider the setup as shown



c/s Area of stand pipe be 'a'

c/s Area of sample be 'A'

Length of sample be 'H'

At time 't1' water level in stand pipe is at 'h1'

In time 'dt' it falls by 'dh'

At time 't2' water level is at 'h2'

Volume (V) ~~Discharge~~ (~~Q~~) $= -a \cdot dh = k \cdot \frac{h}{H} \cdot A \cdot dt$

$\Rightarrow -a \cdot dh = k\frac{h}{H} \cdot A \cdot dt$

$\Rightarrow \int_{h_1}^{h_2} -\frac{dh}{h} = \int_{t_1}^{t_2} \frac{kA}{aH} \cdot dt$

$\Rightarrow \ln\left[\frac{h_1}{h_2}\right] = \frac{kA(t_2-t_1)}{aH}$

$\Rightarrow \boxed{k = \frac{aH}{A(t_2-t_1)} \ln\left[\frac{h_1}{h_2}\right]}$

(9)

(ii) Given: sample height $(H) = 6$ cm

sample c/s area $(A) = 100\ cm^2$

Time interval $(t_2-t_1) = 5$ min $= 300$ sec

stand pipe c/s area $(a) = 2\ cm^2$

$k = \frac{2 \times 6}{100 \times 300} \times \ln\left[\frac{60}{20}\right]$

$\Rightarrow \boxed{k = 4.394 \times 10^{-4}\ cm/s}$

Now, Head causing flow $(\Delta H) = 18$ cm

From darcy's law,

$Q = k \cdot \frac{\Delta H}{L} \cdot A$

$\Rightarrow Q = \left[4.394 \times 10^{-4}\right] \times \frac{18}{6} \times 100$

$\Rightarrow \boxed{\text{Discharge } (Q) = 0.132\ cm^3/s}$

(10)

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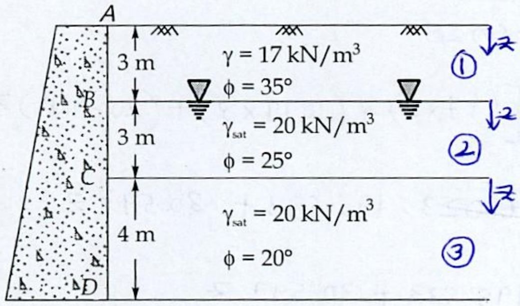
Q.3 (a) For the retaining wall as shown in figure below, plot the distribution of passive earth pressure and determine magnitude of total passive thrust and point of application of total passive thrust.



[20 marks]

Sol:

For Region-① : ($z = 0$ to $3m$)

$$K_{p_1} = \frac{1+\sin\phi}{1-\sin\phi} = \frac{1+\sin 35°}{1-\sin 35°} = 3.69$$

Passive earth pressure $(P_p) = K_{p_1}(\gamma z)$

$= 3.69 \times 17 \times z$

$P_p = 62.733\, z$

At A: At the top $(P_p) = 0$

At B: At the bottom of Region-① ($z = 3$) $\Rightarrow P_p = 188.19$ kN/m²

For Region-② : ($z = 0$ to $3m$)

$$K_{p_2} = \frac{1+\sin 25°}{1-\sin 25°} = 2.464$$

$$P_p = K_{p_2}\left[(17\times 3) + (20-9.81)z\right] + 9.81z$$

$= 2.464\left[51 + 10.19z\right] + 9.81z$

$\Rightarrow P_p = 125.664 + 34.92\, z$

At B: For $z = 0 \Rightarrow P_p = 125.664$ kN/m²

At C: For $z = 3 \Rightarrow P_p = 230.404$ kN/m²

For Region – ③ : ($z=0$ to 4m)

