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	33
Q.2	—
Q.3	60
Q.4	
Section-B	
Q.5	43
Q.6	
Q.7	44
Q.8	32
Total Marks Obtained	212

Signature of Evaluator Rheyab

Cross Checked by .....

Keep it up

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

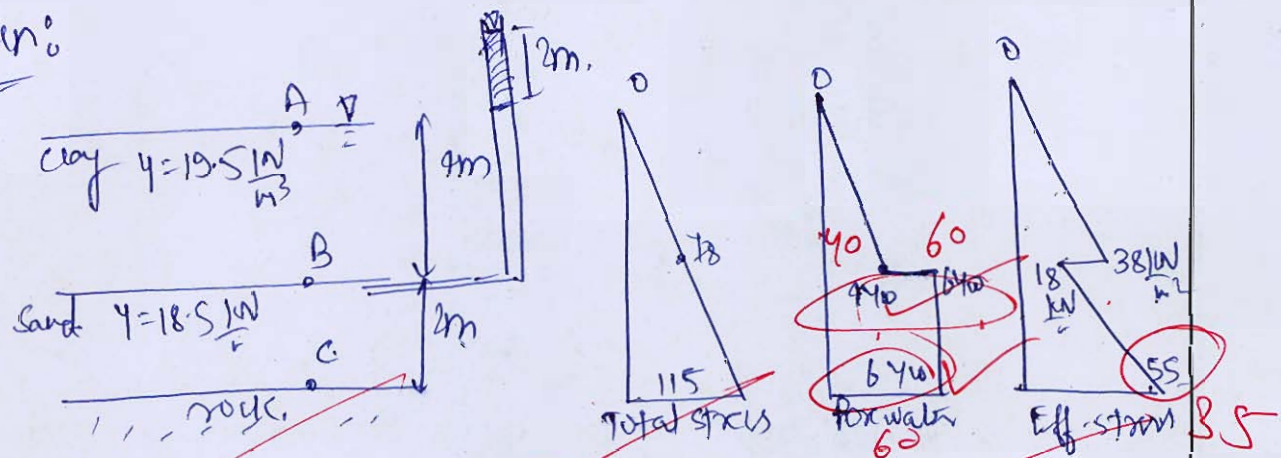
Q.1 (a) **(i)** A soil profile consists of a surface layer of clay 4m thick ($\gamma = 19.5\ kN/m^3$) and a sand layer 2 m thick ($\gamma = 18.5\ kN/m^3$) overlying an impermeable rock. The water table is at the ground surface. If the water level in a stand pipe driven into sand layer rises 2 m above 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)



Total stress

at A = 0

at B = $19.5 \times 4 = 78\ kN/m^2$

at C = $19.5 \times 4 + 18.5 \times 2 = 115\ kN/m^2$

Neutral stress

at A = 0

at B (in clay layer) = $4\gamma_w$

at B (in sand layer) = $6\gamma_w$

at C = $6\gamma_w$

Effective stress

at A = 0

at B (in sand layer) = $78 - 40 = 38\ kN/m^2$

at B (in clay layer) = $78 - 60 = 18\ kN/m^2$

at C = $115 - 60 = 55\ kN/m^2$

~~Total stress~~ ~~Neutral stress~~

11) After reducing 1m artesian head

σ_c = 19.5×4 + 18.5×2 = 115 kN/m²

u = 6γw = 60 kN/m²

$\bar{\sigma}_c$ = 55 kN/m²

∴ No increase in Eff. stress

09

10

Q.1 (b) **(i)** The in-situ unit weight of a medium to coarse sand used as subgrade for a highway, was 16 kN/m³. 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 1m³ 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/m³]

(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]

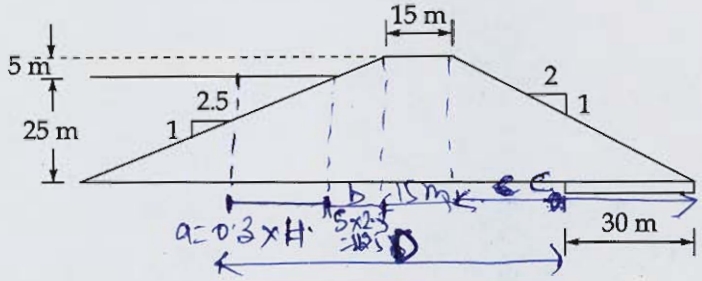
9) γ = 16 kN/m³, V = 1m³ | Wadded = 5.5 kN, Vnew = 1.2 m³

Gs = 2.67

γ = Gs γw

12

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:

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

$a = 0.3 \times 25 \times 2.5 = 18.75\text{m}$, $b = 5 \times 2.5 = 12.5\text{m}$

