Engineering Surveying

Surveying in general: It is a scientific method of collecting data for a certain field.

When the collecting of data related to points locations then the survey will be surveying .

There are two locations for the point:

Arithmetical location or position and field position.

Surveying: Is the science of determining relative positions of certain features on the earth surface in horizontal and vertical plane, or making those positions by taking such measurements in order that the relative positions may be ascertained on a map or plan.

Objectives: The objective of any surveying is to prepare a plan or map with the help of field measurements ,the main objectives are:

1-Measurements and determination of relative positions of certain features on portion of earth surface and to prepare a map or plan.

2- Measurements and determination of relative heights or depths or levels of various points .

3- setting out works such as buildings , sections and curves.

Surveying classification: Surveying may be classified according to:

Division ,Nature of the field of survey ,objective of survey ,instrument used

***Division :**surveying may be divided into two general classes:

Geodetic surveying : which is taking the curvature of earth into account .

Plane surveying: which is not taking the curvature of earth into account .

<u>*Nature of the field of survey:</u>

1- Land survey : Topographic ,Cadastral, Town surveying ,Engineering surveying .

2-Navigation . 3- Astronomical surveying

<u>*Objective of surveying</u>

Mining surveying , military surveying

<u>*Instruments used</u>

Hydrographic surveying, photographic surveying ,aerial surveying .

Fundamental principles

1- Working from whole to part .
2- Fixing surveying stations
   Surveying stations are fixed by at least two measurements :either both linear and angular measurements or by linear or angular measurements.

   sketches

Distance measurements

(make one of the students measure any length either by steps or by feet)

*Direct measurement

* Indirect measurements:
Obstacles in measurements:
1-=that prevent measuring but not ranging(mentioning what is ranging)examples ;river, pond .
2-= that prevents ranging but not measuring,examples,buildings….
3-= that prevent ranging &measuring in mountain terrain.

*measurements may be on plane or slope terrain.

MEASUREMENT SYSTEMS:
1-English system
Unit parts, doubles
2-Metric system
Meter: is 1/10000000 of the distance between equator and the north pole on the longitude passing through Paris city.
Meter parts, meter doubles

TYPES OF TAPES
1-cloth tape
2-plastic tape
3-steel tape
4-Invar tape

TAPE MEASUREMENTS CORRECTIONS:

<u>1-Standarization:</u>

Cs=Li-L ,Li=true length, L=standard length
Total Cs=Cs x D/L
D̀=DxLi/L where:

D̀=corrected distance ,Li=true length
D=measured distance ,L=standard length

Ex:

A distance is measured by a tape with a true length (29,992m),and it is found to be 195m ,calculate the corrected distance?

Sol:

Cs=Li-L

29.992-30=-0.008m

D̀=Dx Li/L

D̀=195x29.992/30

D̀=194.948m

Or:

Total Cs=-0.008x195/30,Total Cs=-0.052m

D̀=195-0.052=194.948m

2-Temprature correction:

Ct=Dxα(T-Ts)   where:

α=expanding factor for the tape material, for steel=0.0000115/˚c

T=temperature during measurement

Ts=standard temperature during manufacturing

Ex:

A steel tape 30m is used to measure a distance which it is found to be 520.327m in 40˚c ,α is $11.6x10^{-6}$find the corrected distance.

C_t=520.327x11.6x10^{-6}(40˚c-20 ˚c)

=0.121m

D̀=520.327+0.121=520.448m

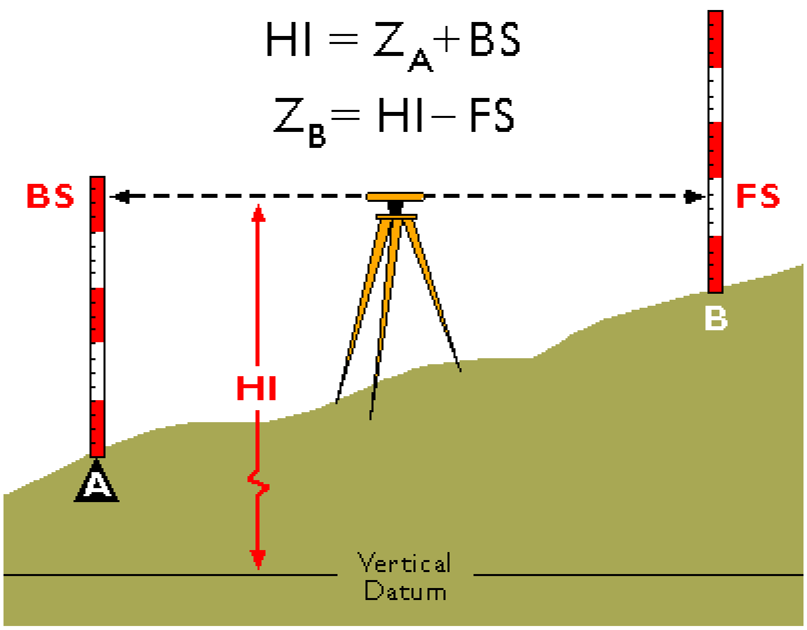
LEVELING

Leveling is the operation of determining the vertical differences in heights of the different points on the surface of the earth, relative to a plane called a datum plane which is used to be the mean sea level.

- **TYPES OF LEVELS**

1-According to accuracy

2-According to the method of adjustment of the line of sight.

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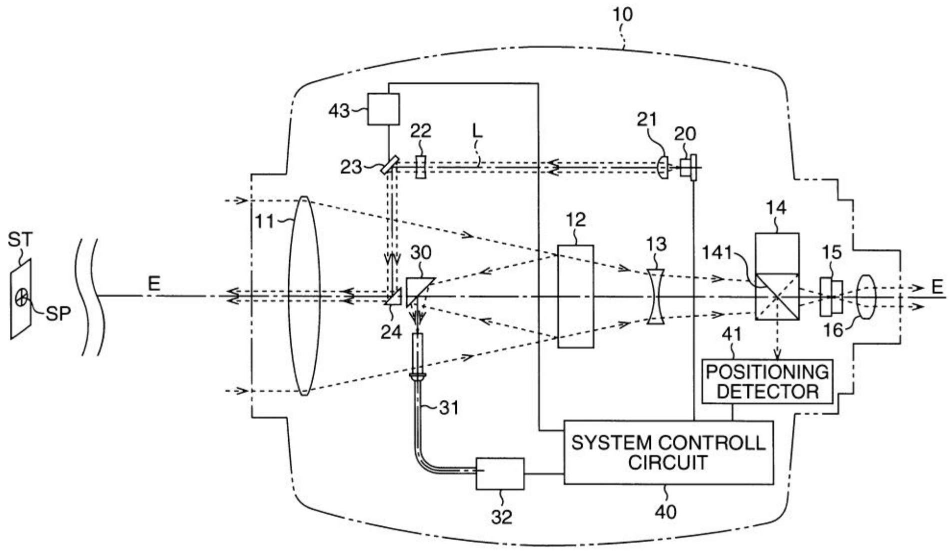
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POSITIONING
DETECTOR
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SYSTEM CONTROLL
CIRCUIT
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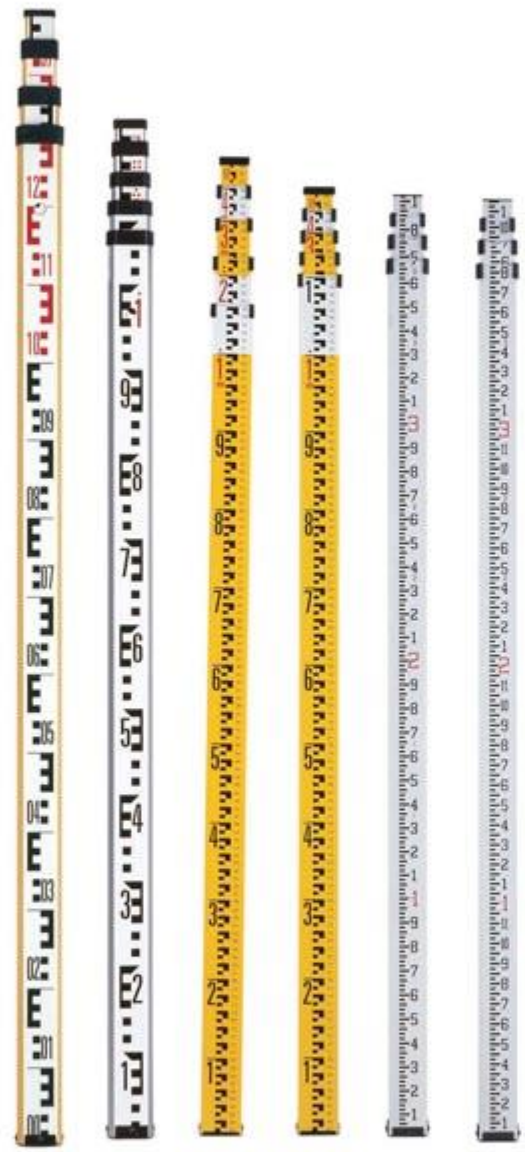
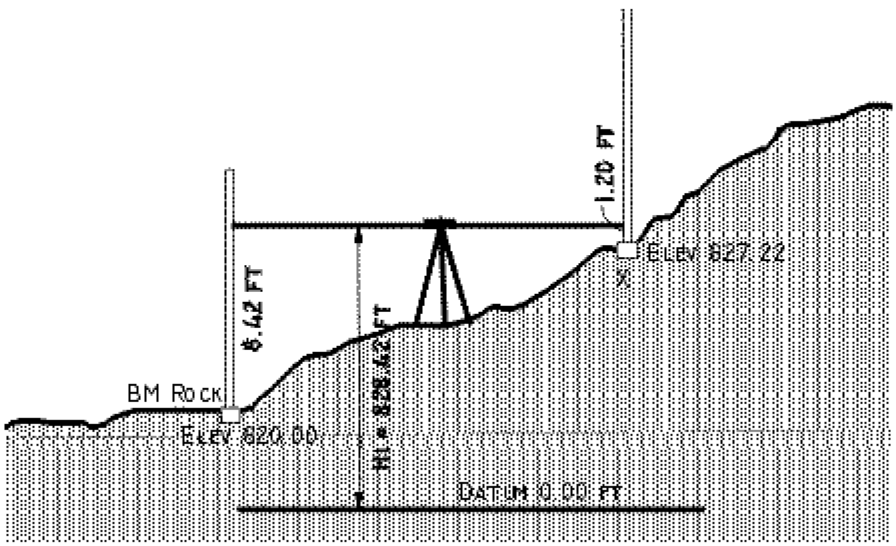
WILD

- **TYPES OF STAVES**



- **<u>LEVELING THEORY</u>**



- **<u>METHODS OF CALCULATING ELEVATIONS:</u>**

1-LINE OF SIGHT METHOD.

2-RISES& FALLS METHOD.

***Accuracy in Leveling and Elevation correcting:**

P.E =K$\sqrt{D}$

P.E: permissible error

K:leveling constant

D:leveling total distance(km)

***K**

EX:

In an oil pipe project the readings of the staves on the center line were:

2.222- 1.677- 1.492- 1.878-2.021- 1.909- 1.663- 1.887- 1.321- 1.787

The second, fifth and the seventh readings represent turning points, theelevation of the first point was (32.222m),calculate the corrected elevations if the corrected elevation of the last point was(32.089m) and the distance between one point and another was (50m),the permissible error was (15mm).

Corr.= error/sum of dist.

EX:

In a series leveling the staves readings were as follows:

1.512- 1.763- 1.878- 2.333- 1.969- 1.112- 2.186- 0.676

The third ,sixth, and eighth readings represents turning points, the elevation of the first point was (30m)and the corrected elevation of

the last point was(32.374m), calculate the corrected elevations of the rest of the points if the distance between each point and another was (50m).

<u>*BENCH MARKS:</u>

Are points which have known elevations on the earth surface, they are usually marked by concrete and metal signs that can stand the bad weather conditions.

***TYPES OF BENCH MARKS**

1-BASIC B.MS.

2-SECONDARY B.MS.

3-ORDINARY B.MS.