$$K_{p_3} = \frac{1+\sin 20^\circ}{1-\sin 20^\circ} = 2.04$$

$$P_p = K_{p_3}\left[(17\times3)+(10.19\times3)+(20-9.81)z\right] + 9.81(z+3)$$

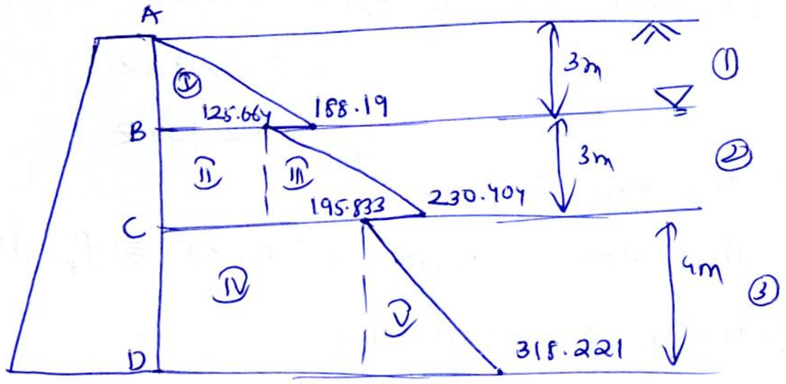
$= ~~186.023~~ \; 195.833 + 30.597z$

$\Rightarrow P_p = 195.833 + 30.597z$

At C: For $z=0$; $P_p = 195.833 \text{ kN/m}^2$

At D: For $z=4$; $P_p = ~~287.624~~ \; 318.221 \text{ kN/m}^2$

Hence the distribution of passive earth pressure is



Zone	Passive thrust	Point of application (from bottom)
Ⅴ	$\frac{1}{2}\times(318.221-195.833)\times4 = 244.776$ kN/m	$\frac{4}{3}$ m
Ⅳ	$195.833\times4 = 783.332$ kN/m	$\frac{4}{2} = 2$m
Ⅲ	$\frac{1}{2}\times(230.404-125.664)\times3 = 157.11$ kN/m	$4+\frac{3}{3} = 5$m
Ⅱ	$125.664\times3 = 376.992$ kN/m	$4+\frac{3}{2} = 5.5$m
Ⅰ	$\frac{1}{2}\times$ ~~125.664~~ 188.19 $\times 3 = 282.285$ kN/m	$4+3+\frac{3}{3} = 8$m

Total passive thrust = 1844.495 KN/m

$$\text{C.G from bottom} = \frac{\left(244.776 \times \frac{4}{3}\right) + \left(783.332 \times 2\right) + \left(157.11 \times 5\right) + \left(376.492 \times 5.5\right) + \left(282.285 \times 8\right)}{1844.495}$$

⇒ Point of application (from bottom) = 3.8 m

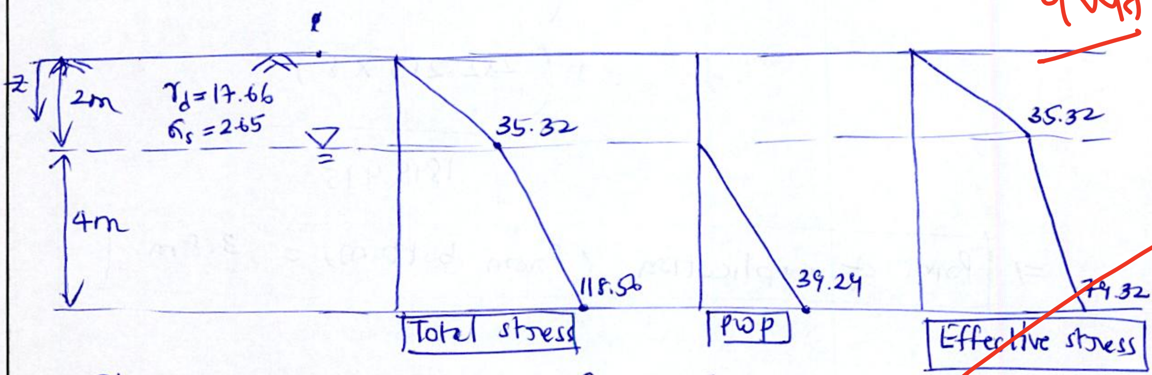
20

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]

Sol):