$c = 30 \times 2 = 60\text{m}$

$D = a + b + 15\text{m} + c - 30 = 76.25\text{m}$

Focal length, $S = \sqrt{76.25^2 + 25^2} - 76.25$

$= 3.99\text{m}$

12

Seepage discharge $= k \times S$

$= 40 \frac{\text{m}}{\text{day}} \times 3.99\text{m}$

$= 159.75 \frac{\text{m}^3}{\text{m-day}}$

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

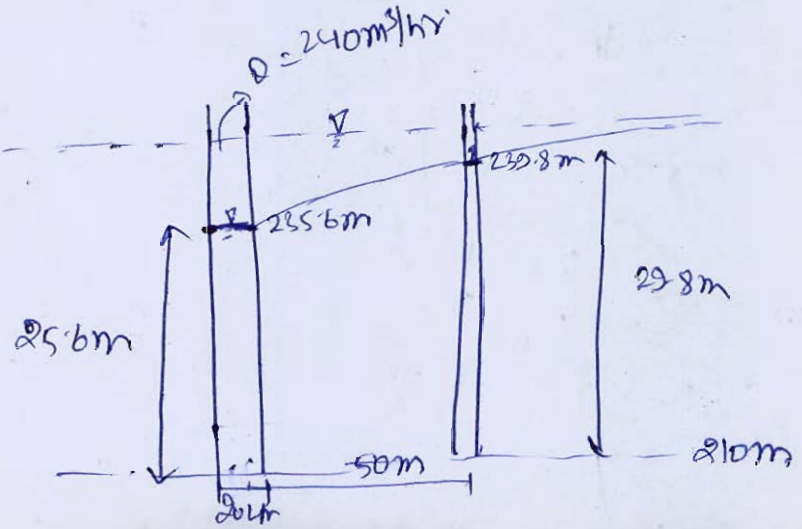
Determine the permeability of aquifer. Also calculate:

(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:-



$$Q = \frac{\pi K [H_2^2 - H_1^2]}{\ln\left(\frac{R_2}{r_w}\right)}$$

$$\Rightarrow 240 \frac{m^3}{hr} = \frac{\pi \times K \times [29.8^2 - 25.6^2]}{\ln\left(\frac{50}{0.1}\right)}$$

$$\Rightarrow \boxed{K = 2.041 \text{ m/hr}}$$

i) $$Q = \frac{\pi K [H_2^2 - H_1^2]}{\ln\left(\frac{R}{r_w}\right)} \qquad (H_1 = 0)$$

$$240 \frac{m^3}{hr} = \frac{\pi \times K [25.6^2 - 0^2]}{\ln\left(\frac{300}{0.1}\right)}$$

$$\Rightarrow \boxed{K = 0.933 \text{ m/hr}}$$

Error = $0.933 - 2.041 = -1.107$ m/hr

ii) $$Q = \frac{\pi \times K [H_2^2 - H_1^2]}{\ln\left(\frac{R}{r_2}\right)}$$

$$240 = \frac{\pi \times 2.041 \times [29.8^2 - 0^2]}{\ln\left(\frac{R}{50}\right)}$$

$$\Rightarrow \boxed{R = 514.83 \text{ m}}$$

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]

i.) Chemical stabilisation :- It is a method in which soil is stabilised by different types of chemical which can absorb moisture from the soil or can reduce the plasticity of the soil. This method can be done with the help of deliquescent material like $CaCl_2$ which absorb moisture and reduce the liquid limit of soil.

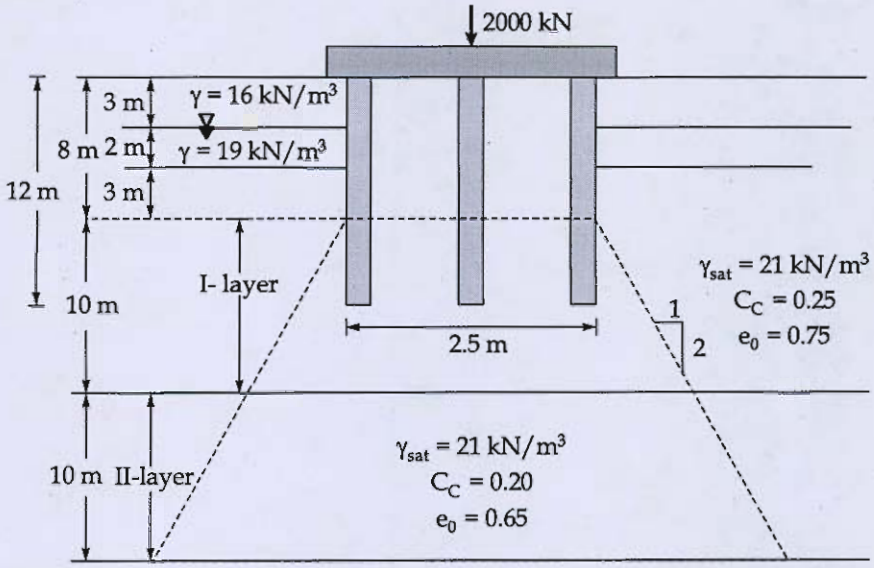
ii) Stabilisation by heating involves changing the properties of soil by thermal means to enhance strength & stability. It can reduce moisture content & improve the performance of for various purposes

Various techniques like combustion heating & electrical heating can be used to achieve these changes

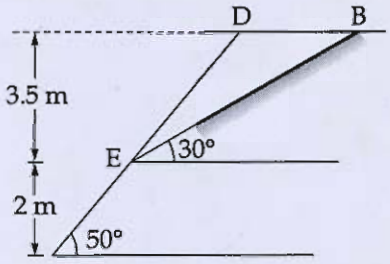
iii) Electrical stabilisation :- This method is also used to improve the properties of soil by the process called Electro-osmosis. In this a current is passed through soil causing the water to migrate to cathode & effectively removing from soil & enhancing the properties of soil

2+2+3

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]

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.

