Université d'Ottawa
Faculté de génie

Département de
Génie Civil

University of Ottawa
Faculty of Engineering

Department of
Civil Engineering

uOttawa
L'Université canadienne
Canada's university

CVG2171/CVG2571
Surveying and Measurements/Mesures et Arpentage

Final Examination/Examen Final
Sunday, 17 April, 2016/ **dimanche 17 avril, 2016**
Duration/**Durée**: 3 hours/**heures**

Professor: A.M. Skaff
Enseignant: Jules-Ange Infante

Closed Book Examination/ **Examen à livre fermé**
Non-programmable calculators allowed/**Les calculatrices non-programmables sont permises**
All problems are of equal value/ **Tous les problèmes sont de poids égal**

Question 1

A piece of land ABCDEA which lies at the corner of Cedar and Elm streets has the following data:/ **Une parcelle de terre ABCDEA se trouvant à l'intersection de la rue des Cèdres et de la rue des Ormes a les données suivantes :**

Segment	**Length/Longueur (m)**	**Bearing/Relèvement**
AB	350.00	N 45°00' W
BC (chord/corde)	424.26	Plein Est/ Due East
CD	150.00	S 45°00' E
DE	200.00	S 45°00' W
EA	141.42	Plein Ouest/ Due West

The radius of the circular curve is 300.00 m. / **Le rayon de la courbe circulaire est de 300,00 m.**

a) Find the co-ordinates of points A, B, C, D and E, if the x-axis passes through line AE and the y-axis through point B (see diagram). The co-ordinates of origin O are 0,0. / **Déterminez les**

coordonnées des points A, B, C, D, et E si l'axe des x passe par la ligne AE et l'axe des y passe par le point B (voir diagramme). Les coordonnées de l'origine, O, sont : (0;0).

b) Calculate the area of this piece of land in hectares. / **Calculez l'aire de cette parcelle en hectares.**

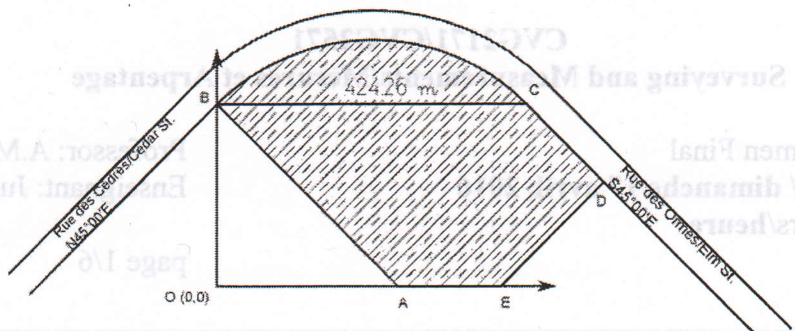


Figure 1: Land area at the corner of Elm and Cedar streets. / ***Parcelle à l'intersection des rues des Ormes et des Cèdres.***

Question 2

The notes for two 5-level consecutive sections (stations) on a proposed highway are as follows: / **Les notes pour deux sections (stations) consécutives à 5 points sont comme suit :**

Station					
65+00	C0.8	C0.2	C4.6	C7.8	C9.1
		25.0		25.0	
66+00	C3.8	C3.2	C5.6	C6.2	C6.0
		25.0		25.0	

a) Complete these notes if the side slopes are 2 horizontal to 1 vertical and the base width is 50 ft. / **Complétez ces notes si les pentes latérales sont de 2 horizontal pour 1 vertical, et la largeur de la base est de 50 ft.**

b) Compute the volume of earthwork between these sections by the Average-End-Area formula. / **Calculez le volume de terre entre ces deux sections para la méthode moyenne des aires.**

c) Compute the volume by the prismoidal formula by applying a correction to the volume obtained in part (b). / **Calculez le volume par la formule prismoïdale en appliquant une correction au volume calculé en b).**