<u>*METHODS OF MAKING B.MS. :</u>

1-LOOP

2-TWO WAYS LEVELLING

3-CHANGING LEVEL AND STAVES LOCATIONS

4-STADIA HAIR METHODS

***<u>ERRORS AND MISTAKES IN LEVELING</u>**

<u>FIRST :</u>INSTRUMENTAL ERRORS:

STAFF:1- manufacturing

2-erosion

LEVEL:1- ERRORS THAT CAN BE FIXED BY THE FACTORY

2- ERRORS THAT CAN BE FIXED BY USERS

SO LEVEL FIXATION CAN BE DEVIDED INTO TWO TYPES:

1-PERMENANT:

A-VERTICALITY

B-TWO-PEGS METHOD

2-TEMPORARY

SECOND:PERSONAL ERRORS;

THIRD:NATURAL OR CLIMATIC ERRORS

1-CURVATURE EFFECT:

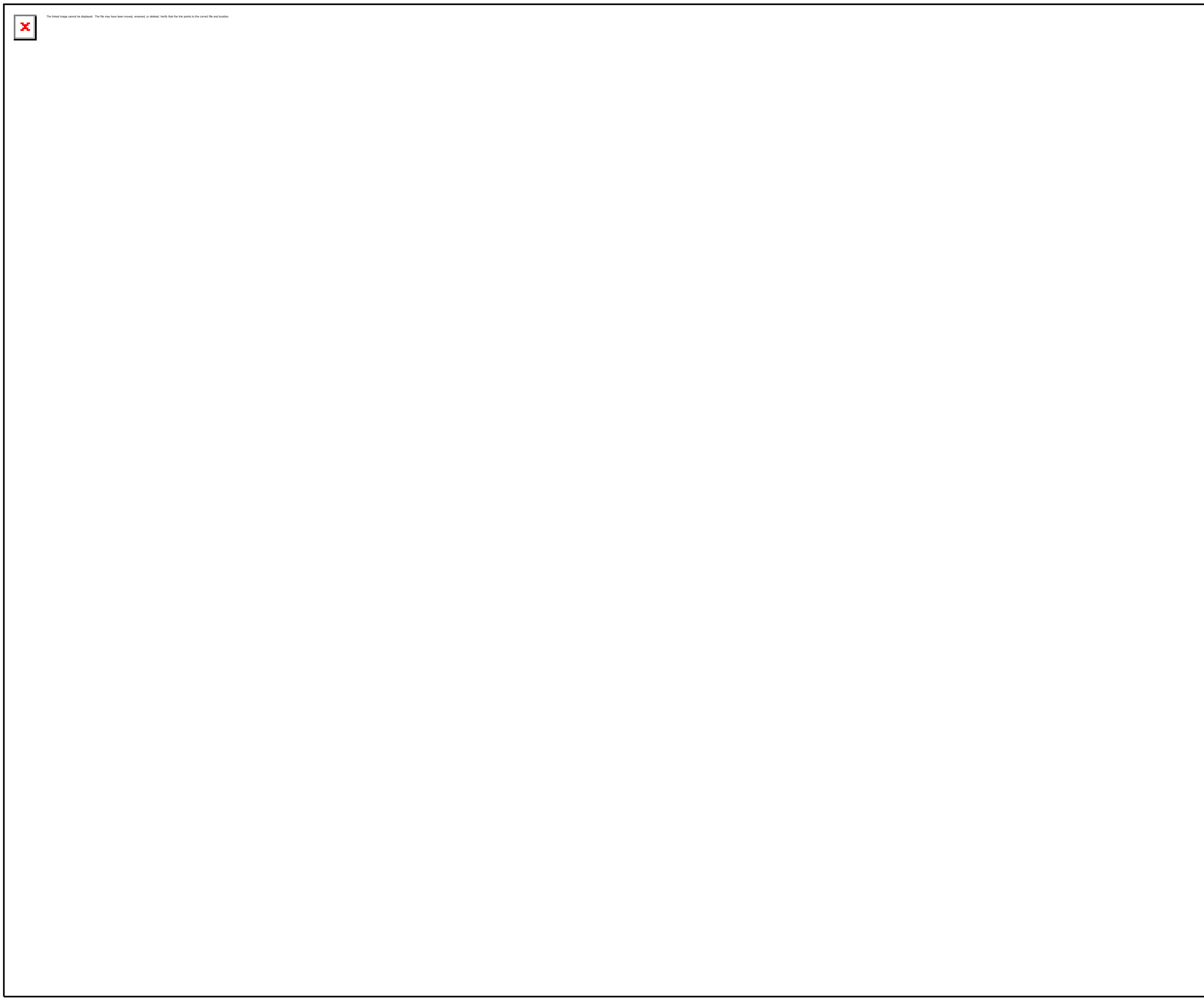
$C=7.84\times10^{-8} D^2$

2-REFRACTION EFFECT:

$r=D^2/14R$

3-COMBINED EFFECT:

$c-r=6.72\times10^{-8}D^2$



$$(\mathbf{R}+\mathbf{C})^2 = \mathbf{R}^2 + D^2$$

$R^2 + 2RC + C^2 = R^2 + D^2$

$2RC + C^2 = D^2$

$2RC = D^2$

$C = D^2/2R$….curvature

α and Δ: in radian

$\Delta = k\,\alpha$

$k = 1/14$

$r = 1/14 \times D^2/R$…..refraction

$c - r = D^2/2R - 1/14 \times D^2/R$

$c - r = 3/7 \times D^2/R$

$c - r = 6.72 \times 10^{-8} D^2$……curvature and refraction

$c = 7.84 \times 10^{-8} D^2$ ……….curvature

$$= 6{\cdot}73 \times 10^{-8} l^2$$

Example 5.14 What will be the effect of curvature and refractio following distances: (a) 1 km, (b) 200 m, (c) 5 km, (d) 160 km

(a) $$E_a = 6{\cdot}73 \times 10^{-2} L^2$$

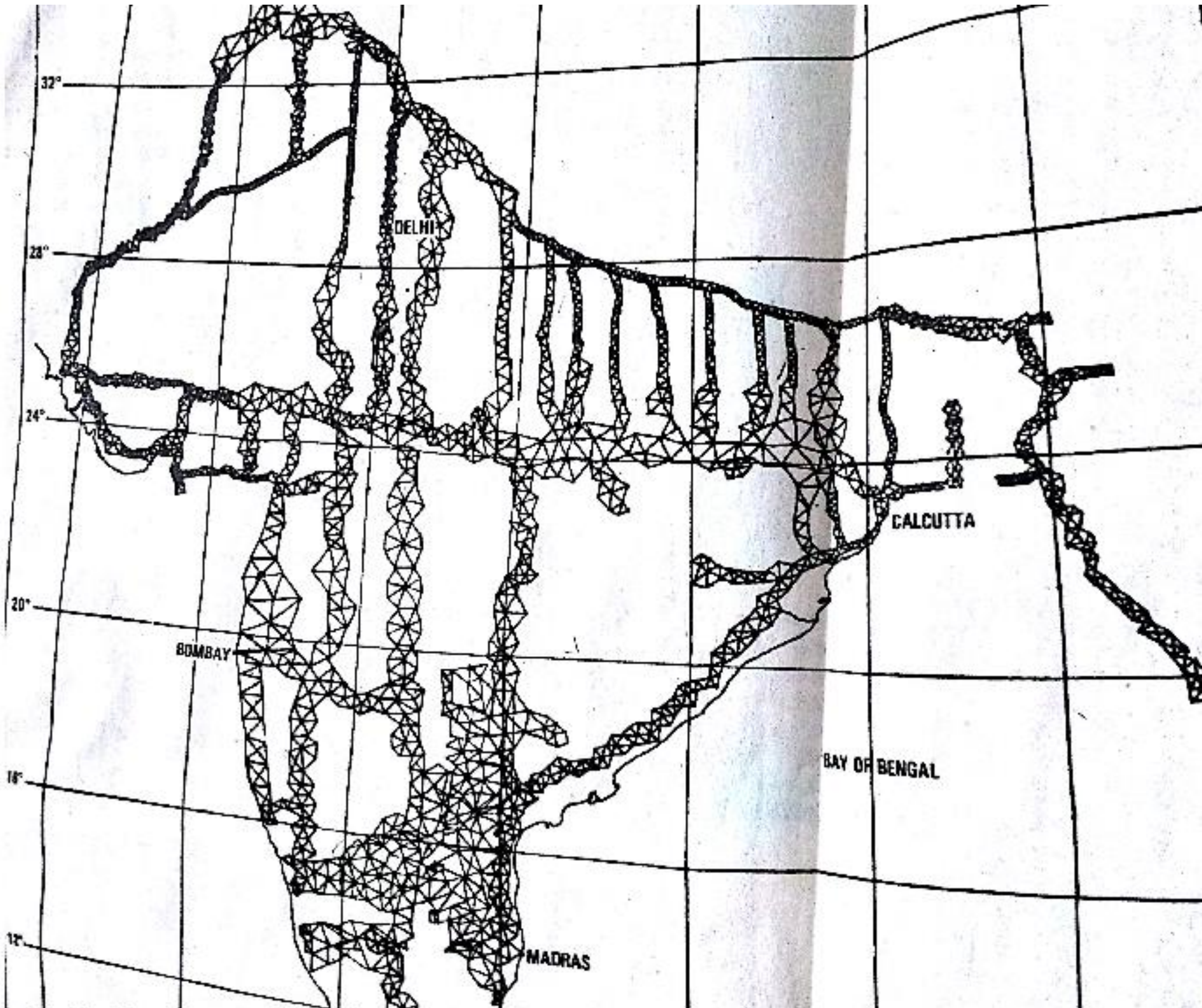
$$= 6{\cdot}73 \times 10^{-2} = \underline{0{\cdot}068 \text{ m}}$$

(b) $$6{\cdot}73 \times 10^{-8} \times 200^2 = \underline{0{\cdot}003 \text{ m}}$$

(c) $$E_c = 6{\cdot}73 \times 10^{-2} \times 5^2 = 1{\cdot}682 \text{ m}$$

(d) $$E_d = 6{\cdot}73 \times 10^{-2} \times 160^2 = 1722{\cdot}9 \text{ m}$$

In ordinary precise levelling it is essential that the lengths of and foresight be equal to eliminate instrumental error. This is als counteract the error due to curvature and refraction, as this erro


32°
28°
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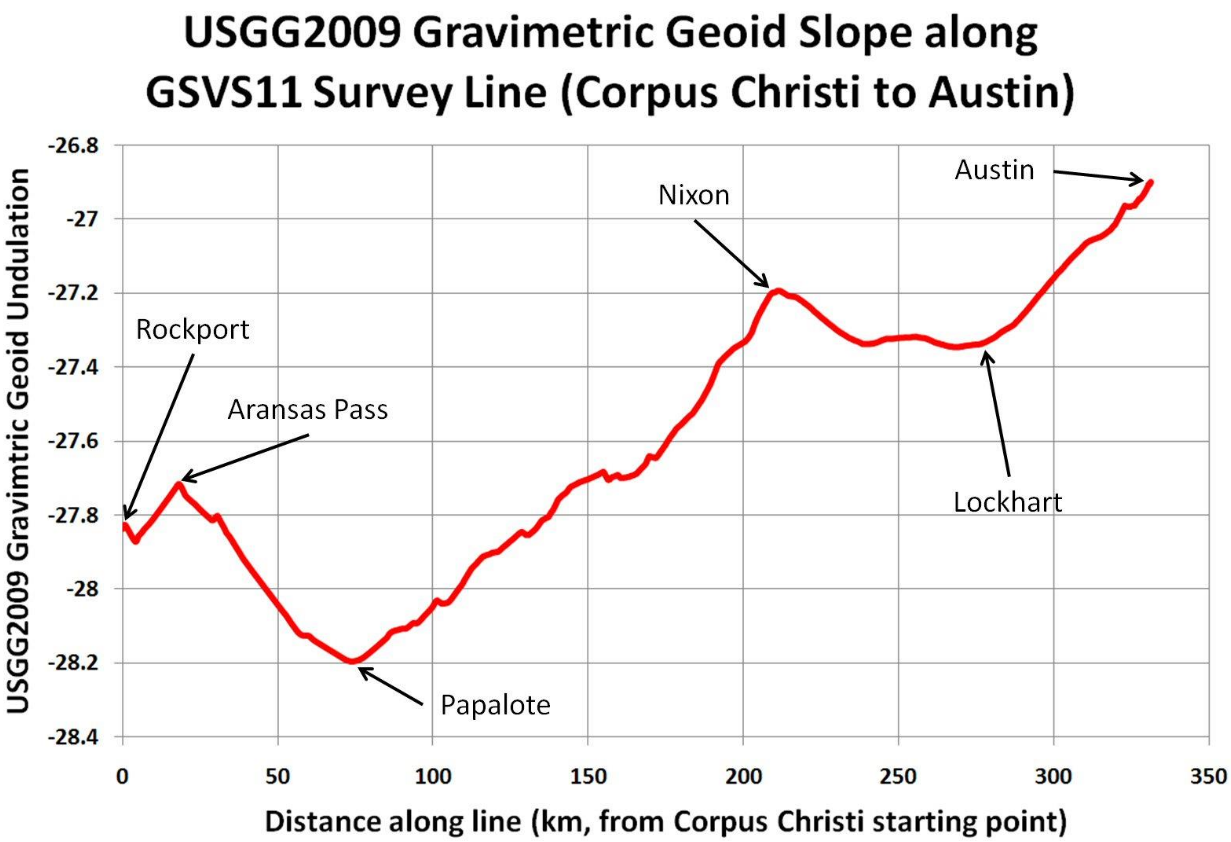
BOMBAY
BAY OF BENGAL
MADRAS


U.S. DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
UNLAWFUL TO DISTURB



Longitudinal& cross sections

Ex:

1.512_1.763_2.878_2.333_1.969_1.112_2.186_0.676

If the design line started from the first point and ended under the last point by 0.75m calculate the depth of cut and the heights of fills in each point.

Grade $_{(unknown)=}$Grade$(_{known)}$ +slope x Dist. to point

Slope = V.Dist./ H.Dist

GROUND_GRADE= + CUT

__GROUND_GRADE=_FILL

TOPOGRAPHIC MAPS

They are maps declare the topographic nature of the ground.