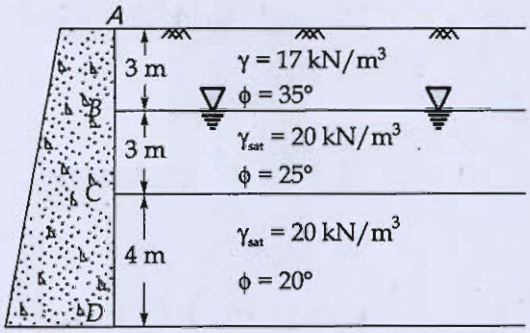
[10 + 10 = 20 marks]

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

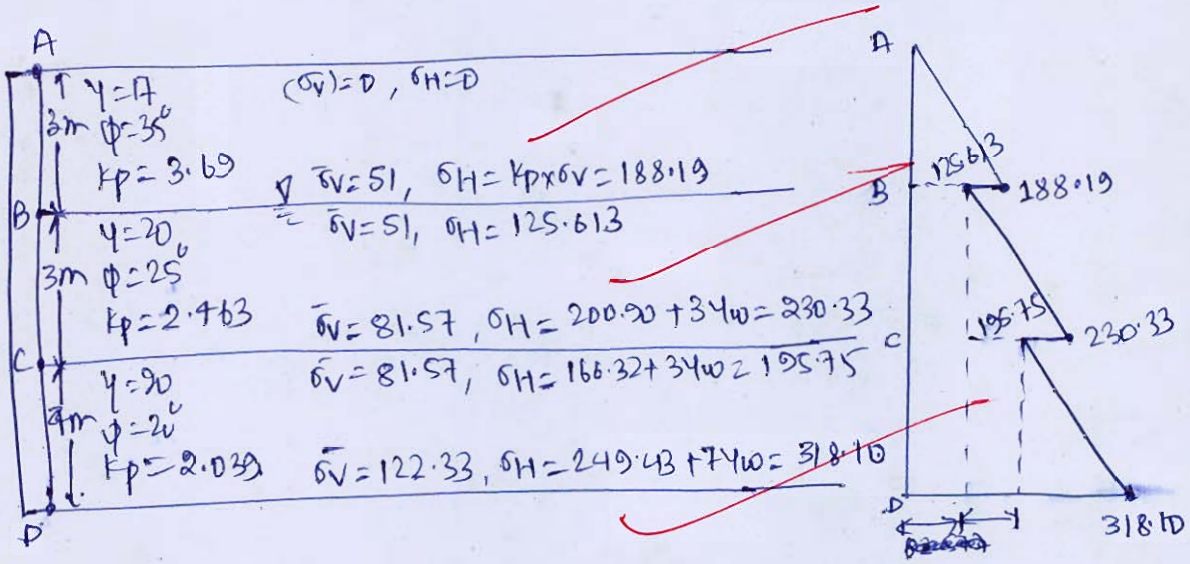
(ii) A soil sample of height 6 cm and area of cross-section 100 cm^2 was subjected to a falling head permeability test. In a time interval of five minutes, the head dropped from 60 cm to 20 cm. If cross-sectional area of stand pipe is 2 cm^2, compute the coefficient of permeability of the soil sample.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

[10 + 10 = 20 marks]

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]



$K_p = \frac{1+\sin\phi}{1-\sin\phi}$

Total passive Thrust = $\frac{1}{2}\times 188.19\times 3 + 125.613\times 7 + \frac{1}{2}\times[230.33-125.613]\times 2$

$+ (195.75-125.613)\times 4$

$+ \frac{1}{2}\times(318.10-195.75)\times 4$

$= 1843.89$ kN/m

Location of Total passive thrust (from bottom)

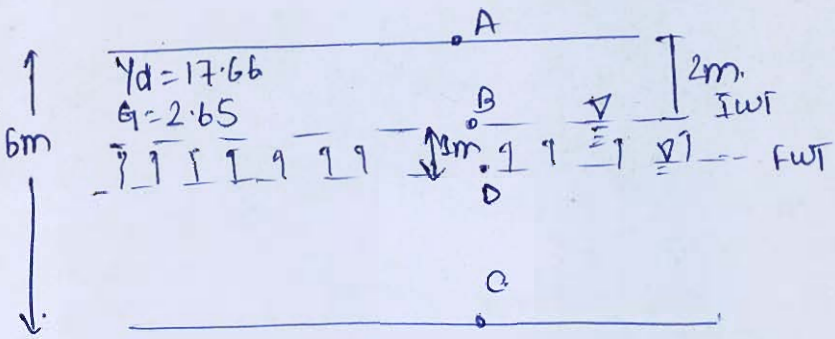
$$= \frac{289.98 \times 8 + 879.29 \times 3.5 + 157.07 \times 5 + 280.548 \times 2 + 244.70 \times \frac{4}{3}}{1843.89}$$

$$= 2.80\ m \quad \text{(From bottom)}$$

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]