Question 3

On a proposed highway, an equal-tangent vertical curve is to be installed to connect a -1%, and a +2% grade. The two grades meet at station 75+00 at elevation 521.25 ft. Field conditions require that the curve should pass through a fixed point of elevation 524.00 ft at station 73+00. / **Le long d'une autoroute prévue, une courbe verticale à tangentes égales doit être construite pour raccorder une pente de -1% et une pente de +2%. Les deux pentes se croisent à la station 75+00 à une altitude de 521,25 ft. Les conditions sur le terrain requièrent que la courbe passe par un point spécifique à une altitude de 524,00 ft à la station 73+00.**

a) Find the length (L) of the curve./ **Calculez la longueur (L) de la courbe.**

b) Find the rate of change in grade per station (r). / **Calculez le taux de changement de pente (r).**

c) Compute the elevations of stations at 100 ft intervals along the curve. Tabulate the results and do the usual checks. / **Calculez les élévations à des stations de 100 ft le long de la courbe. Tabulez les résultats et faites les vérifications d'usage.**

d) Compute the station and elevation of the low point of the curve. / **Calculez la station et l'altitude du point le plus bas sur la courbe.**

Question 4

The back and forward tangents AV, and VB of a railroad meet at station 36+00.00. The angle of intersection, I, is 24°00'. It is desired to connect these two tangents by a circular curve whose degree of curve, by the chord definition, is Dc=4°00'. / **Les tangentes arrière, AV et avant VB d'une voie ferrée se rencontrent à la station 36+00,00. L'angle d'intersection, I, est de 24°00'. On désire joindre ces deux tangentes par une courbe circulaire dont le degré de la courbe, par la définition de la corde est de Dc=4°00'.**

a) Calculate, R, the radius of this curve, T, the tangent distance, L, the length of the curve, M, the middle ordinate, E, the external distance, and the stations of the beginning of curve, A, and its end, B. / **Calculez, R, le rayon de cette courbe, T, sa distance tangente, L, la longueur de la courbe, M, la flèche, et E, la contre-flèche, ainsi que les stations du début de la courbe, A, et de la fin, B.**

b) Calculate and tabulate all data required to lay out this curve in the field by the deflection angles and chords method. Stations are 100 ft apart. / **Calculez et mettez en tableau toutes les données requises pour implanter cette courbe sur le terrain par la méthode des angles de déflexion et des cordes. Les stations sont à des intervalles de 100 ft.**

Question 5

All parts are INDEPENDENT

a) A bridge, 110 m long, measures 36.67 mm on a vertical photograph. Find the approximate dimensions (in meters) of a large building that also appears and this photograph and whose sides measure 22.00 mm by 18.33 mm. / . **Un pont d'une longueur de 110 m, mesure 36,67 mm sur une photographie verticale. Déterminez les dimensions approximatives (en mètres) d'un édifice apparaissant également sur cette photo et dont les côtés mesurent 22,00 mm par 18,33 mm.**

b) Determine the height of the smoke-stack (tower) in front of Colonel By Hall at the University of Ottawa which appears on a vertical photograph taken from an aircraft flying at a height, H, of

7000 ft above its base. The distance from the principal point of this photo to the tower base is 86.52 mm and to the tower top is 88.87 mm./ **Déterminez la hauteur de la cheminée devant le pavillon Colonel By de l'université d'Ottawa qui apparaît sur une photo verticale prise depuis un appareil volant à une altitude, H, de 7000 ft au-dessus de la base de cette dernière. La distance depuis le point central de la photo à la base de la cheminée est de 86,52 mm, et au haut de la cheminée elle est de 88,87 mm.**

c) A 20-mile strip of terrain is to be photographed for highway mapping. The aerial camera to be used has a lens of focal length 12 in and takes 9×9 inches photographs. The ground elevation varies from a low of 900 ft to a high of 1 100 ft above mean sea level. The plane has to make one flight line and the average width of the photographic coverage is to be 1800 ft.

   i. What will be the average scale of the photographs? /**Une bande de terre doit être photographiée pour raison de cartographie routière. La caméra aérienne utilisée a une distance focale de 12 in, et fait des photos de 9×9 pouces. L'altitude du sol varie de 900 ft au-dessus du niveau de la mer au plus bas point, jusqu'à 1100 ft au-dessus du niveau de la mer au plus haut point. L'avion doit faire une seule ligne de vole et la largeur moyenne de la couverture photographique doit être de 1800 ft.**

   ii. What flying height, above mean sea level, should be used for this flight?/ **À quelle altitude, au-dessus du niveau de la mer, l'avion devra-t-il voler ?**