Case-I : WT is 2m below GL



Given: $\gamma_d = 17.66\ kN/m^3$, $G_s = 2.65$

$$\Rightarrow \gamma_d = \frac{\gamma_\omega G_s}{1+e} = \frac{9.81 \times 2.65}{1+e} = 17.66$$

$$\Rightarrow e = 0.472$$

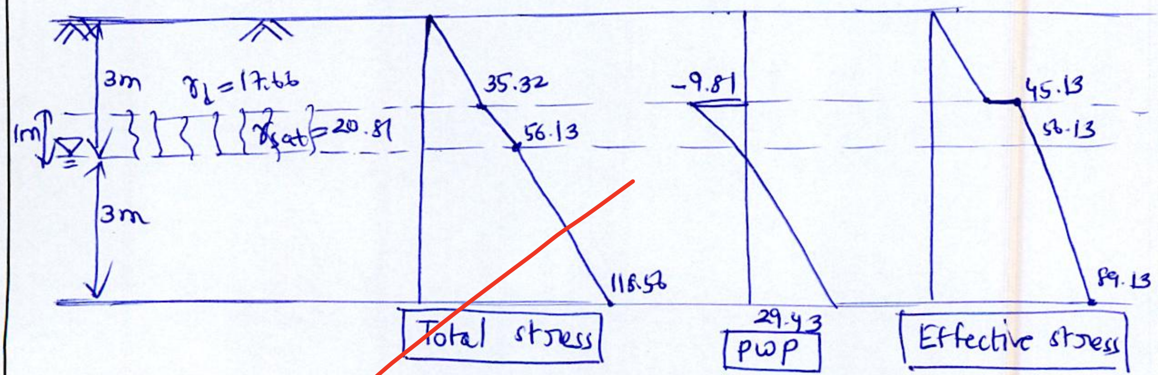
$$\gamma_{sub} = \frac{\gamma_\omega (G_s - 1)}{1+e} = 10.997\ kN/m^3$$

$$\gamma_{sat} = 10.997 + 9.81 = 20.81\ kN/m^3$$

Position	Total stress (σ)	PWP (u)	Effective stress ($\bar{\sigma}$) = $\sigma - u$
z=0	0	0	0
z=2	17.66×2 = 35.32 kN/m²	0	35.32 kN/m²
z=6	(17.66×2)+(20.81×4) = 118.56 kN/m²	9.81×4 = 39.24 kN/m²	79.32 kN/m²

Case-(II): WT is at 3m below GL

unit ?



Here, 1m above water table is capillary zone.

Position	Total stress (σ)	PWP (u)	$\bar{\sigma} = \sigma - u$
z = 0	0	0	0
z = 2	17.66 × 2 = 35.32 kN/m²	-(9.81 × 1) = -9.81 kN/m²	35.32 - (-9.81) = 45.13 kN/m²
z = 3	(17.66 × 2) + (20.81 × 1) = 56.13 kN/m²	0	56.13 kN/m²
z = 6	(17.66 × 2) + (20.81 × 4) = 118.56 kN/m²	(9.81 × 3) = 29.43 kN/m²	89.13 kN/m²

(20)

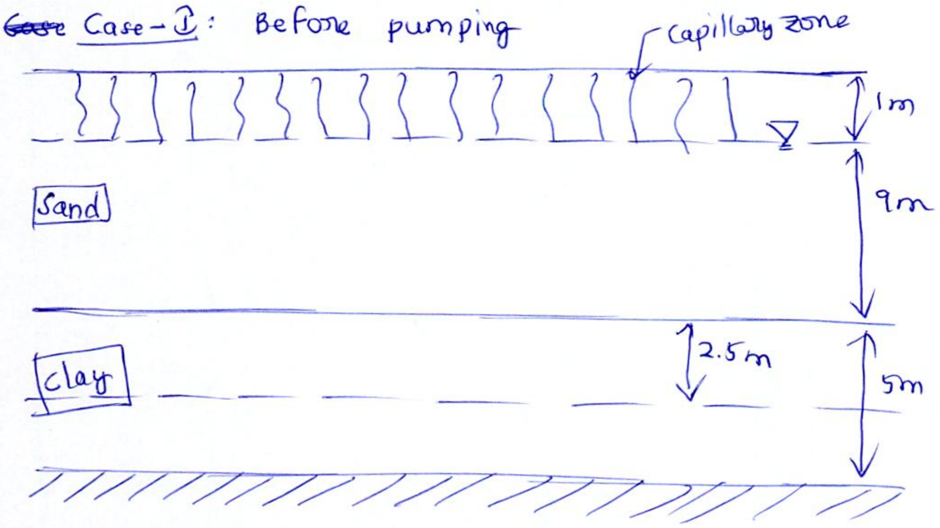
Q.3 (c) A light weight building stands or a 10 m thick stratum of sand. Beneath the sand stratum, a clay layer of 5 m thick exists. The clay layer is underlain by a rock stratum. The water table lies at a depth of 1.0 m below ground surface and the sand above the water table is saturated with capillary 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]