CONTOUR LINES:

They are unreal lines passing through points that have same elevations.

CONTOUR INTERVAL:

It is the vertical distance between two consecutive contour lines.

CONTOUR SPACING:

It is the horizontal distance between two consecutive contour lines.

SLOPE= C.I. /C.S.

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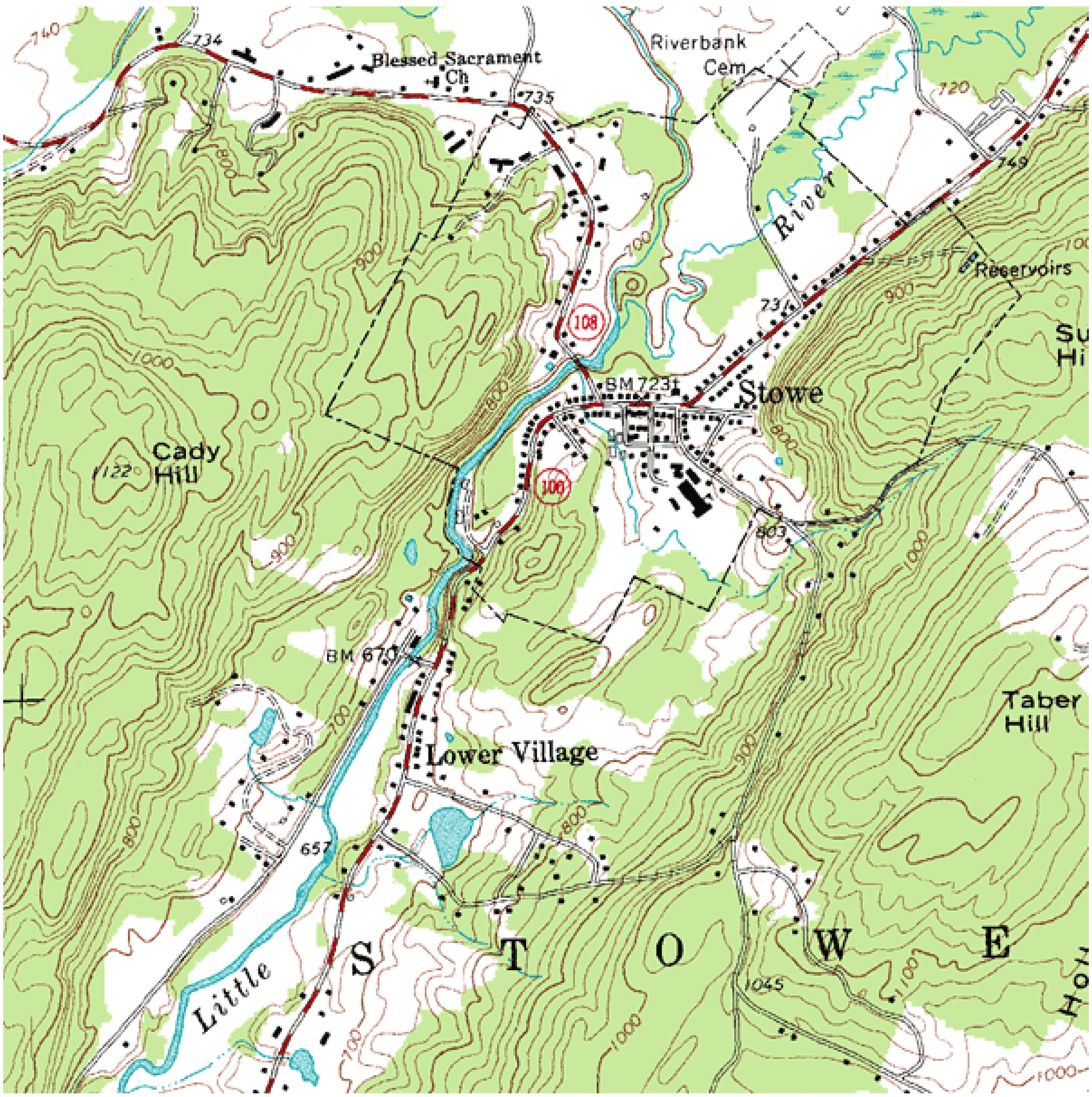
Topographic map

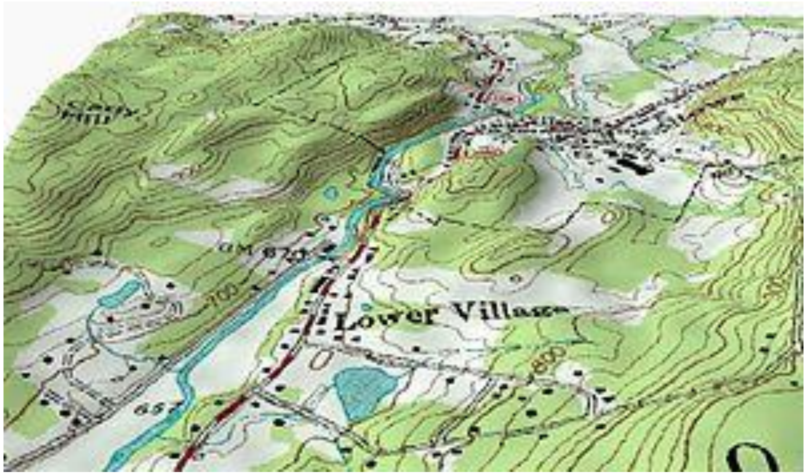
In modern mapping, a topographic map is a type of map characterized by large-scale detail and quantitative representation of relief, usually using contour lines but, historically, using a variety of methods. Traditional definitions require a topographic map to show both natural and man-made features. A topographic map is typically published as a map series, made up of two or more map sheets that

combine to form the whole map. A contour line is a combination of two line segments that connect but do not intersect; these represent elevation on a topographic map.

The Canadian Centre for Topographic Information provides this definition:[1]

A topographic map is a detailed and accurate graphic representation of cultural and natural features on the ground.





***METHODS OF MAKING CONTOUR MAPS:**

1-by sections

2-by grid method

3-sattalite and remote sensing

<u>AREAS AND VOLUMES</u>

1-AREAS OF IRREGULAR SHAPES

METHODS OF CALCULATING IRREGULAR SHAPES:

1-OLD GRAGHIC METHODS

2-MATHEMATICAL METHODS;

a-Trapezoidal rule

b-Simpson’s rule

c-sections method

3-mechanical method

plannimeter

Trapezoidal rule

Figure 9.8 shows an area bounded by a survey line and a boundary. The survey line is divided into a number of small equal intercepts of length x, and the offsets O_1, O_2 etc. are measured, either directly on the ground or by scaling from the plan. If x is short enough for the length of boundary between the offsets to be assumed straight, then the area is divided into a series of trapezoids.

$$\text{Area of trapezoid 1} = \frac{O_1 + O_2}{2} \cdot x$$

$$\text{Area of trapezoid 2} = \frac{O_2 + O_3}{2} \cdot x$$

$$\text{Area of trapezoid 6} = \frac{O_6 + O_7}{2} \cdot x$$

Summing up, we get

$$\text{Area} = \frac{x}{2}(O_1 + 2O_2 + 2O_3 + \cdots + O_7)$$

.8

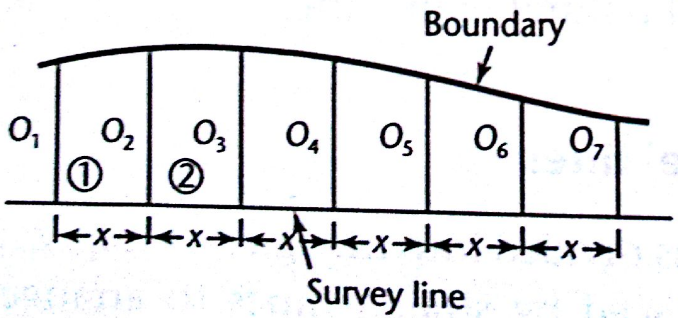
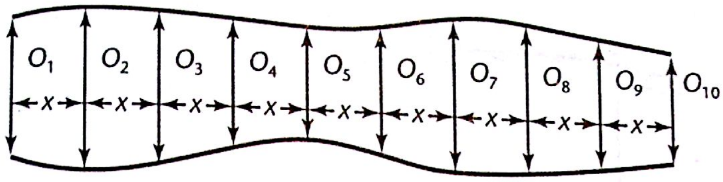


Fig. 9.9



In the general case with n offsets, we get

$$\text{Area} = x\left(\frac{O_1 + O_n}{2} + O_2 + O_3 + \cdots + O_{n-1}\right) \tag{9.6}$$

If the area of a narrow strip of ground is required, this method may be used by running a straight line down the strip as shown in Fig. 9.9, and then measuring offsets at equal intercepts along this. By the same reasoning it will be seen that the area is given by

$$\text{Area} = x\left(\frac{O_1 + O_n}{2} + O_2 + O_3 + \cdots + O_{n-1}\right)$$

Example 9.3

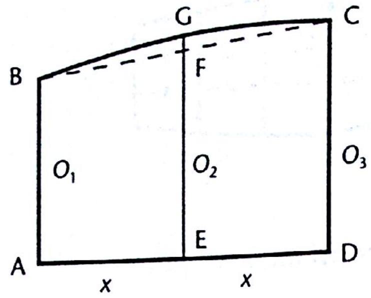
Calculate the area of the plot shown in Fig. 9.9 if the offsets, scaled from the plan at intervals of 10 m, are:

Offset	O_1	O_2	O_3	O_4	O_5
Length (m)	16.76	19.81	20.42	18.59	16.76
Offset	O_6	O_7	O_8	O_9	O_{10}
Length (m)	17.68	17.68	17.37	16.76	17.68

$$\text{Area} = 10\left(\frac{16.76 + 17.68}{2} + 19.81 + 20.42 + 18.59 + 16.76 + 17.68 + 17.68 + 17.37 + 16.76\right)$$

$= 1622.9\ \text{m}^2$

$=$ **0.162 hectares**



The portion of the area contained between offsets O_1 and O_3

$= ABGCDA$

$=$ trapezoid $ABFCDA +$ area $BGCFB$

$$= \frac{O_1 + O_3}{2} \cdot 2x + \tfrac{2}{3} \text{ (area of circumscribing parallelogram)}$$

$$= \frac{O_1 + O_3}{2} \cdot 2x + \tfrac{2}{3} \cdot 2x\left(O_2 - \frac{O_1 + O_3}{2}\right)$$

$$= \frac{x}{3}(3O_1 + 3O_3 + 4O_2 - 2O_1 - 2O_3)$$

$$= \frac{x}{3}(O_1 + 4O_2 + O_3)$$

For the next pair of intercepts, area contained between offsets O_3 and O_5

$$= \frac{x}{3}(O_3 + 4O_4 + O_5)$$

For the final pair of intercepts, area contained between offsets O_5 and O_7

$$= \frac{x}{3}(O_5 + 4O_6 + O_7)$$

Summing up, we get

$$\text{Area} = \frac{x}{3}[(O_1 + O_7) + 2(O_3 + O_5) + 4(O_2 + O_4 + O_6)] \qquad (9.7)$$

In the general case,

$$\text{Area} = \frac{x}{3}(X + 2O + 4E)$$

where $X =$ sum of first and last offsets, $O =$ sum of the remaining odd offsets, and $E =$ sum of the even offsets.

Simpson's rule states, therefore, that the area enclosed by a curvilinear figure divided into an even number of strips of equal width is equal to one-third the width of a strip, multiplied by the sum of the two extreme offsets, twice the sum of the remaining odd offsets, and four times the sum of the even offsets.

4

In a tape and offset survey the following offsets were taken to a fence from a survey line:

Chainage (m)	0	20	40	60	80
Offset (m)	0	5.49	9.14	8.53	10.67
Chainage (m)	100	120	140	160	180
Offset (m)	12.50	9.75	4.57	1.83	0

Find the area between the fence and the survey line.

Note that the term 'chainage' refers to a cumulative increase in distance measured from a starting point on the line: that is, zero chainage.

There are 10 offsets, and because Simpson's rule can be applied to an *odd* number of offsets only, it will be used here to calculate the area contained between the first and ninth offsets. The residual triangular area between the ninth and tenth offsets is calculated separately. It is often convenient to tabulate the working.