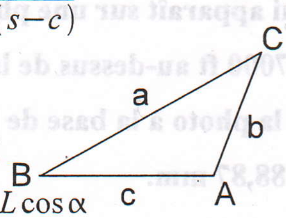
   iii. If it is specified that the overlap (end lap) between photos be 60% and that 2 extra exposures be added at each end of the flight line, find how many photographs will be required. / **Si on a spécifié que le recouvrement longitudinal (end lap) entre deux photos consécutives doit être de 60 %, et que 2 photos de plus doivent être ajoutées à la fin de chaque ligne de vol, combien de photos seront requises au total ?**

Frequently Used Equations/**Équations Fréquemment Utilisées**

Area/**Aires**

$$Area=\sqrt{s(s-a)(s-b)(s-c)}$$

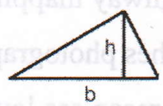
$$s=\frac{1}{2}(a+b+c)$$



$$a^2=b^2+c^2-2\cdot b\cdot c\cos A$$

$$Dep.=L\sin\alpha \qquad Lat.=L\cos\alpha$$

$$A_{triangle}=\frac{b\cdot h}{2}$$



$$m_{perp}=-1/m$$

(perpendicular slopes)

Volume (note: 1 yd³=27 ft³)

average end area:

$$V_e=\frac{A_1+A_2}{2}\times L \quad \text{(vol. in units of legth}^3\text{)}$$

$$C_p=\frac{L}{12}\cdot(c_1-c_2)(w_1-w_2) \quad \text{(vol. in units of length}^3\text{)}$$

borrow pit method:

$$V=\sum(h_{i,j}\cdot n)\left(\frac{A}{4}\right) \quad \text{(vol. in units of length}^3\text{)}$$

Solving a quadratic/**Solution quadratique**

$$x=\frac{-b\pm\sqrt{b^2-4ac}}{2a}$$

Photogrammetry/**Photogrammétrie**

$$S=\frac{f}{H} \qquad S=\frac{f}{H-h}$$

$$X_A=\frac{(H-h_A)x_a}{f} \quad ; \quad Y_A=\frac{(H-h_A)y_a}{f}$$

$$d=\frac{r_{top}\cdot h_{tower}}{H-h_{base}}$$; d is relief displacement

$$photo\ \ scale=\frac{photo\ \ distance}{map\ \ distance}\times map\ \ scale$$

Determination of the Meridian/**Détermination du Méridien**

L.C.T. = G.C.T ± $\Delta\lambda$

360° de longitude = 24 hours

15° de longitude = 1 hour

1° de longitude = 4 min (time)

Circular Curves/**Courbes Circulaires**

$$R=\frac{50\ ft}{\sin\left(\frac{D}{2}\right)}$$, Chord Definition

$$R=\frac{5729.58}{D}(ft)=\frac{1746.37}{D}(m)$$, Arc Definition

$$T=R\tan\frac{I}{2};\ L=R\theta^{rad}=R\theta^{\circ}\frac{\pi}{180};\ L=100\frac{I}{D}$$

$$\frac{R}{R+E}=\cos\frac{I}{2} \quad ; \quad E=R\left(sec\frac{I}{2}-1\right)$$

$$LC=2R\sin\frac{I}{2} \quad ; \quad chord=2R\sin\left(\frac{\theta}{2}\right)$$

$$\frac{R-M}{R}=\cos\frac{I}{2} \quad ; \quad M=R\left(1-\cos\frac{I}{2}\right)$$

$c_a=2R\sin\delta_a$; or $\delta_a=0.3c_aD$ (δ_a in minutes)

δ_a=def. angle. incr., c_a=subchord

Vertical (Parabolic) Curves/ **Courbes Verticales**

$$\frac{offset\ \ at\ \ a}{offset\ \ at\ \ V}=\left[\frac{x_a}{L/2}\right]^2$$

$$Y=Y_{BVC}+g_1x+\left(\frac{r}{2}\right)x^2 \quad ; \quad r=\frac{g_2-g_1}{L}$$

$$L=\frac{g_2-g_1}{max.\ \ allowable\ \ change\ \ in\ \ grade\ \ per\ \ station}$$