Sol): Case-I: Before pumping



$\frac{\gamma_w G_s}{1+e} = (\gamma_d)_{sand} = \frac{9.81 \times 2.65}{1.75} = 14.86 \ kN/m^3$

$\frac{\gamma_w (G_s+e)}{1+e} = (\gamma_{sat})_{sand} = \frac{9.81 \times (2.65+0.75)}{1.75} = 19.06 \ kN/m^3$

$(\gamma_d)_{clay} = \dfrac{9.81 \times 2.7}{1+0.6} = 16.55 \ kN/m^3$

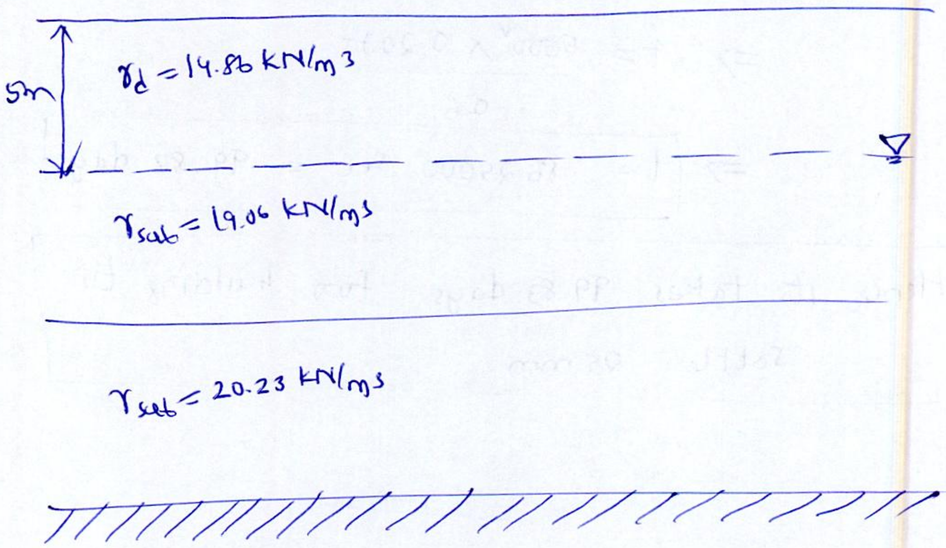
$(\gamma_{sat})_{clay} = \dfrac{9.81 \times (2.7+0.6)}{1+0.6} = 20.23 \ kN/m^3$

At the middle of clay,

Initial effective stress $(\bar{\sigma}_1) = [[(19.06) \times 10] + (20.23 \times 2.5)] - [9.81 \times 11.5]$

$\Rightarrow \boxed{\bar{\sigma}_1 = 128.36 \ kN/m^2}$

Case - II : After pumping



Final effective stress $(\bar{\sigma}_2) = [(14.86 \times 5) + (19.06 \times 5)] + (20.23 \times 2.5) - (9.81 \times 7.5)$

$\Rightarrow \boxed{\bar{\sigma}_2 = 146.6 \ kN/m^2}$

For clay : $C_v = 6 \times 10^{-3} \ cm^2/s = 0.6 \ mm^2/s$

$C_c = 0.09(w_L(\%) - 10) = 0.09(40-10) = 0.27$

Ultimate settlement $(\Delta H_u) = \dfrac{C_c H}{1+e_0} \log_{10}\left[\dfrac{\bar{\sigma}_2}{\bar{\sigma}_1}\right]$

$= \dfrac{0.27 \times 5}{1.6} \log_{10}\left[\dfrac{146.6}{128.36}\right]$

Ultimate settlement $(\Delta H_u) = 48.69\ mm$

For $\Delta H = 25\ mm$

% Consolidation $= U(\%) = \frac{25}{48.69} \times 100 = 51.35\%$

$\Rightarrow T_v = \frac{\pi}{4}[U(\%)]^2$ (As $U < 60\%$)