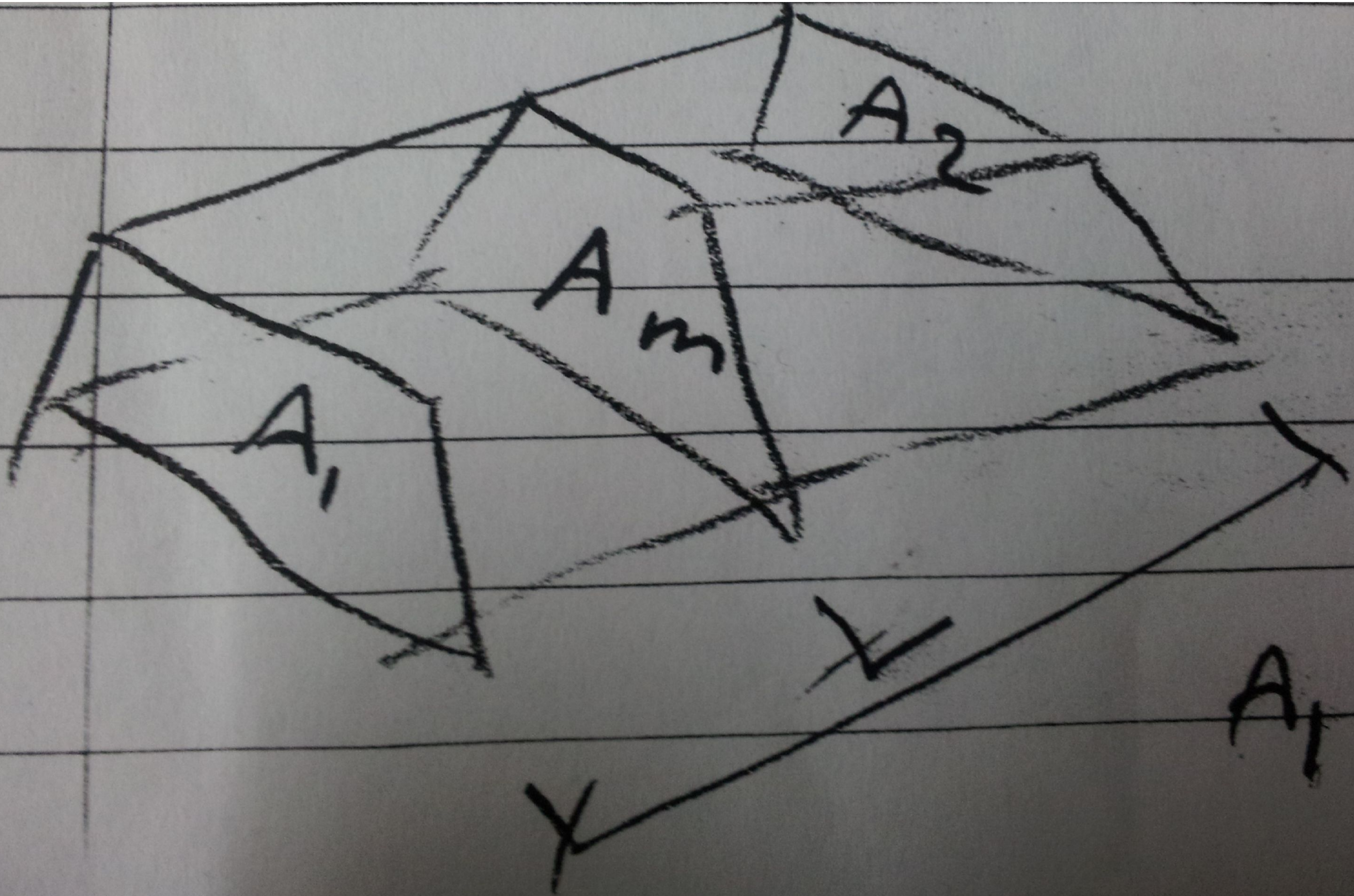
Offset no.	Offset	Simpson multiplier	Product
1	0	1	0
2	5.49	4	21.96
3	9.14	2	18.28
4	8.53	4	34.12
5	10.67	2	21.34
6	12.50	4	50.00
7	9.75	2	19.50
8	4.57	4	18.28
9	1.83	1	1.83
			$\Sigma = 185.31$

Area $(O_1 – O_9) = \frac{20}{3} \times 185.31 = 1235.40\ m^2$

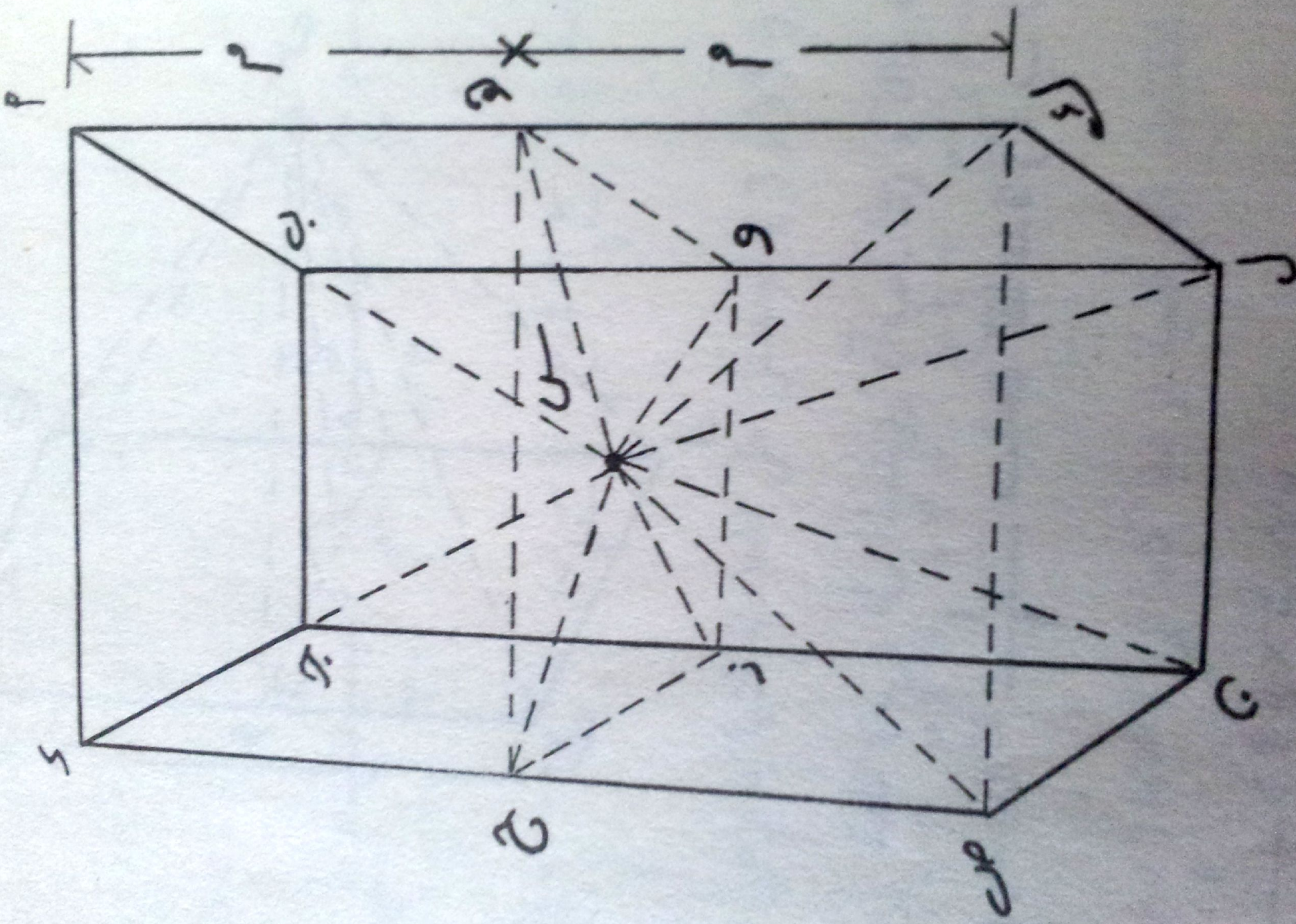
Area $(O_9 - O_{10}) = \frac{20}{2} \times 1.83 \quad = \underline{\ \ 18.30\ m^2}$

$1253.70\ m^2$

= **0.125 hectares**



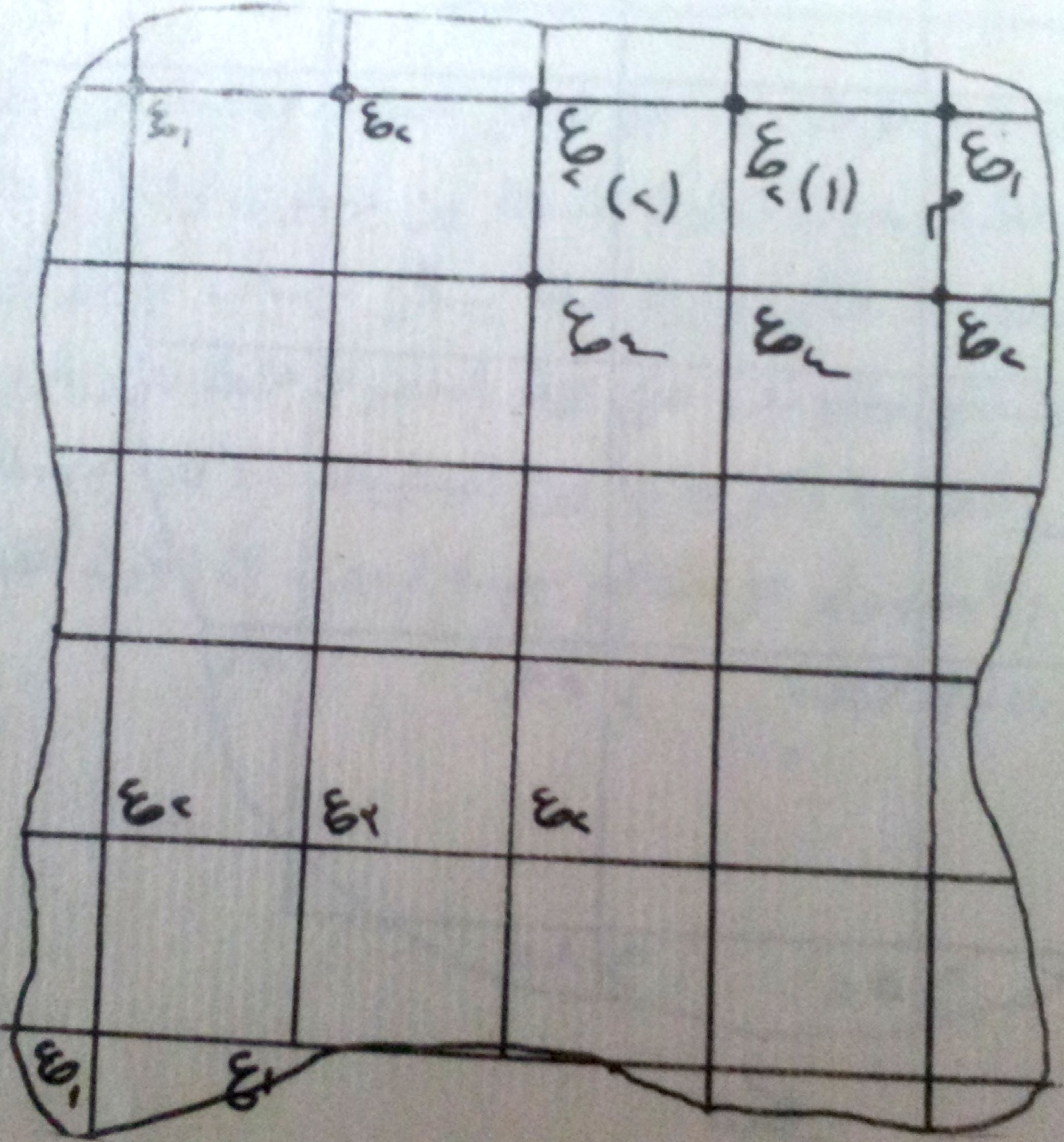
$A_1 = h$



$\frac{م^2}{٤}$ [مجموع الارتفاعات ($ع_1$) + ٢ × مجموع

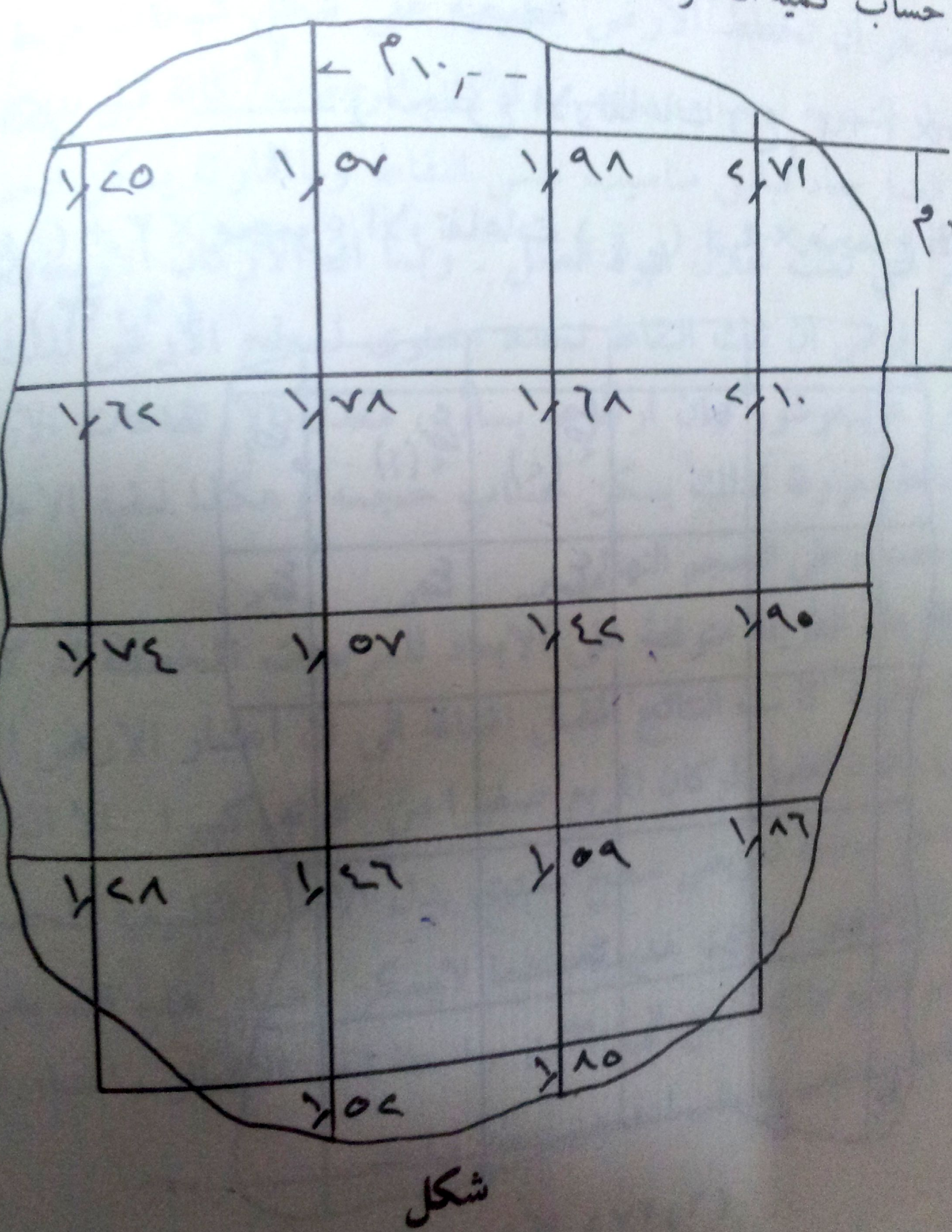
× مجموع الارتفاعات ($ع_3$) + ٤ × مجموع الارتفاعا