$$x=\left[\frac{-g_1L}{g_1-g_2}\right]$$; x=distance of min/max from BVC

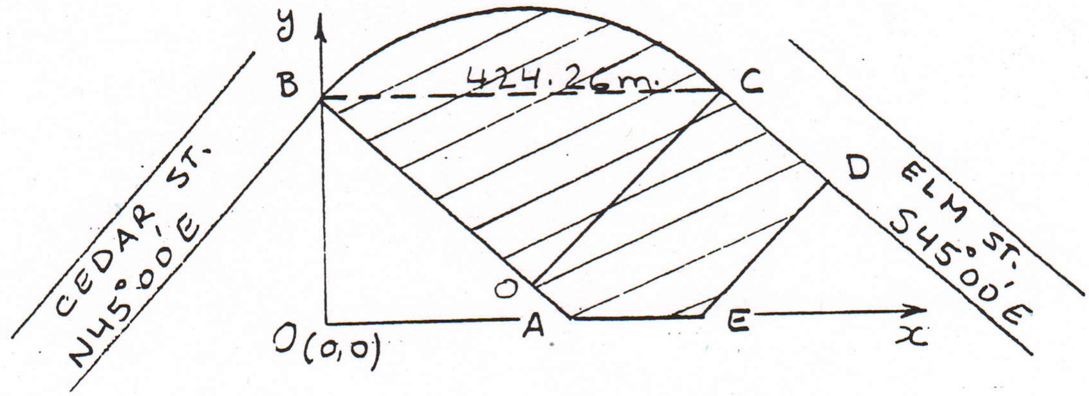
CVG 2171
SURVEING AND MEASUREMENTS
Final Exam

April, 2016

SOLUTIONS

1-

a)



Line	Length (m)	Bearing	Departure (m)	Latitude (m)
AB	350.00	N45°00'W	-247.49	+247.49
BC	424.26	East	+424.26	00.00
CD	150.00	S45°00'E	+106.07	-106.07
DE	200.00	S45°00'W	-141.42	-141.42
EA	141.42	West	-141.42	00.00

Point	x	y
A	247.49	0.00
B	0.00	247.49
C	424.26	247.49
D	530.33	141.42
E	388.91	0.00

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b) Area of traverse ABCDEA:

	x's	y's
A	247.49	0.00
B	0.00	247.49
C	424.26	247.49
D	530.33	141.42
E	388.91	0.00
A	247.49	0.00

$$Area = \frac{1}{2}\Big[(247.49 \times 247.49 + 0.00 + 424.26 \times 141.42 + 0.00 + 0.00 - (0.00 + 247.49 \times 424.26 + 247.49 \times 530.33 + 141.42 \times 388.91 + 0.00)\Big]$$

$$= \frac{1}{2}(61251.30 + 59998.85) - (105000.11 + 131251.37 + 54999.65)$$

$$= \frac{1}{2}(-170000.98) = -85000.49$$

$\therefore$ Area of ABCDEA $= 85000.49\,m^2$

8

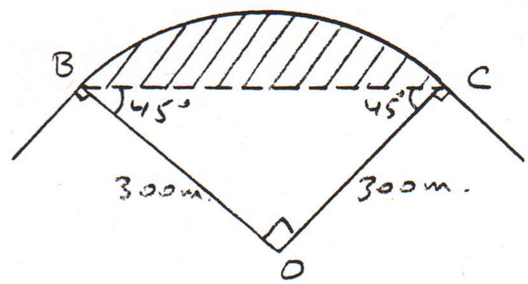
Cont'd...

1. b) Cont'd

Area of Sector OBC :

$\pi r^2 \times \frac{\theta}{360} =$

$\pi \times (300)^2 \times \frac{90}{360} = 70686 \, m^2$



Area of Δ OBC:

$\frac{300 \times 300}{2} = 45000 \, m^2$

$\therefore$ Area between chord BC and arc BC :

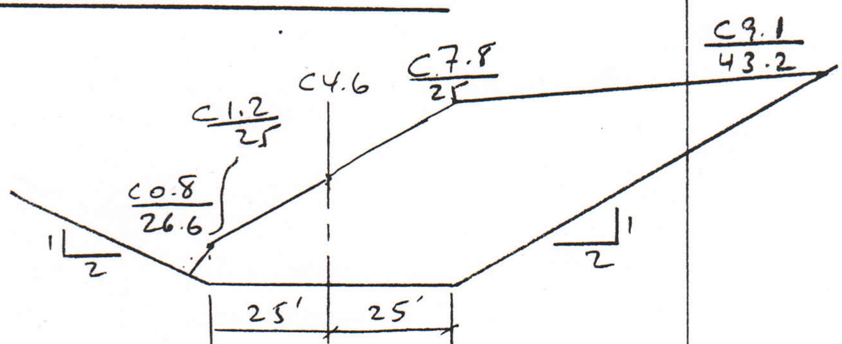
$70686 - 45000 = 25686 \, m^2$

4

Hence, area of the piece of land :

$85000.49 + 25686 = \underline{\underline{110686.49 \, m^2}} = \underline{\underline{11.07 \text{ hectares}}}$ ANS.