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

$$= 20.806 \ \frac{kN}{m^3}$$

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

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

$$\Rightarrow e = 0.472$$

Total stress

At A = 0

at B = $\gamma_d \times 2 = 35.32 \ kN/m^2$

at C = $\gamma_d \times 2 + \gamma_{sat} \times 4 = 118.544 \ \frac{kN}{m^2}$

Pore water pressure

at A = 0

at B = 0

at C = $4\gamma_w = 39.24 \ \frac{kN}{m^2}$

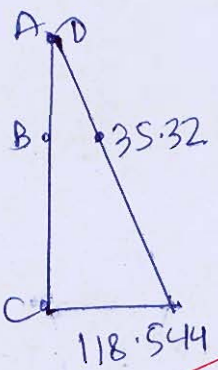
Effective stress

at A = $\sigma_{total} - u = 0$

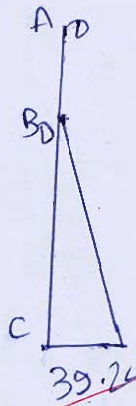
at B = 35.32 kN/m²

at C = 118.544 − 39.24 = 79.304 kN/m²

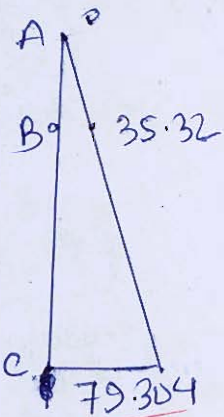
Total stress



Pore water pressure



Eff. stress



After lowering of water Table

* Total stress

~~at A = D~~ at A = 0

~~at B = 35.32 kN/m²~~ at B = 4 × 2 = 35.32 kN/m²

at D = 17.66 × 2 + 20.806 × 1 = 56.126 kN/m²

at C = 56.126 + 3 × 4 sat = 118.544 kN/m²

* Pore water pressure

at A = 0

at B = $-\gamma_w$ = −9.81 kN/m²

at D = 0

at C = $3\gamma_w$ = 29.43 kN/m²

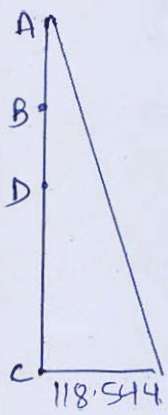
* Eff stress

at A = 0, at B = 35.32 (just above)

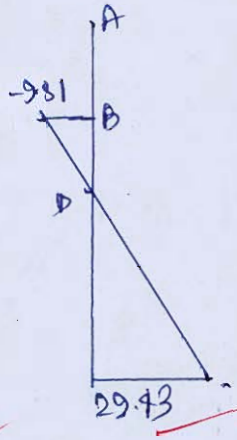
at B = 45.13 kN/m² (just below)

at D = 56.126 kN/m²

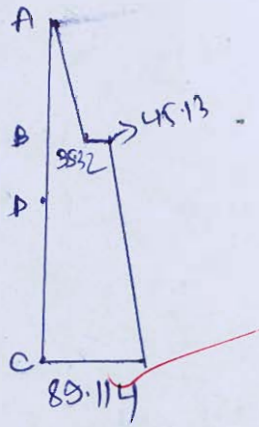
at C = 89.114 kN/m²



Total stress



Pore water pressure



Eff-stress

20

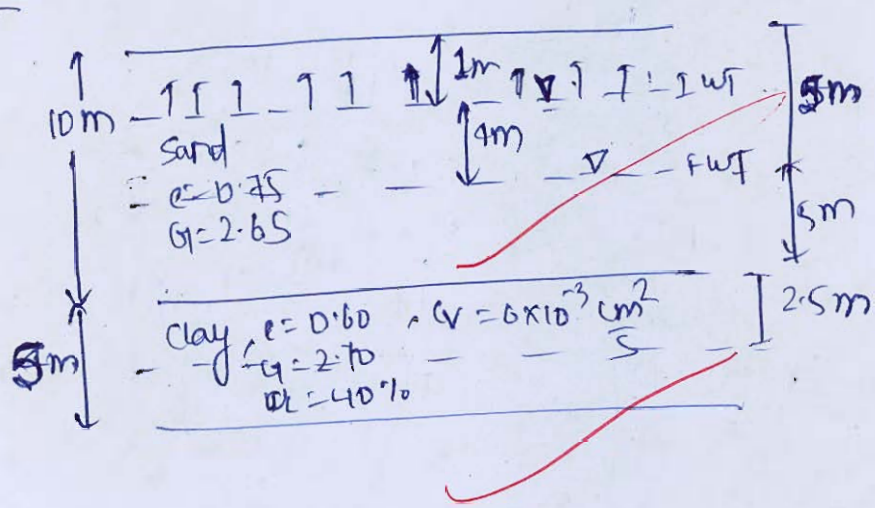
Q.3 (c) A light weight building stands or a 10 m thick stratum of sand. Beneath the sand stratum, a clay layer of 5 m thick exists. The clay layer is underlain by a rock stratum. The water table lies at a depth of 1.0 m below ground surface and the sand above the water table is saturated with capillary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



$(\gamma_{dry})_{sand} = \frac{G\gamma_w}{1+e} = 14.8551 \frac{kN}{m^2}$

$(\gamma_{sat})_{sat} = \frac{(G+Se)\gamma_w}{1+e} = 19.059 \frac{kN}{m^2}$

$(\gamma_{sat})_{clay} = 20.233 \frac{kN}{m^2}$

Total stress at mid-depth of clay layer before change in water level

$\sigma = (\gamma_{sat} \times 1)_s + (\gamma_{sat} \times 9)_s + (\gamma_{sat})_{clay} \times 2.5$

$= 241.1725 \ kN/m^2$

$u = 11.5 \gamma_w = 112.815 \ kN/m^2$

Eff. stress $= \sigma - u = 128.357 \ kN/m^2$

Stress after change in water level. (mid-depth)

$\sigma = 5 \times (\gamma_{dry})_s + 5 \times (\gamma_{sat})_s + 2.5 \times (\gamma_{sat})_c$