)



شكل (٢٧ و ٦)

... في ... مربع
... المربع يساوى ١٠ م وان الارتفاعات الموشرة ازاء كل ركن تبين عمق ...
... المطلوب حساب كمية الحفر .



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Example 9.8

An embankment is formed on ground that is level transverse to the embankment but falling at 1 in 20 longitudinally so that three sections 20 m apart have centre-line heights of 6.00, 7.60 and 9.20 m respectively above original ground level. If side slopes of 1 in 1 are used, determine the volume of fill between the outer sections when the formation width is 6.00 m, using the trapezoidal rule.

Using equation (9.8):

$$A = h(b + mh)$$

$$A_1 = 6.00(6.00 + 6.00) = 72.00 \text{ m}^2$$

$$A_2 = 7.60(6.00 + 7.60) = 103.36 \text{ m}^2$$

$$A_3 = 9.20(6.00 + 9.20) = 139.84 \text{ m}^2$$

Note that the mid-area A_2 is not the mean of A_1 and A_3.

$$V = \frac{20.00}{2}(72.00 + 2 \times 103.36 + 139.84)$$

$$= \mathbf{4185.6\ m^3}$$

Example 9.9 Using the data of Example 9.8 solved by the end-areas method, compute the volume by the prismoidal formula.

(a) Taking $D = 40$ m

$$V = \frac{40}{6}(72.00 + 4 \times 103.36 + 139.84)$$

$$= \mathbf{4168.5\ m^3}$$

(b) Taking $D = 20$ m, and applying the prismoidal correction to the 'end-areas' volumes:

$$V_1 = \frac{20}{2}(72.00 + 103.36)$$

$$= 1753.6\ \text{m}^3$$

$$\text{PC} = \frac{Dm}{6}(h_1 - h_2)^2$$

$$= \frac{20 \times 1}{6}(6.00 - 7.60)^2$$

$$= 8.53\ \text{m}^3$$

$$V_2 = \frac{20}{2}(103.36 + 139.84)$$

$$= 2432\ \text{m}^3$$

Example 9.10

A cutting is to be made in ground which has a transverse slope of 1 in 5. The width of formation is 8.00 m and the side slopes are 1 vertical to 2 horizontal. If the depths at the centre lines of three sections 20 m apart are 2.50, 3.10 and 4.30 m respectively, determine the volume of earth involved in this length of the cutting.

From equation (9.11):

$$A = \frac{1}{2m}\left[\left(\frac{b}{2} + mh\right)(w_1 + w_2) - \frac{b^2}{2}\right]$$

From equations (9.9) and (9.10):

$$w_1 = \left(\frac{b}{2} + mh\right)\left(\frac{k}{k-m}\right)$$

$$w_2 = \left(\frac{b}{2} + mh\right)\left(\frac{k}{k+m}\right)$$

Hence $\frac{k}{k-m} = \frac{5}{3}$, $\frac{k}{k+m} = \frac{5}{7}$, because $m = 2$ and $k = 5$

Tabulating,

Section	h	mh	$b/2 + mh$	w_1	w_2	$w_1 + w_2$	A (m^2)
1	2.50	5.00	9.00	$9.00 \times \frac{5}{3} = 15.00$	$9.00 \times \frac{5}{7} = 6.43$	21.43	40.24
2	3.10	6.20	10.20	$10.20 \times \frac{5}{3} = 17.00$	$10.20 \times \frac{5}{7} = 7.29$	24.29	53.94
3	4.30	8.60	12.60	$12.60 \times \frac{5}{3} = 21.00$	$12.60 \times \frac{5}{7} = 9.00$	30.00	86.50

(a) Treating the whole as one prismoid:

$$V = \frac{40}{6}(40.24 + 4 \times 53.94 + 86.50)$$

$$= \mathbf{2283.3\ m^3}$$

(b) Using end-areas formula with prismoidal correction:

$$V_{EA} = \frac{20}{2}(40.24 + 2 \times 53.94 + 86.50)$$

$$= 2346.2\ m^3$$

From equation (9.27):

$$PC = \frac{D}{6}\frac{k^2}{k^2 - m^2} \cdot m(h_1 - h_2)^2$$

Therefore

$$\text{Total PC} = \frac{20}{6} \times \frac{25}{21} \times 2[(2.50 - 3.10)^2 + (3.10 - 4.30)^2]$$

$$= 14.3\ m^3$$

$$\text{Therefore } V_P = 2346.2 - 14.3$$

$$= \mathbf{2331.9\ m^3}$$

Backsight	Intersight	Foresight	Height of collimation	Reduced level	Distance (m)	Remarks
						BM on gate,
0.663			99.423	98.760		98.76 m AOD
	1.946			97.477	0	Staff station A
	1.008			98.415	20	B
	1.153			98.270	40	C
2.787		1.585	100.625	97.838	60	D
						(change point)
	2.270			98.355	80	E
	1.218			99.407	100	F
		0.646		99.979	120	G
3.450		2.231		99.979		
2.231				98.760		
1.219				1.219		

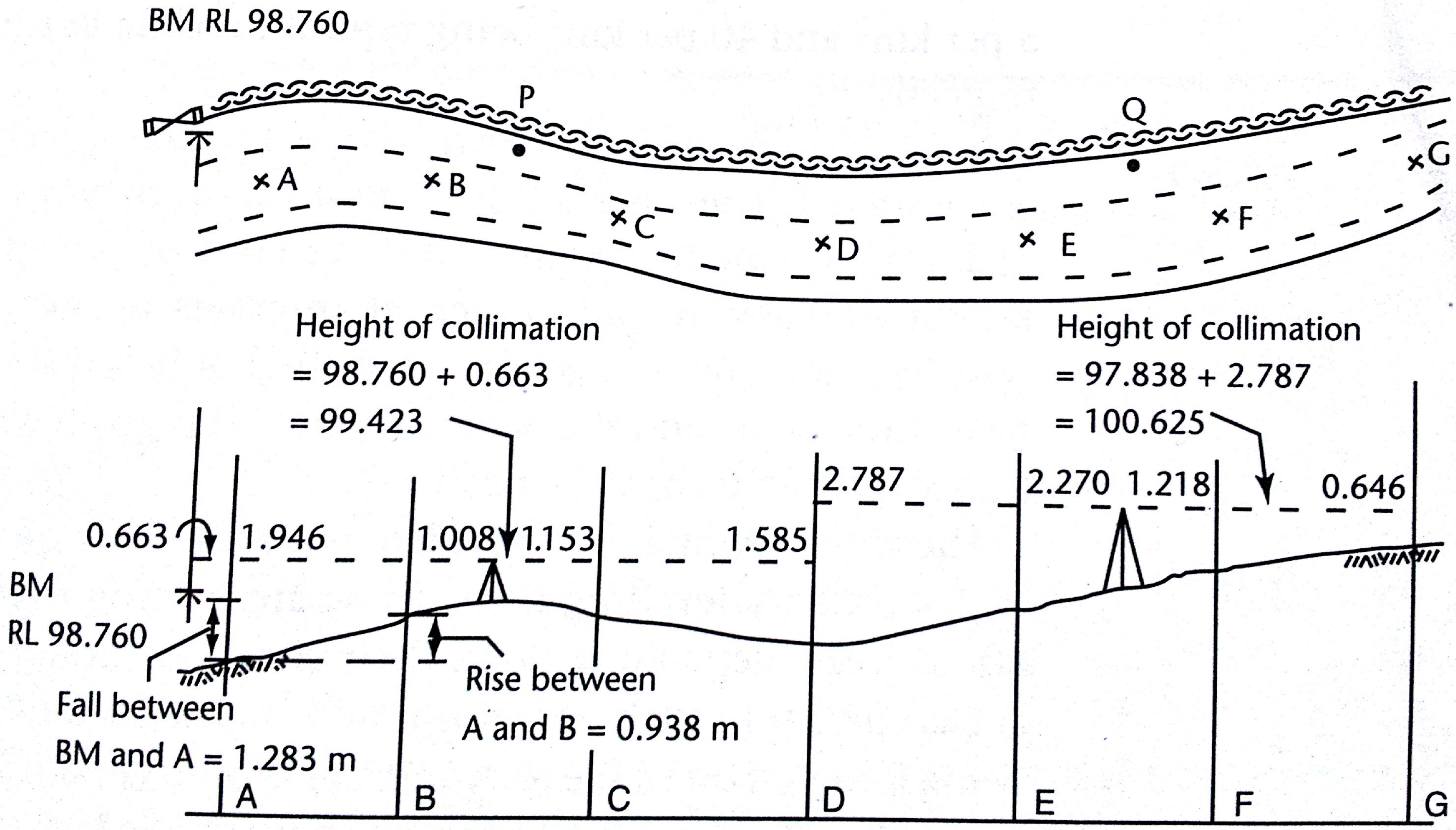

BM RL 98.760
P
Q
A
B
C
D
E
F
G
Height of collimation
= 98.760 + 0.663
= 99.423
Height of collimation
= 97.838 + 2.787
= 100.625
0.663
1.946
1.008
1.153
1.585
2.787
2.270
1.218
0.646
BM
RL 98.760
Fall between
BM and A = 1.283 m
Rise between
A and B = 0.938 m
A
B
C
D
E
F
G

Table 3.1

Backsight	Intersight	Foresight	Rise	Fall	Reduced level	Distance (m)	Remarks
0.663					98.760		BM on gate, 98.76 m AOD
	1.946			1.283	97.477	0	Staff station A
	1.008		0.938		98.415	20	B
	1.153			0.145	98.270	40	C
2.787		1.585		0.432	97.838	60	D (change point)
	2.270		0.517		98.355	80	E
	1.218		1.052		99.407	100	F
		0.646	0.572		99.979	120	G
3.450		2.231	3.079	1.860	99.979		
2.231			1.860		98.760		
1.219			1.219		1.219		

Example 3.4

The following figures were extracted from a level field book; some of the entries are illegible because of exposure to rain. Insert the missing figures and check your results. Re-book all the figures by the rise and fall method, and state the advantage of this method of booking.

BS	IS	FS	H of I	RL	Remarks
?			279.08	277.65	OBM
	2.01			?	
	?			278.07	
3.37		0.40	?	278.68	
	2.98			?	
	1.41			280.64	
		?		281.37	TBM

(London)

Each line in a level book can be regarded as an equation, which can be drawn up by applying the principles just outlined.