2. a)



Station 65+00

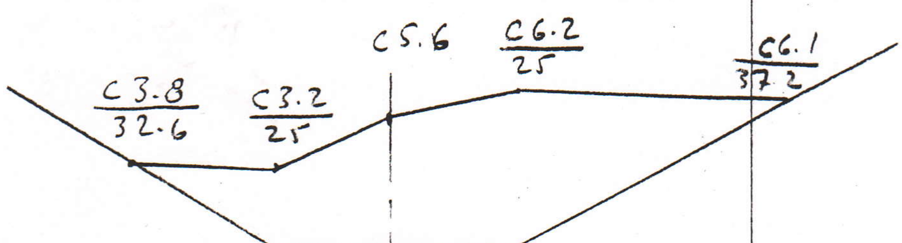
$(0.8 \times 2) + 25 = 26.6$

$(9.1 \times 2) + 25 = 43.2$

$\text{Area} = \left(\frac{1.2 \times 1.6}{2}\right) + \left(\frac{1.2 + 4.6}{2}\right) \times 25 + \left(\frac{4.6 + 7.8}{2}\right) \times 25 + \left(\frac{7.8 \times 18.2}{2}\right)$

$= 0.96 + 72.5 + 155 + 70.98 = \underline{299.44 \, ft^2}$

Station 66+00



$(3.8 \times 2) + 25 = 32.6'$

$(6.1 \times 2) + 25 = 37.2'$

2. (Cont'd)

$$\text{Area} = \left(\frac{3.2 \times 7.6}{2}\right) + \left(\frac{3.2 + 5.6}{2}\right) \times 25 + \left(\frac{5.6 + 6.2}{2}\right) \times 25 + \left(\frac{6.2 \times 12.2}{2}\right)$$

$$= 12.16 + 110 + 147.5 + 37.82 = 307.48 \text{ ft}^2$$

b) Volume by Average-End-Area Formula:

$$V_e = \frac{A_1 + A_2}{2} \times \frac{L}{27} \text{ yd}^3$$

$$= \frac{299.44 + 307.48}{2} \times \frac{100}{27} = \underline{\underline{1123.93 \text{ yd}^3}}$$ ANS.

c) Volume by prismoidal Formula (V_p):

$$C_p = \frac{L}{12 \times 27}(C_1 - C_2)(w_1 - w_2), \text{ where } C_1 = 4.6 \text{ ft}, C_2 = 5.6 \text{ ft}$$
$$w_1 = 26.6 + 43.2 = 69.8 \text{ ft}$$
$$w_2 = 32.6 + 37.2 = 69.8 \text{ ft}$$

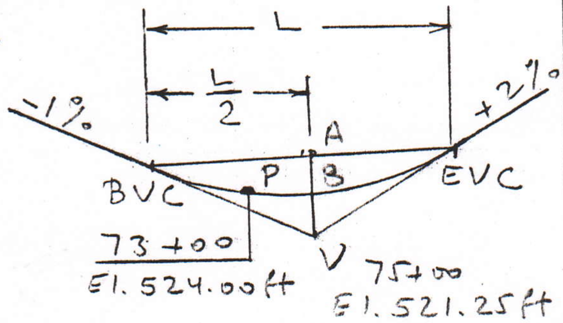
$$C_p = \frac{100}{12 \times 27}(4.6 - 5.6)(69.8 - 69.8) = 0$$

$$\therefore V_p = V_e - C_p = 1123.93 - 0 = \underline{\underline{1123.93 \text{ yd}^3}}$$ ANS.