$\Rightarrow T_v = 0.207$

$T_v = \frac{C_v t}{H_e^2}$

It is a single drainage $\Rightarrow H_e = H = 5m$

$\Rightarrow t = \frac{5000^2 \times 0.207}{0.6}$

$\Rightarrow$ $t = 8625000\ sec = 99.83\ days$

Hence it takes 99.83 days for building to settle 25mm

20

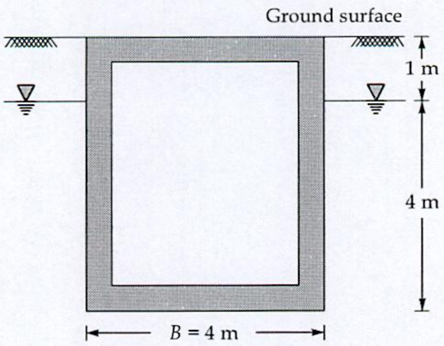
Q.4 (a) **(i)** A square footing of (2.5 m × 2.5 m) size has been founded at 1.2 m below the ground level in a cohesive soil having a bulk density of 1.8 t/m^3 and an unconfined compressive strength of 5.5 t/m^2. Determine the ultimate and safe bearing capacity of the footing for a FOS of 2.54 by

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]

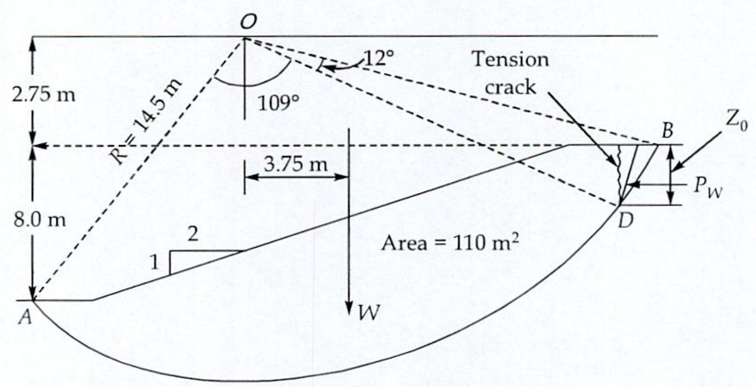
[14 + 6 = 20 marks]

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 (ϕ_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]

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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:

For $L = 100m$, $s = 0.99m$

$\Rightarrow ks + c = 100$

$\Rightarrow 0.99k + c = 100 \rightarrow (1)$

For $L = 300m$, $s = 3m$

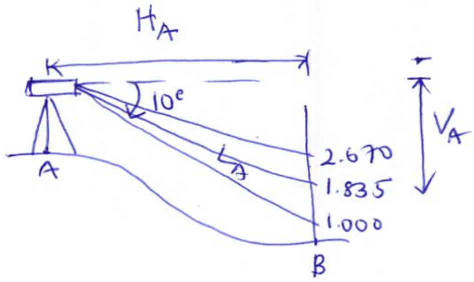
$\Rightarrow 3k + c = 300 \rightarrow (2)$

From (1) & (2), Multiplication constant $(k) = 99.5$
Additive constant $(c) = 1.49$

Now,

$s = 2.670 - 1.000 = 1.670$

$\theta = -10°$



$\Rightarrow$ As staff is vertical

$L_A = ks\cos\theta + c$

$\Rightarrow L_A = [99.5 \times (1.670) \times \cos 10°] + 1.49 = 165.13m$

Horizontal distance from A $[H_A] = L_A \cos\theta$
$= 165.13 \times \cos 10° = 162.62\ m$

Now, $RL_B = RL_A + HI - V_A - S_2$

$= 450.5 + 1.42 - [165.13 \times \sin 10°] - 1.835$

$\Rightarrow RL_B = 421.41m$

12

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]

Sol:

(ii) Sources of errors in GIS:

(a) Multi-path errors

(b) Recieving antenna error

(c) Satellit clock error

(d) Propagation medium error

(e) Emitting antenna error

1

Insufficient Answer

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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.

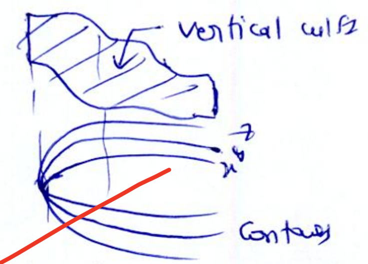
	I	*II*
Staff reading	1.680	1.602
Eye-piece end of bubble	20	10
Object glass end of bubble	10	20

[6 + 6 = 12 marks]

Sol:

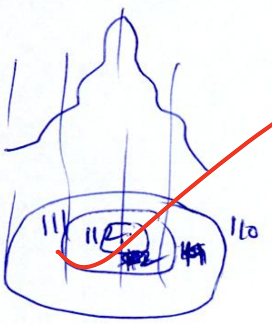
(i) Characteristics of contours:

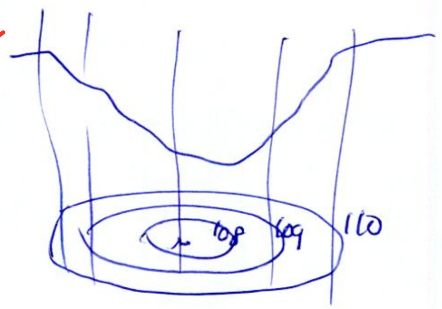
* Contour is a line which joints of equal reduced levels above earth. (or) on earth
* Contours are closed curves. They closes within map & outside maps.
* Two contours intersect only in the case of Vertical cliff & Caves.



* Two contours pass each other only in the case of overhanging cliff

* Concentric contours increasing outwards indicate ~~mountain~~ lake & decreasing outwards indicate mountain





4

* closely spaced contours indicate steep slope & widely spaced contours indicate gentle slope

(ii) We know that,

$$\text{Sensitivity of bubble tube } (\alpha) = \left(\frac{l}{R} \times 206265\right)''$$

$$= \left(\frac{S}{Dn} \times 206265\right)''$$

From the table,

$S = 1.680 - 1.602 = 0.078$

$D = 80\text{m}$

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

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

$\Rightarrow$ **Radius of curvature = 20.513 m**

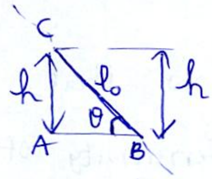
6

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]

Sol: Let, the level difference be 'h'

Measured distance be 'l_0'



$\Rightarrow$ True distance = True horizontal distance

$= AB$

$= l_0 \cos\theta$

Correction $= TV - MV$

$= l_0 \cos\theta - l_0$

$= l_0 [\cos\theta - 1]$

$= l_0 \left[\frac{\sqrt{l_0^2 - h^2}}{l_0} - 1 \right]$

$= \sqrt{l_0^2 - h^2} - l_0$

$= l_0 \left[\sqrt{1 - \left(\frac{h}{l}\right)^2} \right] - l_0$

$\Rightarrow$ Correction $= l_0 \left(\left[1 - \left(\frac{h}{l_0}\right)^2 \right]^{1/2} \right) - l_0$

(As $h \ll l_0$) $= l_0 \left[1 - \frac{h^2}{2l_0^2} \right] - l_0$

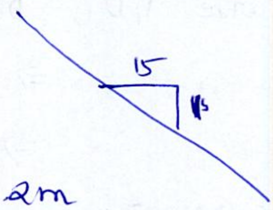
$= l_0 - \frac{h^2}{2l_0} - l_0$

$\Rightarrow$ **slope correction $= -\frac{h^2}{2l_0}$**

(5)

Measured length (MV) = 90m

Misaligned length = 0.9m



Slope correction $= -\dfrac{6^2}{2\times 90} = -0.2m$

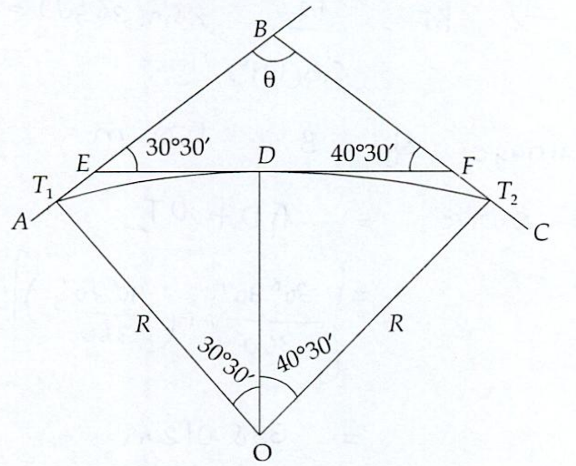
$h = \dfrac{90}{15} = 6$

Misalignment correction $= -\dfrac{0.9}{30}\times 90 = -2.7m$

Hence Correct horizontal distance

$= 90 - 0.2 - 2.7 = 87.1m$

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 ∠*BEF* = 30°30′ and ∠*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]