Thus, line 1, H of I = RL + BS

Hence, BS = H of I − RL

= 279.08 − 277.65

= 1.43

line 2, RL = H of I − IS

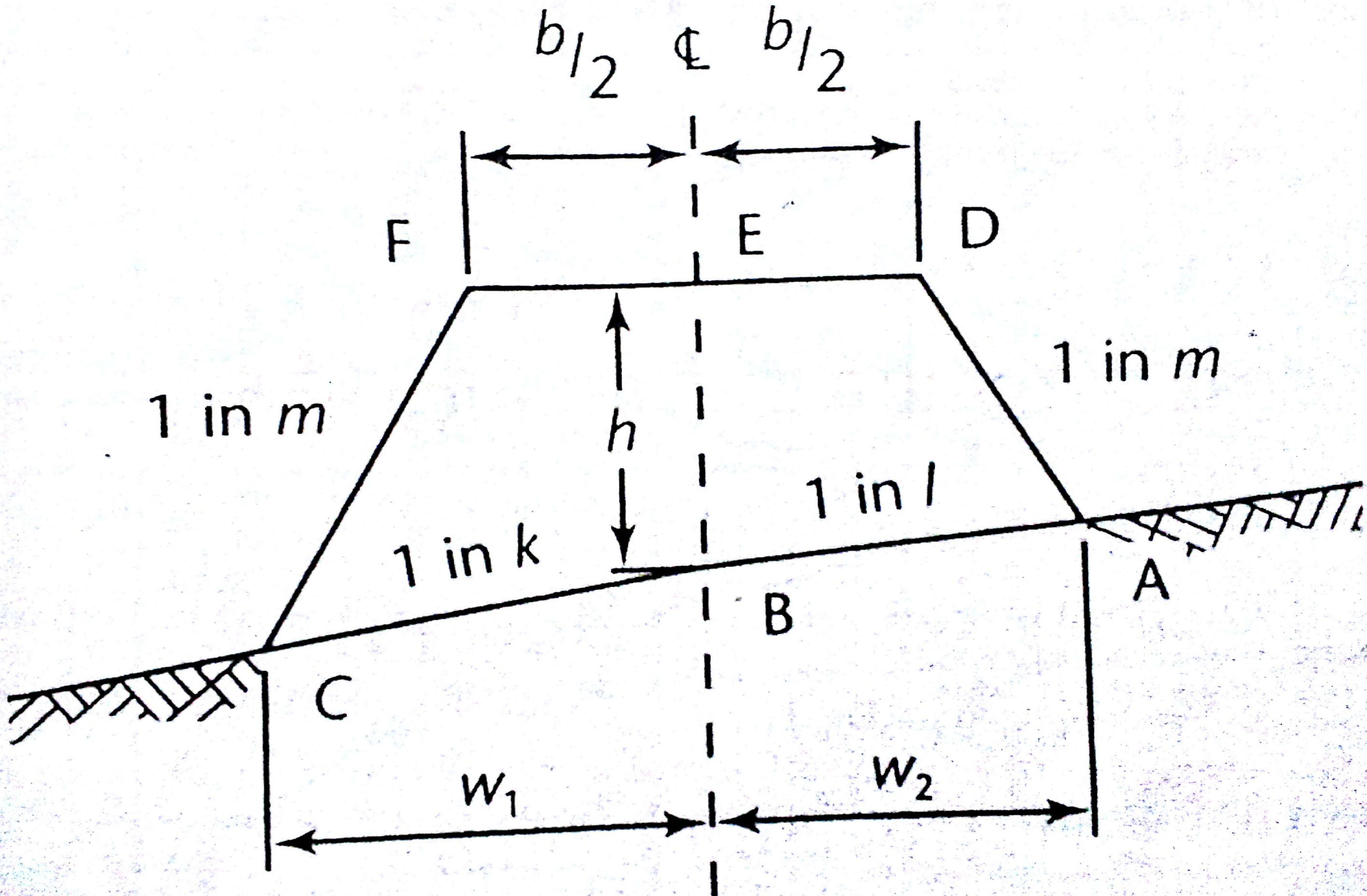
= 279.08 − 2.01

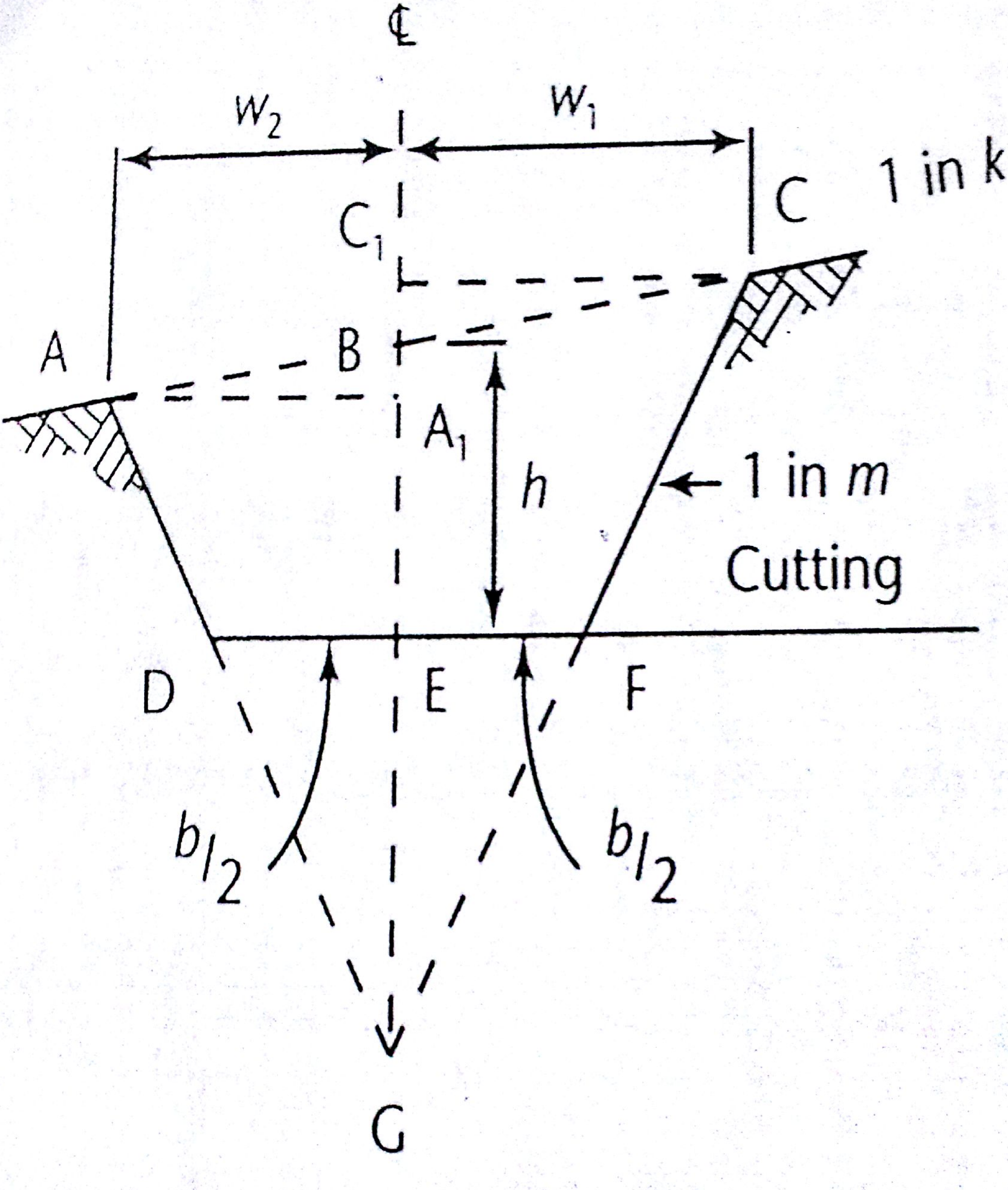
= 277.07

In this way, the field book is completed as follows; the reader should carry out the re-booking by applying the principles outlined. The total rise and total fall are 4.30 m and 0.58 m respectively.

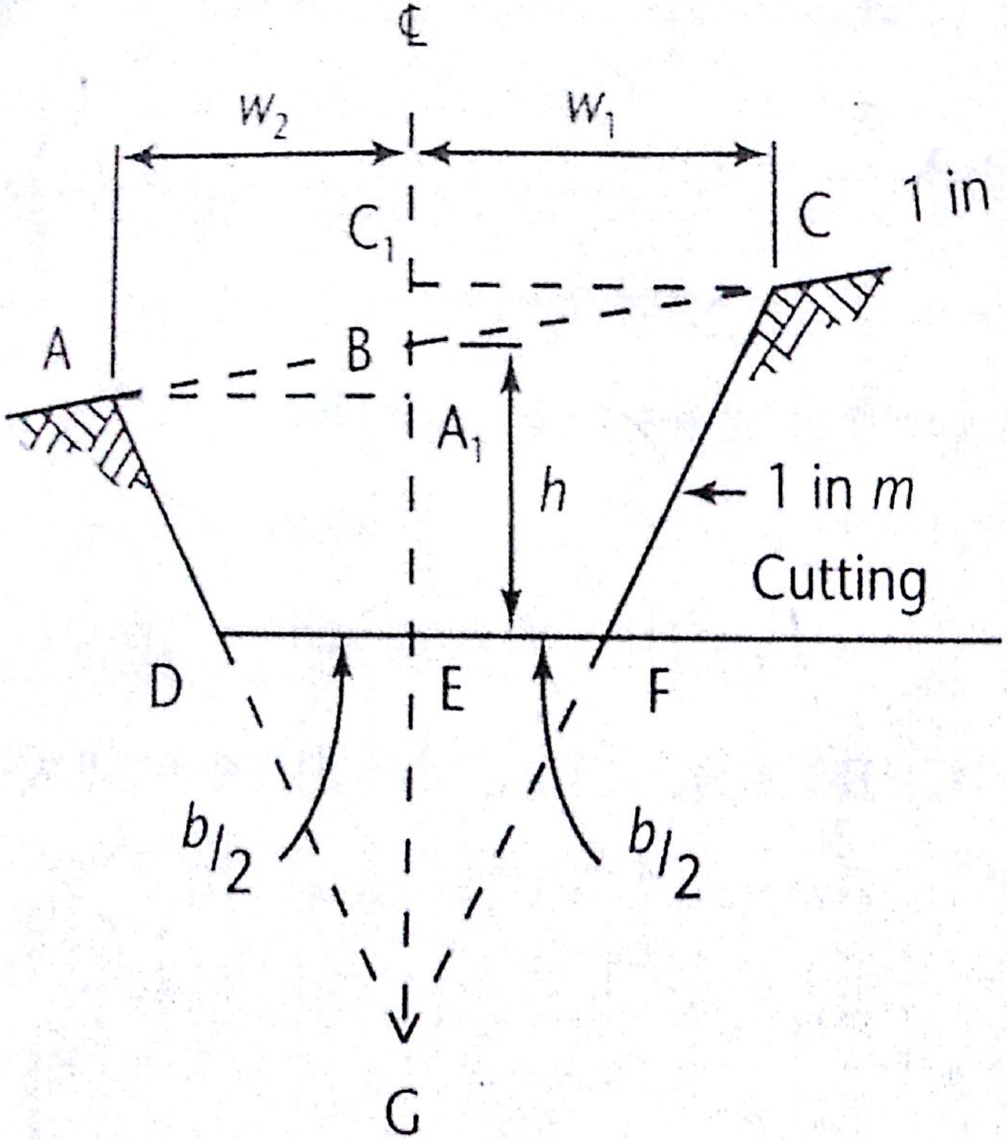
BS	IS	FS	HI	RL	Remarks
1.43			279.08	277.65	OBM
	2.01			277.07	
	1.01			278.07	
3.37		0.40	282.05	278.68	
	2.98			279.07	
	1.41			280.64	
		0.68		281.37	TBM
4.80		1.08		281.37	
1.08				277.65	
3.72				3.72	

This is a purely academic exercise, and in practice under such circumstances the whole of the work would be re-levelled.


b/2
℄
b/2
F
E
D
1 in m
h
1 in m
1 in l
1 in k
A
B
C
w1
w2

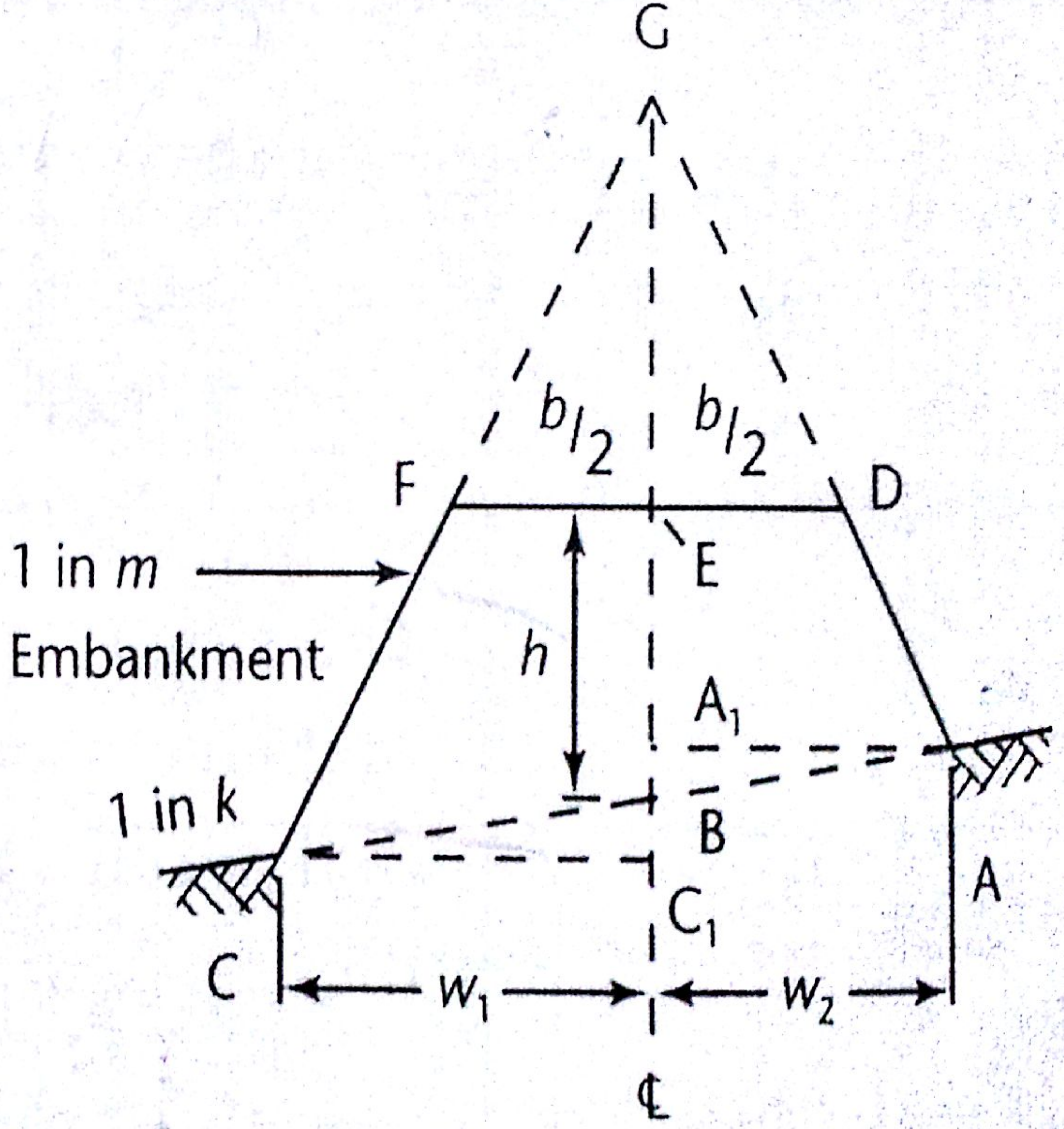


(a)