3.

a) Elev. of BVC $= 521.25 + 1 \times \frac{L}{2}$
$= 521.25 + \frac{L}{2}$

Elev. of EVC $= 521.25 + 2 \times \frac{L}{2}$
$= 521.25 + L$



$$\therefore \text{Elev. of } A = \frac{521.25 + \frac{L}{2} + 521.25 + L}{2}$$
$$= 521.25 + \frac{3L}{4}$$

$$VB = \frac{VA}{2} = \frac{\left(521.25 + \frac{3L}{4}\right) - 521.25}{2} = \frac{3L}{8} = \text{offset at } V.$$

tangent elev. at 73+00 = 521.25 + 2×1 = 523.25 ft.
$\therefore$ Offset at P = 524.00 − 523.25 = 0.75 ft.

$$\frac{\text{offset at P}}{\text{offset at V}} = \left[\frac{x_p}{L/2}\right]^2; \quad \frac{0.75}{\frac{3L}{8}} = \left[\frac{\left(\frac{L}{2} - 2\right)}{L/2}\right]^2$$

$$\frac{6}{3L} = \frac{L^2 - 8L + 16}{L^2}; \quad L^2 - 8L + 16 = 0$$

i.e. $(L-8)(L-2) = 0$; $\therefore$ L = 8 sta. or L = 2 sta.

Use L = 8 sta. or 800 ft. ANS.

3. Cont'd.

b) Rate of change in grade per station $= \frac{g_2 - g_1}{L} = \frac{2 - -1}{8} = 0.375$ ANS.

c)

	Station	tan. Elev. (ft)	tan offset (ft)	Curve Elev. (ft)	1st. diff.	2nd. diff.
BVC	71+00	525.25	0.00	525.25		
					0.81	
	72+00	524.25	0.19	524.44		0.37
					0.44	
P	73+00	523.25	0.75	524.00		0.38
					0.06	
	74+00	522.25	1.69	523.94		0.37
					-0.31	
V	75+00	521.25	3.00	524.25		0.38
					-0.69	
	76+00	523.25	1.69	524.94		0.37
					-1.06	
	77+00	525.25	0.75	526.00		0.38
					-1.44	
	78+00	527.25	0.19	527.44		0.37
					-1.88	
EVC	79+00	529.25	0.00	529.25		

✓ Checks

Offset @ 72+00 & 78+00 : $3.00 \times \left(\frac{1}{4}\right)^2 = 0.19$ ft.

offset at 73+00 & 77+00 : $3.00 \times \left(\frac{2}{4}\right)^2 = 0.75$ ft.

offset at 74+00 & 76+00 : $3.00 \times \left(\frac{3}{4}\right)^2 = 1.69$ ft.

offset at V (75+00) $= \frac{3L}{8} = \frac{3 \times 8}{8} = 3.00$ ft.

d) $x = \frac{g_1 L}{g_1 - g_2} = \frac{-1 \times 8}{-1-2} = 2.6\bar{6}$ sta. $= 2+66.67$ from BVC

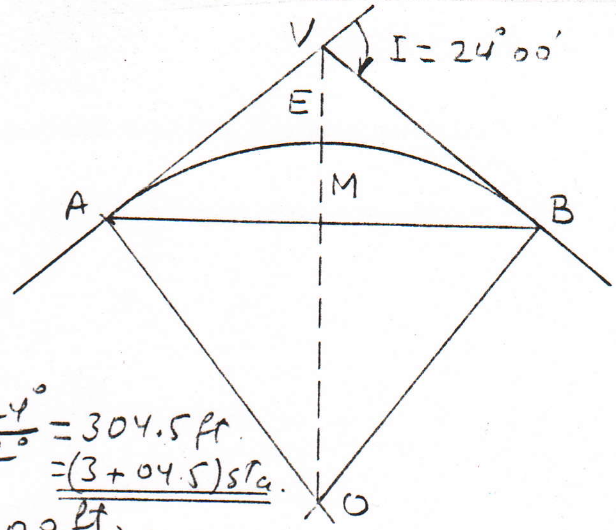
∴ Station of Low point : (71+00) + (2+66.67) = 73+66.67 ANS.

Tangent elev. at low point = 525.25 − 2.67×1 = 522.58 ft.

offset at 73+66.67 $= 3 \times \left(\frac{2.67}{4}\right)^2 = 1.34$ ft.

∴ Elev. of Low point : 522.58 + 1.34 = 523.92 ft. ANS.

4.



a) $R = \dfrac{50}{\sin \frac{D_c}{2}}$

$R = \dfrac{50}{\sin \frac{4°00'}{2}} = \underline{\underline{1432.7 \text{ ft.}}}$ ANS.