$= 220.1525 \ kN/m^2$

$u = 7.5 \gamma_w = 73.57 \ kN/m^2$

$\bar{\sigma} = \sigma - u = 146.5775 \ kN/m^2$

Increase in Eff. stress = $18.22 \ kN/m^2$

for clay layer, $C_c = 0.009 (w_L - 10) = 0.27$

$$\Delta H = \frac{H_D C_c}{1+e} \log\left(\frac{\sigma + \Delta\sigma}{\sigma}\right)$$

$$= \frac{5 \times 0.27}{1.6} \log\left(\frac{146.5775}{128.357}\right) = 48.639 \text{ mm}$$

For 25 mm settlement

% consolidation $= \frac{25}{48.639} \times 100 = 51.39\%$

$$T_V = \frac{\pi}{4} \times (0.5139)^2 = \frac{C_V \times t}{(500)^2}$$

20

$$\Rightarrow t = 8638048.744 \text{ secs}$$

$$t = 99.97 \text{ days}$$

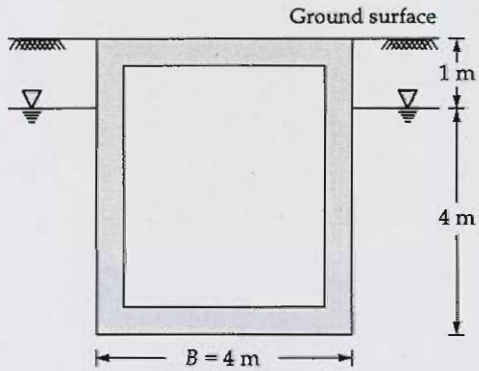
Q.4 (a) **(i)** A square footing of (2.5 m × 2.5 m) size has been founded at 1.2 m below the ground level in a cohesive soil having a bulk density of 1.8 t/m^3 and an unconfined compressive strength of 5.5 t/m^2. Determine the ultimate and safe bearing capacity of the footing for a FOS of 2.54 by

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]

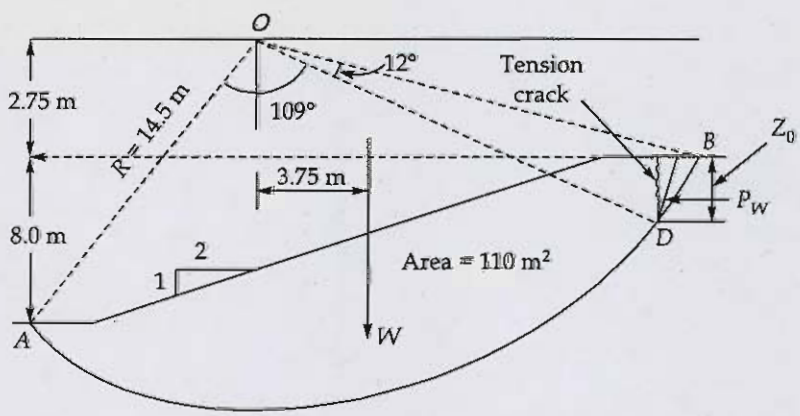
[14 + 6 = 20 marks]

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]

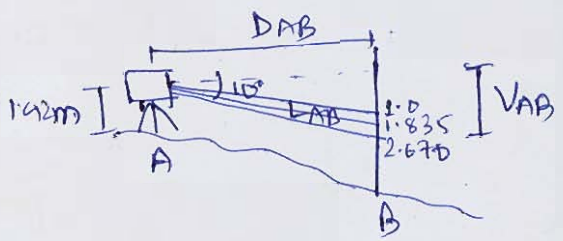
Soln:-

$D_1 = 100m$, $D_2 = 300m$

$D_1 = KS_1 + C \Rightarrow 100 = K \times 0.99 + C$ — (i)

$D_2 = KS_2 + C \Rightarrow 300 = K \times 3 + C$ — (ii)

On solving (i) & (ii) $\Rightarrow$ $K = 99.502$, $C = 1.492$



$L_{AB} = KS_{1000} + C = 99.502 \times 1.670 + 1.49 = 165.135m$ $\times\cos(-10)$

$D_{AB} = L_{AB}\cos\theta = 162.627m$

$V = L_{AB}\sin\theta = 28.675m$

12

$(RL)_B = (RL)_A + H.I - V_{AB} - 1.835$

$= 421.41m$

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]

ii) Sources of Error in GIS

(a) Human error (b) Instrument error.

(c) Data collection error (d) Data processing error.

1

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:

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

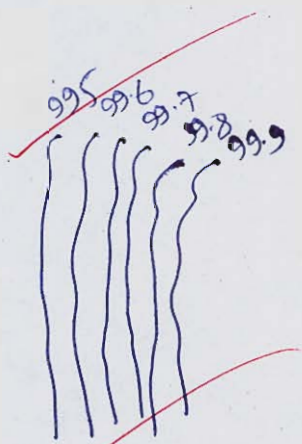
$\alpha = \frac{S}{nD} = \frac{L}{R}$

$\Rightarrow \frac{(1.680-1.602)}{10 \times 80} = \frac{2\times10^{-3}}{R}$

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

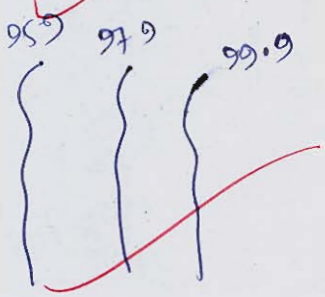
i) (a) for very steep slope

The spacing b/w contours will be very less



ii) (b) for uniform slope

The spacing will be more



(c) For hill

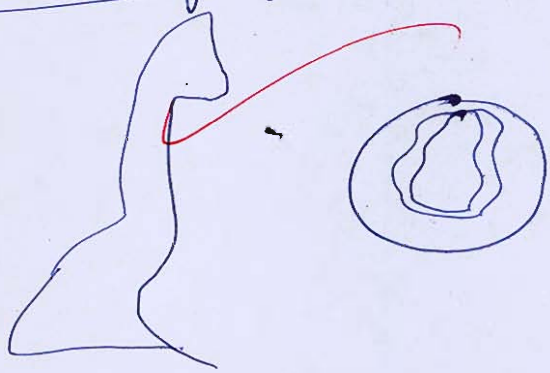
5 ✓6

contours inside will have higher elevation than contours outside

(d) For ponds

contours inside will have lower elevation than contours outside

(e) Overhanging cliff

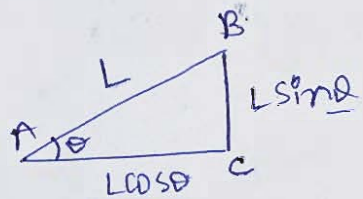


NO contours will intersect except overhanging cliff

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°



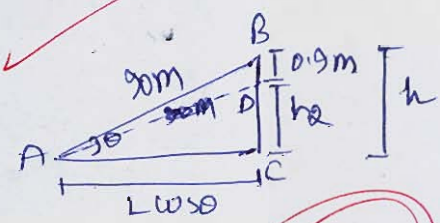
Let we measure the distance AB = L on sloping ground.

So, AC = LCosθ

correction = True value − Measured value

= (LCosθ − L) = L(Cosθ − 1)

$\tan\theta = \frac{1}{15}$, θ = 3814°



h = 90 × Sinθ = 5.986m

h2 = h − 0.9m = 5.086m

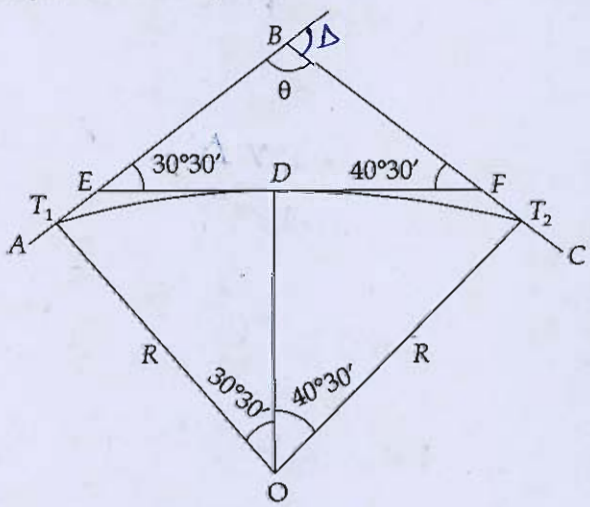
AC = LCosθ = 89.800m

So, AD = $\sqrt{h_2^2 + AC^2}$ = 89.943m

So, measured Length = 89.943m

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]

In ΔBEF

$\theta = 180^\circ - (30^\circ 30' + 40^\circ 30') = 109^\circ$

$\Delta = 180^\circ - 109^\circ = 71^\circ$

$$\frac{\sin\theta}{EF} = \frac{\sin 30^\circ 30'}{BF} = \frac{\sin 40^\circ 30'}{BE}$$

$$\Rightarrow \frac{\sin 109^\circ}{175} = \frac{\sin 30^\circ 30'}{BF} = \frac{\sin 40^\circ 30'}{BE}$$

$\Rightarrow BF = 93.937\,m, \quad BE = 120.202\,m.$

* Also

Length of Tangent $ED = R\tan\left(\frac{30^\circ 30'}{2}\right)$

" " " $DF = R\tan\left(\frac{40^\circ 30'}{2}\right)$

$ED + DF = EF = 175\,m = R\left(\tan\left(\frac{30^\circ 30'}{2}\right) + \tan\left(\frac{40^\circ 30'}{2}\right)\right)$

$$\boxed{R = 272.77\,m}$$

(2)

So, Length of $EA = R\tan\left(\frac{30^\circ 30'}{2}\right) = 74.367\,m.$

Length of $BA = BE + EA = 194.569\,m$

* Length of curve $= \frac{\pi R \times \Delta}{180} = 337.840\,m$

* Chainage of $T_1 = 1500 - BA = \boxed{1305.431\,m}$

* " " $T_2 = 1305.431 +$ Length of curve

$= 1643.271\,m$

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:

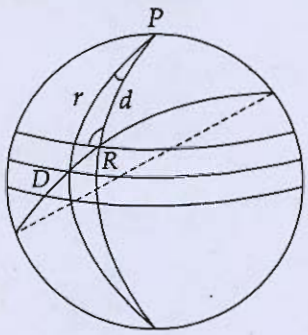
2.650, 3.740, (–2.830)(B), 4.270(C), 4.640, 0.380, 0.960(D), 1.640; 2.840, 3.480(E), 4.680 and 4.260(F).