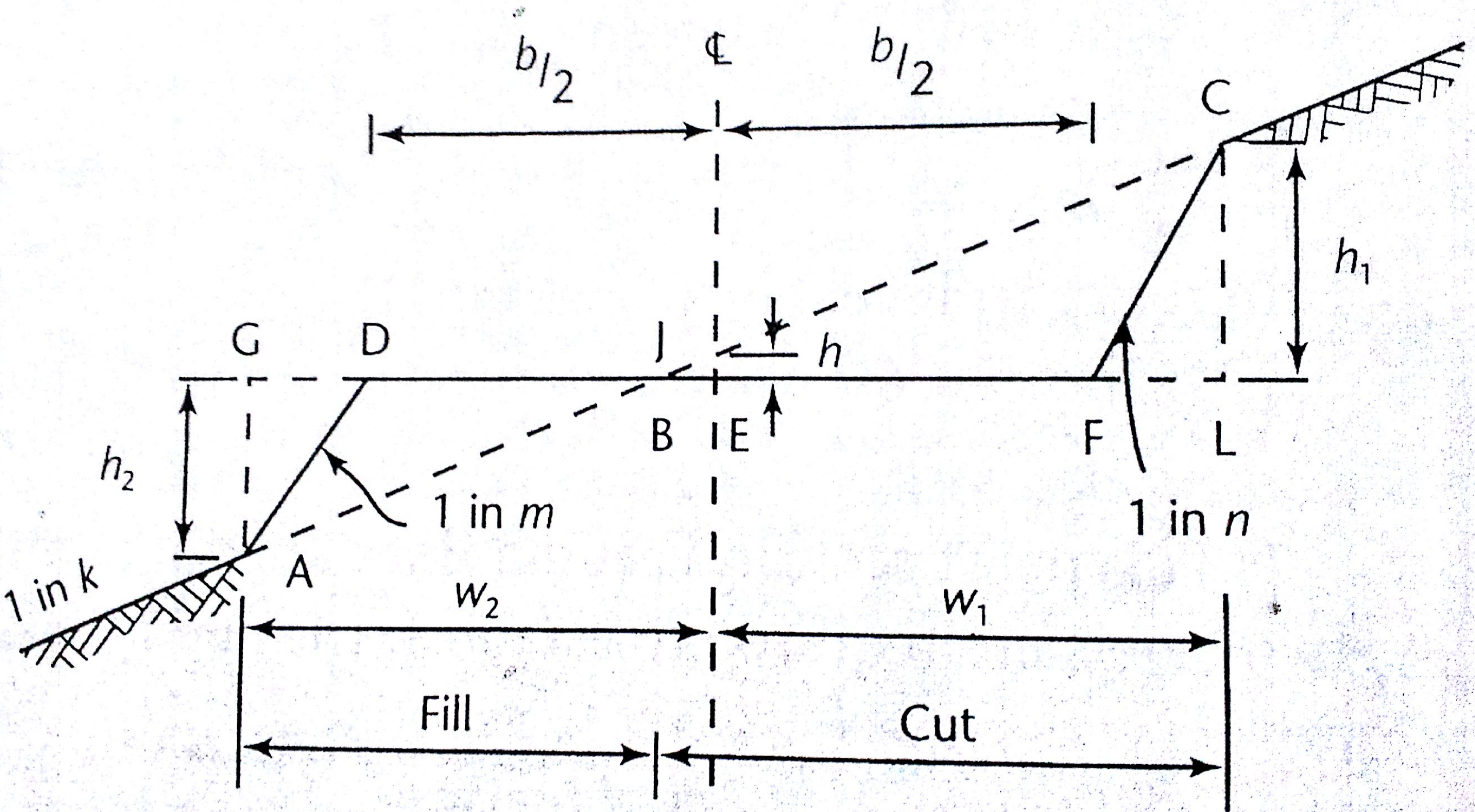
℄
w_2
w_1
C_1
C
1 in k
A
B
A_1
h
1 in m
Cutting
D
E
F
$b/2$
$b/2$
G

(a)



G
$b/2$
$b/2$
F
D
E
1 in m
Embankment
h
A_1
1 in k
B
A
C_1
C
w_1
w_2
℄

(b)


b/2
℄
b/2
C
h1
G
D
J
h
B
E
F
L
h2
1 in m
1 in n
1 in k
A
w2
w1
Fill
Cut

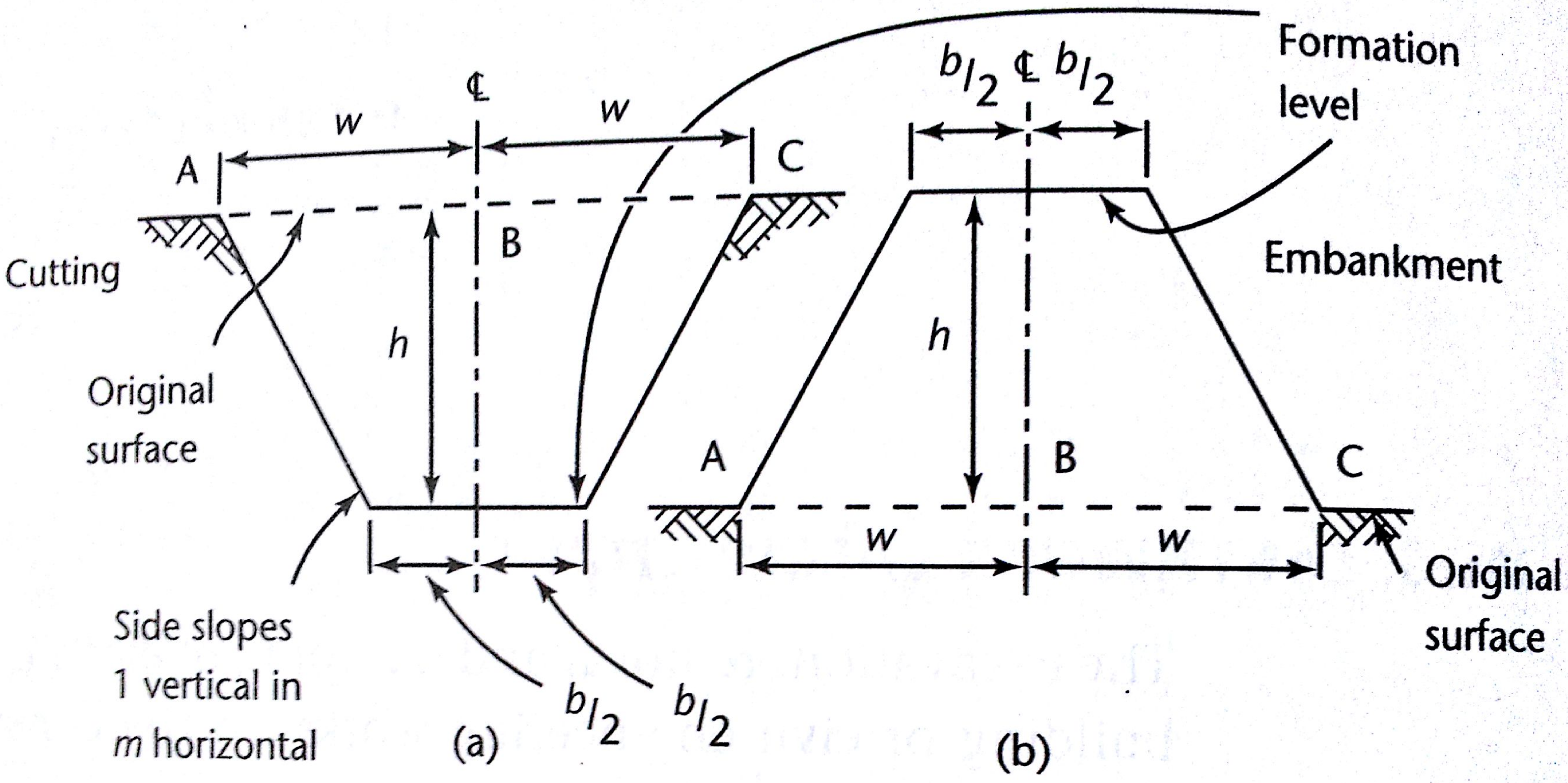
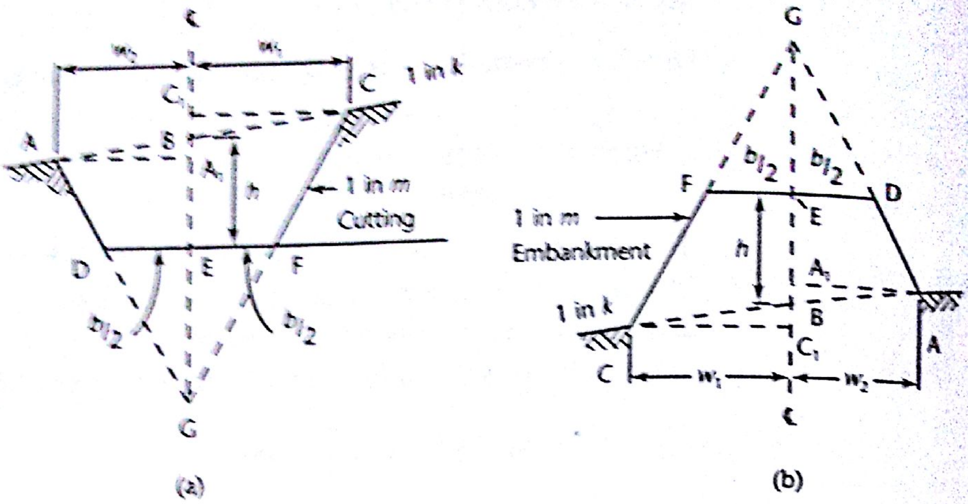

Formation
level
b/2 ℄ b/2
℄
w
w
A
C
B
Cutting
h
Original
surface
Embankment
h
A
B
C
w
w
Original
surface
Side slopes
1 vertical in
m horizontal
b/2
b/2
(a)
(b)

Fig. 9.12



$$A_1B = \frac{w_2}{k}$$

Also, if the side slopes intersect at G, then GE will be the vertical difference in level over a horizontal distance of $b/2$.

$$\text{Hence GE} = \frac{b}{2m}$$

Because triangles C_1CG and EFG are similar,

$$\frac{CC_1}{EF} = \frac{GC_1}{GE}$$

$$\frac{w_1}{b/2} = \frac{b/2m + h + w_1/k}{b/2m}$$

$$\text{Therefore } w_1 = \left(\frac{b}{2} + mh\right)\left(\frac{k}{k-m}\right) \qquad (9.9)$$

$$\text{Also} \quad \frac{AA_1}{DE} = \frac{GA_1}{GE}$$

$$\frac{w_2}{b/2} = \frac{b/2m + h - w_2/k}{b/2m}$$

$$\text{Hence} \quad w_2 = \left(\frac{b}{2} + mh\right)\left(\frac{k}{k+m}\right) \qquad (9.10)$$

The area of the cutting or the embankment is the area ACFDA,

= area BCG + area ABG − area DFG

$$= \tfrac{1}{2}w_1\left(\frac{b}{2m} + h\right) + \tfrac{1}{2}w_2\left(\frac{b}{2m} + h\right) - \tfrac{1}{2}b\,\frac{b}{2m}$$

$$= \frac{1}{2m}\left[\left(\frac{b}{2} + mh\right)(w_1 + w_2) - \frac{b^2}{2}\right] \qquad (9.11)$$

Difference in level between C and F

$$= h + \frac{w_1}{k} \qquad (9.12)$$

Difference in level between A and D

$$= h - \frac{w_2}{k} \qquad (9.13)$$

This type of section is sometimes known as a *two-level section*, because two levels are required to establish the cross-fall of 1 in k.