Sol): For curve T_1D, Deflection angle = $30°30'$

$\Rightarrow$ Tangent length $(T_1E) = R\tan\frac{\Delta}{2}$

$\Rightarrow$ $T_1E = R\tan(15°15') = ED$

For curve T_2D, Deflection angle = $40°30'$

$\Rightarrow$ Tangent length $(T_2F) = R\tan\frac{\Delta}{2}$

$\Rightarrow$ $T_2F = R\tan(20°15') = FD$

From ΔBEF, $EF = 175m$

$\Rightarrow ED + DF = 175$

$\Rightarrow T_1E + T_2F = 175$

$\Rightarrow R[\tan(15°15') + \tan(20°15')] = 175$

$\Rightarrow$ $R = 272.777m$

Radius of curve $(R) = 272.77m$

Now, from ΔBEF, $\dfrac{BE}{\sin(40°30')} = \dfrac{BF}{\sin(30°30')} = \dfrac{EF}{\sin(109°)}$

$\Rightarrow BE = \dfrac{175}{\sin(109°)} \times \sin(40°30') = 120.2\,m$

$\Rightarrow BF = \dfrac{175}{\sin(109°)} \times \sin(30°30') = 93.94\,m$

Given: chainage of $B = 1500\,m$

Length of curve $= T_1D + DT_2$

$= \left[\left(\dfrac{30°30'}{360}\right) + \left(\dfrac{40°30'}{360}\right)\right] \times 2\times\pi\times 272.77$

$= 338.012\,m$

Chainage of T_1 = chainage of $B - BT_1$

$= 1500 - (120.2 + (272.77\times\tan(15°15'))$

$\Rightarrow$ Chainage of $T_1 = 1305.43\,m$

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Chainage of T_2 = chainage of T_1 + Length of Curve

= 1305.43 + 338.012

⇒ Chainage of T_2 = 1643.45m

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).

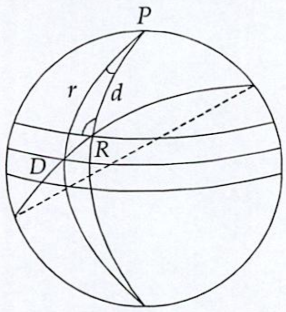
1. Tabulate the readings in the form of a level-book page. Reduce the readings and apply the usual checks.

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]

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]

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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]

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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]

Sol: (i) (a) Least count: It is the minimum measurement that can be made using an instrument. It is the length of one division on a main scale (without Vernier). If Vernier scale is present, Least count is length of one division on main scale by no. of divisions on vernier scale.

Eg: Least count of theodolite is 20″

(b) Closing error :

* Normally, Σlatitude $= 0$ & Σ departure $= 0$ for a closed traverse
* If due to errors, Σ latitude $\neq 0$ and (or) Σdeparture $\neq 0$, closing error is defined as $\sqrt{(\Sigma\text{latitude})^2 + (\Sigma\text{departure})^2}$
* It is corrected by (i) Bowditch method
  (ii) Transit method etc.

(c) Arithmetic check.

* It is the usual check performed in levelling work to ensure the measurements are accurate
* It is

$$\left(\Sigma(B.S) - \Sigma(F.S)\right) = \left(\Sigma \text{Rise} - \Sigma \text{Fall}\right)$$
$$= \text{Last station RL} - \text{first station RL}$$

(d) Local attraction :

* It is the phenomenon of magnetic needle attracted to local fields other than earth's magnetic field
* It can be due to DC current wires, iron items, metal items etc.
* It is a source of error in bearing of lines.

(e) Whole to the part :

* It is the first principle of surveying.
* It means working from the whole to the part.
* It is useful in minimising the propogational errors.