$T = R\tan\frac{I}{2} = 1432.7 \tan\frac{24°}{2°} = 304.5 \text{ ft} = \underline{\underline{(3+04.5) \text{ sta.}}}$ ANS.

$L = 100 \cdot \frac{I}{D} = 100 \times \frac{24°}{4°} = 600 \text{ ft.} = \underline{\underline{6+00 \text{ sta.}}}$ ANS.

$M = R\left[1 - \cos\frac{I}{2}\right] = 1432.7\left(1 - \cos\frac{24°}{2}\right) = \underline{\underline{31.3 \text{ ft.}}}$ ANS.

$\frac{R}{R+E} = \cos\frac{I}{2}$; $\frac{1432.7}{1432.7+E} = \cos\frac{24}{2} = 0.9781476$

$0.9781476E = 31.3$; $\therefore E = \underline{\underline{32.0 \text{ ft}}}$ ANS.

Station A: $(36+00) - (3+04.5) = \underline{\underline{32+95.5 \text{ sta.}}}$ ANS.

Station B: $(32+95.5) + (6+00) = \underline{\underline{38+95.5 \text{ sta.}}}$ ANS.

b) $\delta_\alpha = 0.3 C_\alpha D$ (d_α in minutes)

At point A: $\delta_{\alpha 1} = 0.3 \times 4.5 \times 4° = 5.4 \text{ min.}$ $[(33+00)] - [(32+95.5)] = 4.5 \text{ ft.}$

At point B: $\delta_{\alpha 2} = 0.3 \times 95.5 \times 4° = 114.6 \text{ min} = 1°54.6 \text{ min.}$

$[(38+95.5)] - [(38+00)] = 95.5 \text{ ft.}$

Station	Chord (ft)	Deflection Angle	
32+95.5	0.00	00° 00'	
33+00	4.50	00° 5.4'	$+\delta_{\alpha 1} = 0°4.5'$
34+00	100.00	02° 5.4'	$+ D/2 = 2°$
35+00	100.00	04° 5.4'	$+ D/2 = 2°$
36+00	100.00	06° 5.4'	$+ D/2 = 2°$
37+00	100.00	08° 5.4'	$+ D/2 = 2°$
38+00	100.00	10° 5.4'	$+ D/2 = 2°$
38+95.5	95.50	12° 5.4'	$+\delta_{\alpha 2} = 1°54.6'$

$= \frac{I}{2}$ (checks) ✓

5.

a) $\text{Scale} = \frac{36.67}{110 \times 1000} = \frac{1}{3000}$

$\therefore$ Dimensions of building: Length $= 22.00 \times 3000 = \underline{\underline{66.00m.}}$
Width $= 18.33 \times 3000 = \underline{\underline{54.99m.}}$ } ANS.

b) $d = \frac{rh}{H}$; $\therefore h = \frac{Hd}{r}$;

$H = 7000 \text{ ft} \times 0.3048 = 2133.6 \text{ m}.$
$d = 88.87 - 86.52 = 2.35 \text{ mm}$
$r = 88.87 \text{mm}$

$\therefore h = \frac{2133.6 \times 2.35}{88.87} = \underline{\underline{56.42 \text{ m}}}.$ = Height of smoke-stack. ANS.

c)

i) $9'' = 1800 \text{ ft}$; $\therefore \text{Scale} = \frac{9''}{1800} = \frac{1''}{200 \text{ft}}$; $\underline{\underline{1'' = 200 \text{ft}}}$ } ANS.
or $\underline{\underline{1 : 2400}}$

ii) $S_{av.} = \frac{f}{H - h_{av.}}$

$\frac{1}{200} = \frac{12}{H - 1000}$ $h_{av.} = \frac{900 + 1100}{2} = 1000 \text{ ft}.$

$\therefore H = 2400 - 1000 = \underline{\underline{1400 \text{ ft}}}$ = $\underline{\underline{\text{Flying height}}}$ ANS.

iii) Lineal advance per photograph $= 100 - 60 = 40\%$.

$= 9'' \times 200 \times 0.40 = 720 \text{ ft}.$

$\therefore$ No of photographs $= \frac{20 \times 5280}{720} = 146.7 = 147$ photos.

Hence, Total No of photographs:

$147 + 2 + 2 = \underline{\underline{151 \text{ photographs}}}$ ANS.