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:

L = 150 km, B = 15 km

No. of flight lines required $= \frac{15 \times 10^3}{(1-0.28) \times 23 \times 250} + 1$

(N_1)

$= 4.62 \simeq 5$

~~Ground Base distance = $\frac{150 \times 10^3}{(1-0.65) \times 23 \times 250}$~~

Ground Base distance = $(1-0.65) \times 23 \times 250$

$= 2012.50$ m.

Exposure Time = $\frac{2012.50}{270 \times \frac{5}{18}}$ = 26.833 secs

∵ Least count of Intervalometer = 0.5 sec

SO, Exposure Time = 26.5 secs

Now, Ground Base distance = $270 \times \frac{5}{18} \times 26.5$

$= 1987.5$ m

No of photos per flight line (N_2) = $\frac{150 \times 10^3}{1987.5} + 1$

$= 76.47 \approx 77$

SO, Total No. of photographs req = $N_1 \times N_2$

$= 5 \times 77$

$= 385$

20

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]

Line	Latitude (m)	Departure (m)	Length of Side $=\sqrt{L^2+D^2}$	correction in Latitude $= -L \times \frac{\text{Length of line}}{\text{Perimeter}}$	Correction in departure $= -D \times \frac{\text{Length of line}}{\text{Perimeter}}$	corrected Latitude	corrected Departure.
AB	0	183.79	183.79	−0.056	0.069	−0.056	183.859
BC	128.72	98.05	161.81	−0.049	0.0613	128.671	98.1113
CD	177.76	−140.85	226.798	−0.069	0.0859	177.691	−140.764
DE	−76.66	−154.44	172.419	−0.053	0.0653	−76.713	−154.374
EF	−177.09	0	177.09	−0.054	0.0671	−177.144	0.0671
FA	−52.43	13.08	54.036	−0.0166	0.020	−52.446	13.10
	$\Sigma = 0.3$	$\Sigma = -0.37$	$\Sigma = 975.943$				

Bearing of line D $= \tan^{-1}\left(\frac{D}{L}\right)$

$= \tan^{-1}\left(\frac{-140.764}{177.69}\right)$

$= -38^\circ 83'$

11) $L_{tape} = 30m$, $T_0 = 20^\circ C$, $P_0 = 10kg$, $P_m = 15kg$.

$T_m = 32^\circ C$, $L = 780m$, $a = 0.03cm^2$

$w = 0.693 kg$, $\alpha = 11 \times 10^{-6}$, $E_s = 2.1 \times 10^6 kg/cm^2$

(1) Supported at Every 30m

correction for Temperature $= \alpha \times L_{Tape} (T_0 - T_m)$

$= -0.00396m$

correction for pull $= \frac{(P_0 - P_m)L}{AE}$

$= -0.00238m$

correction for Sag $= -\frac{w^2 L}{24 P_m^2} = -0.002668$

Total correction for Single length of Tape $= -0.009$

Total correction for measured Line $= -0.009 \times \frac{780}{30}$

$= -0.2342m$

True length of Line $= 780 - 0.2342$

$= 779.765m$

(2)

At Every 15m (n=2)

correction for Temperature = -0.00396 m

" " Pull = -0.00238 m

" " Sag = $-\frac{w^2 L}{24 n^2 P_0^2}$

$= -0.000667$ m

Total correction for one tape length = -0.007 m

17

correction for Line = $\frac{780}{30} \times -0.007$

$= -0.182$ m

Corrected length = 779.817m

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]

(ii)

1) Probable Error of single observation

Weighted Avg $= \dfrac{2 \times 30^\circ 24' 20'' + 2 \times 30^\circ 24' 18'' + 3 \times 30^\circ 24' 19''}{7}$

$= 30^\circ 24' 18.57''$

Probable Error $= \pm 0.6745 \sqrt{\dfrac{(x - \bar{x})^2}{n-1}}$

(OC)

$= \pm 0.0001226$

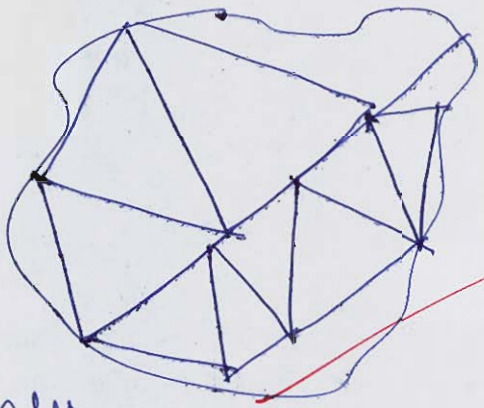
4+3

(2) Probable error of mean $= \dfrac{\sigma_S}{\sqrt{n}}$

$= 0.00004629$

(5)

i) Objectives of Triangulation Surveys



If we have to calculate or survey the area which is irregular then we select different triangles which has to be well conditioned for surveying the area which can make the job simple.

For selecting the triangle.

The Triangle have to be well conditioned triangle which means no angle is greater than 120° & less than 30° most appropriate triangle is equilateral Δ but it can't be selected every time.

So, a isosceles Δ with Base angle 56°14' is the most appropriate Δ

Strength of figure denotes whether the triangle selected is how much appropriate for triangulation

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

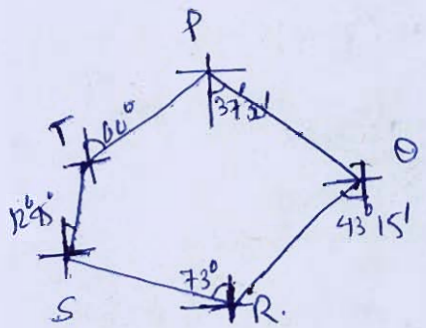
Calculate the interior angles and correct them for observational errors.