Example 9.6

Calculate the side widths and cross-sectional area of an embankment to a road with formation width of 12.50 metres, and side slopes 1 vertical to 2 horizontal, when the centre height is 3.10 m and the existing ground has a cross-fall of 1 in 12 at right angles to the centre line of the embankment.

Referring to Fig. 9.12(b):

$$w_1 = \left(\frac{b}{2} + mh\right)\left(\frac{k}{k-m}\right)$$

where $b = 12.50$, $k = 12$, $m = 2$ and $h = 3.10$ m.

$$\text{Hence } w_1 = \left(\frac{12.50}{2} + 2 \times 3.10\right)\left(\frac{12}{10}\right)$$

$$= 14.94 \text{ m}$$

$$w_2 = \left(\frac{b}{2} + mh\right)\left(\frac{k}{k+m}\right)$$

$$= \left(\frac{12.50}{2} + 2 \times 3.10\right)\left(\frac{12}{14}\right)$$

$$= 10.67 \text{ m}$$

From equation (9.11):

$$\text{area} = \frac{1}{2m}\left[\left(\frac{b}{2} \times mh\right)(w_1 + w_2) - \frac{b^2}{2}\right]$$

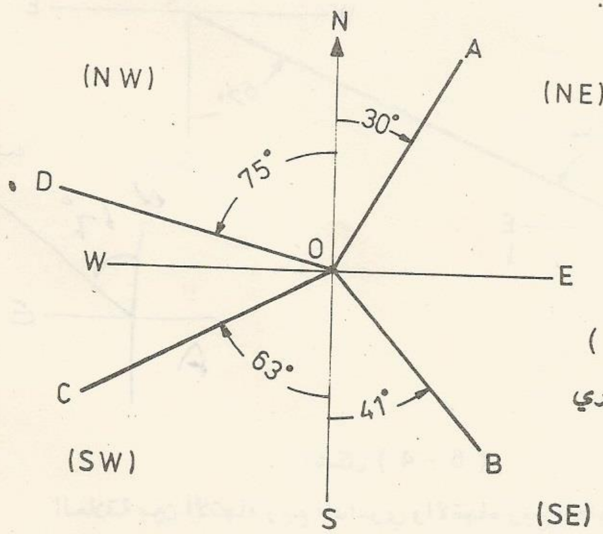
$$= \frac{1}{4}\left\{12.45 \times (14.94 + 10.67) - \frac{12.50^2}{2}\right\}$$

$$= \mathbf{60.18\ m^2}$$

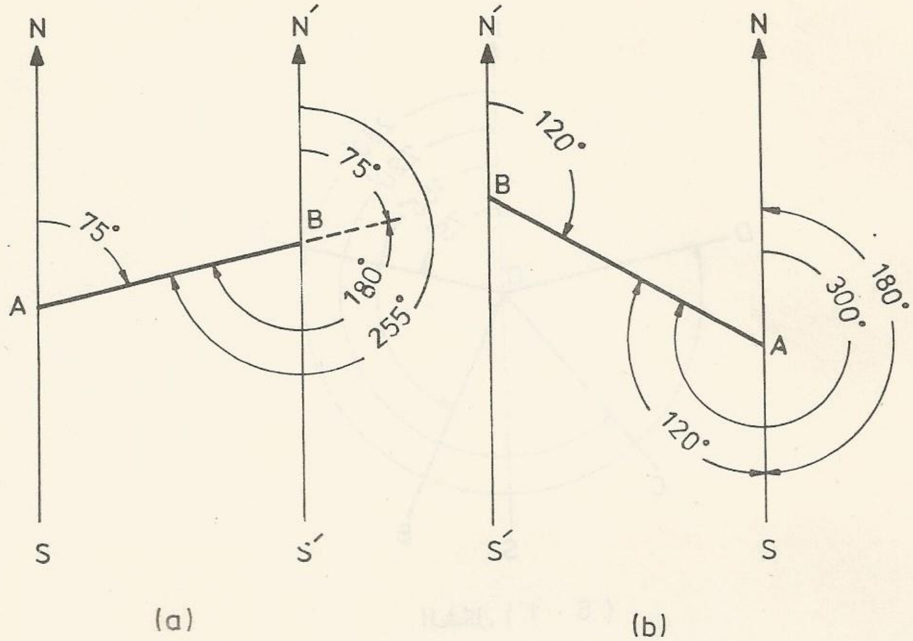
Sections part in cut and part in fill (Fig. 9.13)

Inspection of Fig. 9.13 shows that the 'cut' position is similar to the 'cut' position right of the centre line of Fig. 9.12(a), and hence

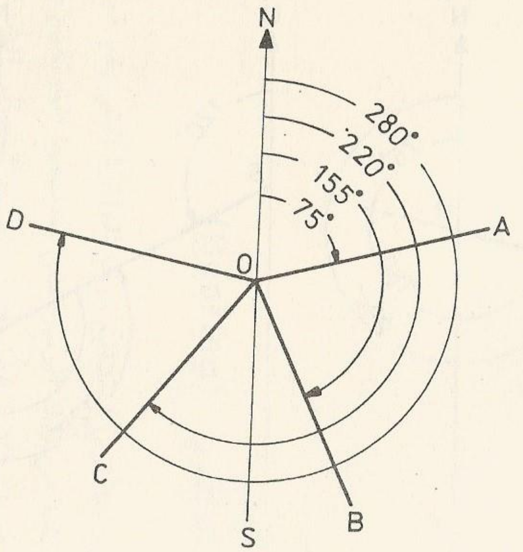
المسند اليه الاتجاه .



الشكل (3 - 6)
الاتجاه ربع الدائري

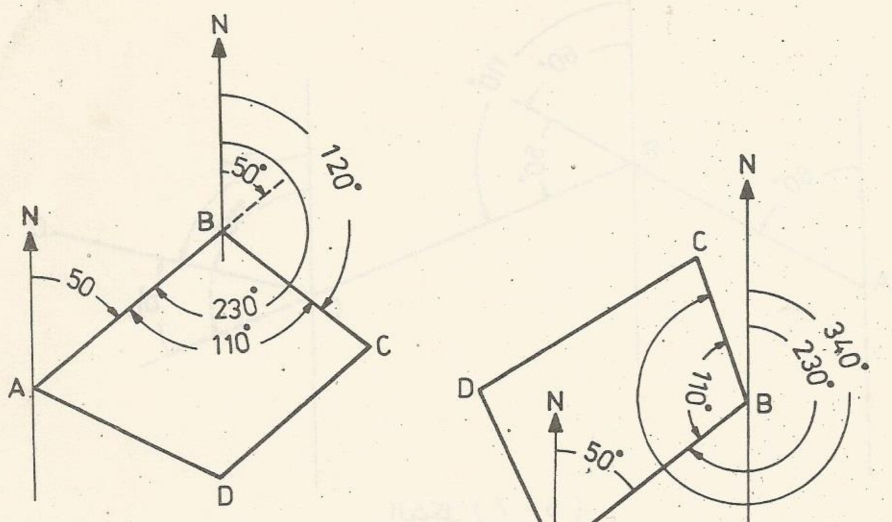


الشكل (2 - 6)
العلاقة بين الاتجاه الدائري والاتجاه الدائري الخلفي

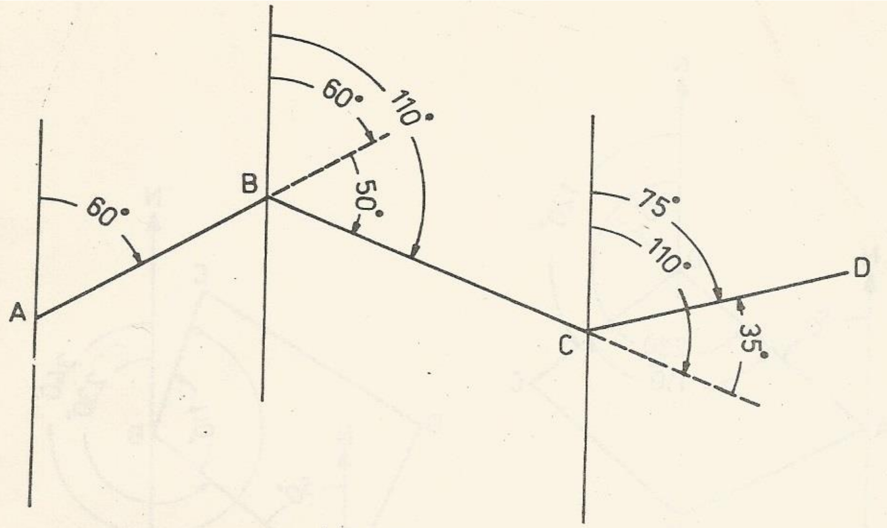


الشكل (1 - 6)

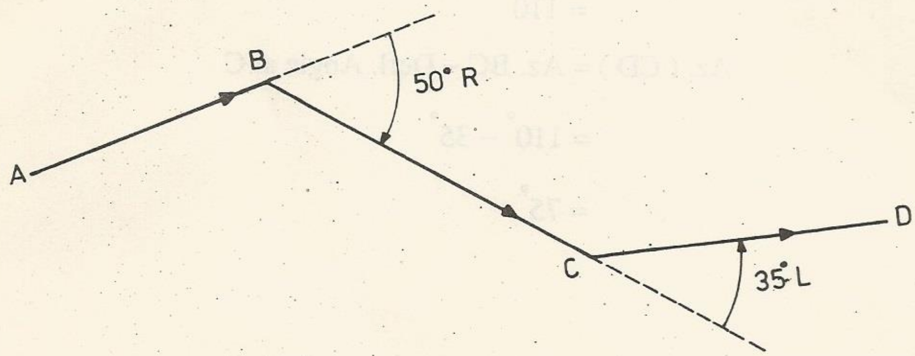
الاتجاهات الدائرية



الشكل (8 - 6)

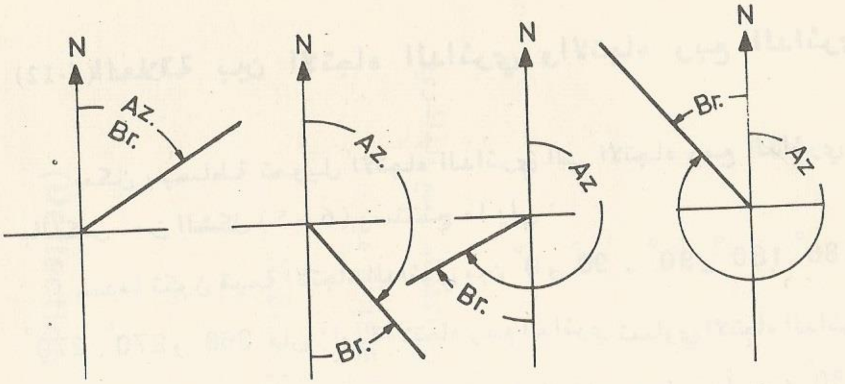


الشكل (7 - 6)



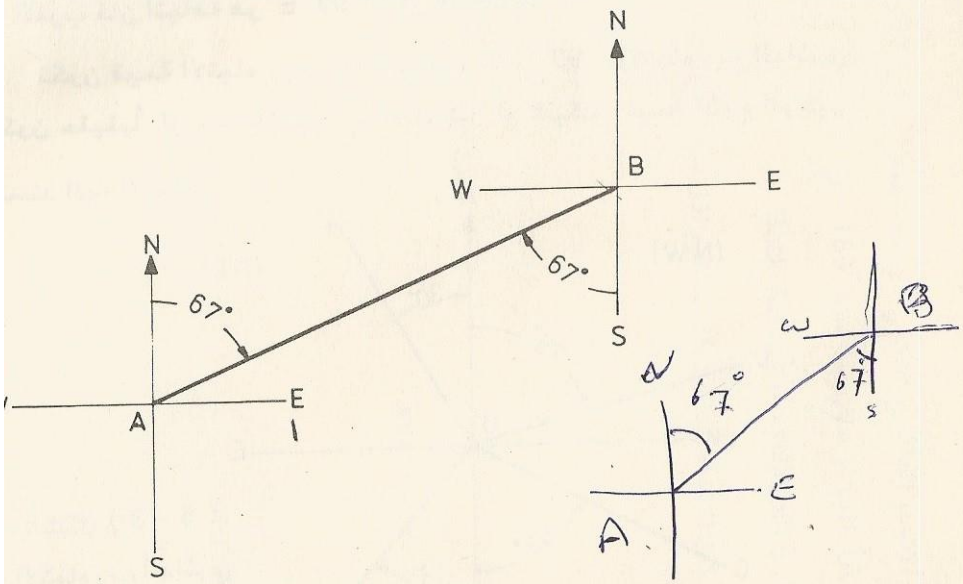
الشكل (6 - 6)

زوايا الانحراف



الشكل (5 - 6)

العلاقة بين الاتجاه الدائري والاتجاه ربع الدائري



الشكل (4 - 6)