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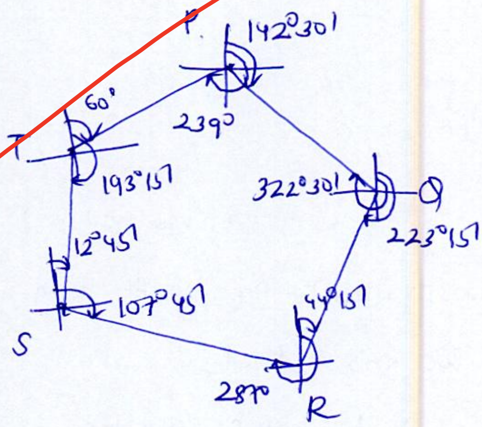
(ii) Whole circle bearings:

Line	PQ	QR	RS	ST	TP
FB	142°30'	223°15' ~~44°15'~~	287°00'	12°45'	60°00'
BB	322°30'	44°15' ~~223°15'~~	107°45'	193°15'	239°00'

Now, interior angles:



$\angle P = -142°30' + 239°$

$\Rightarrow \angle P = 96°30'$

$\angle Q = 322°30' - 223°15'$

$\Rightarrow \angle Q = 99°15'$

$\angle R = (360 - 287) + 44°15'$

$\Rightarrow \angle R = 117°15'$

$\angle S = 107°45' - 12°45'$ $\Rightarrow \angle S = 95°$

$\Rightarrow \angle T = 193°15' - 60°$ $\Rightarrow \angle T = 133°15'$

Sum of interior angles = 541°15'

Designated sum = 540°

$\Rightarrow$ Correction per angle = $\dfrac{540 - 541°15'}{5} = 15'$

Hence corrected internal angles are

$\angle P = 96°15'$
$\angle Q = 99°00'$
$\angle R = 117°00'$
$\angle S = 94°45'$
$\angle T = 133°00'$

(10)

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.

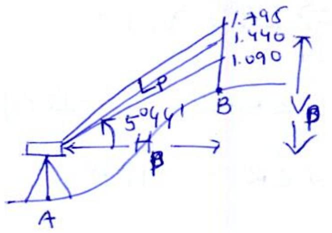
(ii) The R.L. of staff station B.

(iii) Stadia readings with instrument Q.

[20 marks]

Sol): Instrument - P (staff held Vertical)

We know that



$$L_p = K(s\cos\theta) + C$$

$$= \left(100 \times [1.795 - 1.090] \times (\cos 5°44')\right) + 0.3$$

$$\Rightarrow \boxed{L_p = 70.447\,m}$$

(i) Distance between instrument station & staff station is $H_p = L_p \cos\theta$

$$= 70.447 \times \cos(5°44')$$

$$\Rightarrow \boxed{H_p = 70.095\,m}$$

(ii) Given: $RL_A = 100\,m$

$$\Rightarrow RL_B = RL_A + (H.I)_p + V_p - S_2$$

$$= 100 + 1.4 + (70.447 \times \sin(5°44')) - 1.44$$

$$= 100 + 1.4 + 7.037 - 1.44$$

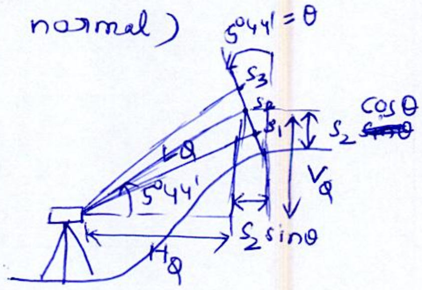
$$\Rightarrow \boxed{RL_B = 106.997\,m}$$

(ii) Instrument - Q (staff held normal)

Let the stadia readings be

s_1, s_2 & s_3

$\Rightarrow s = s_3 - s_1$



Now, $H_Q = H_P = 70.095$

$\Rightarrow \left[(95 \times s) + 0.45\right]\cos(5°44') + s_2 \sin(5°44') = 70.095$

$\Rightarrow (94.525)s + 0.448 + 0.099\, s_2 = 70.095$

$\Rightarrow (94.525)s + 0.099\, s_2 = 69.995 \rightarrow (1)$

$RL_B = 106.997$

$\Rightarrow RL_A + (HI)_Q + V_Q - s_2 \cos\theta = 106.997$

$\Rightarrow 100 + 1.45 + \left[(95 \times s) + 0.45\right]\sin(5°44') - s_2 \cos(5°44')$
$= 106.997$

$\Rightarrow 9.49\, s - 0.995\, s_2 = 5.502 \rightarrow (2)$

From (1) & (2), $s = 0.739$, $s_2 = 1.518$

$\Rightarrow s_1 = s_2 - \frac{s}{2} = 1.148$

$\Rightarrow s_3 = s_2 + \frac{s}{2} = 1.887$

(iii) Hence stadia readings with instrument 'Q' are

$s_1 = 1.148$
$s_2 = 1.518$
$s_3 = 1.887$

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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