[10 + 10 = 20 marks]

Soln

(a)

(ii)



Interior Angles = BB of line − FB of previous lines

$\angle P = 96^\circ 30'$

$\angle Q = 99^\circ 15'$

$\angle R = 117^\circ 15'$

$\angle S = 149^\circ 30'$

$\angle T = 133^\circ 15'$

Sum $= 541^\circ 15'$

$(2n-4) \times 90 = 540$

Error $= (541^\circ 15' - 540^\circ)$

$= 1^\circ 15'$

Sum of Internal angle $= 595^\circ 45'$ $\left(\frac{1^\circ 15'}{5} = -0^\circ 15'\right)$

Error $= 595^\circ 45' - 590^\circ = 5^\circ 45'$

correction per angle $= \frac{-5^\circ 45'}{5} = -1^\circ 9'$

Corrected Angle

$\angle P = 95^\circ 21'$

$\angle Q = 98^\circ 6'$

$\angle R = 116^\circ 6'$

$\angle S = 148^\circ 21'$

$\angle T = 132^\circ 6'$

2 + 8

(a)

i) **Least count** :- It is the least measurement in units a instrument can count

eg. For vernier scale, LC = $\frac{S}{n}$

S = mainscale reading, n = ~~vernier scale~~ & reading

n = no. of readings

ii) Closing Error = $\tan^{-1}\left(\frac{D}{L}\right)$

when the traverse is not closed at the initial & final points due to error in measurment, that is called closing error

iii) **Arithmetic check** :- This is done to check the accuracy of measurements

eg. $\Sigma BS - \Sigma FS$ = Last RL − First RL

= Rise − Fall

iv) Local attraction :- Due to the presence of magnetic materials around the survey area the compass show some error that error is called Local attraction.

v) **whole to part** :- This is done to reduce the error in measurment to bigger surveys.

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:

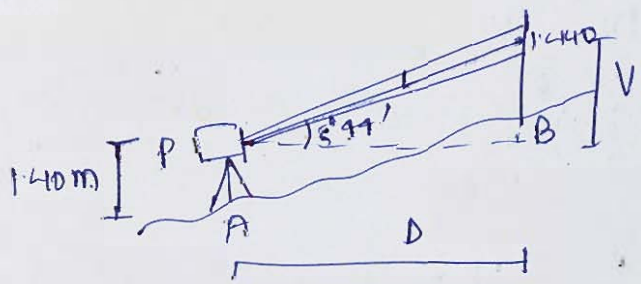
(i) The distance between instrument station and staff station.

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

(iii) Stadia readings with instrument Q.

[20 marks]

Soln:



For Instrument P

$L_{AB} = KS\cos\theta + C = 100 \times (1.795 - 1.090) \times \cos^2 5°44'70.3$

$= 70.447\text{m}$

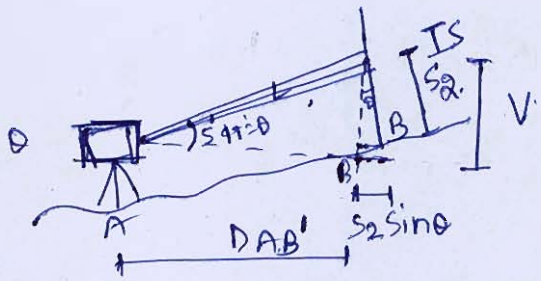
$D_{AB} = L_{AB}\cos\theta = 70.094\text{m}$

$V_{AB} = L_{AB}\sin\theta = 7037\text{m}$

(i) Distance b/w instrument station & staff station $= D_{AB} = 70.094\text{m}$

(ii) $(RL)_B = (RL)_A + H.I + V - 1.440$

$= 106.997\text{m}$



$L_{AB} = KS + C = 95 \times S + 0.95$

$(DAB') = L_{AB} \cos\theta = 94.5245 + 0.4477$

$V = L_{AB} \sin\theta = 9.490S + 0.0449$

$(RL)_B = (RL)_A + H.I + V - S_2 \cos\theta$

$= 100 + 1.45 + 9.49S + 0.0449 - S_2 \times 0.9949$

$106.977 = 101.49 + 9.49S - 0.9949 S_2$

$\Rightarrow \boxed{9.49S - 0.9949 S_2 = 5.502} \quad -(i)$

And

$DAB = DAB' + S_2 \sin\theta$

$70.094 = 94.524S + 0.4477 + 0.0998 S_2$

$\Rightarrow \boxed{94.524S + 0.0998 S_2 = 69.6463} \quad (ii)$

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From (i) & (ii)

$S = 0.7352$ $\quad S_2 = 1.483$

So, $S_3 = S_2 + \frac{0.7352}{2} = 1.850$

$S_1 = S_2 - \frac{S}{2} = 1.115$

So

$S_1 = 1.115$, $S_2 = 1.483$, $S_3 = 1.850$

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]

(i) Relief displacement, d ∝ r h / H

(ii) Temporary Adjustment

(a) Centering (b) Levelling (c) orientation

(iii) compensating error →

■■■■

Space for Rough Work

Space for Rough Work

$C \pm (TV - MV)$

$D \cdot 6745 \sqrt{\frac{(x - \bar{x})^2}{(n-1)}}$