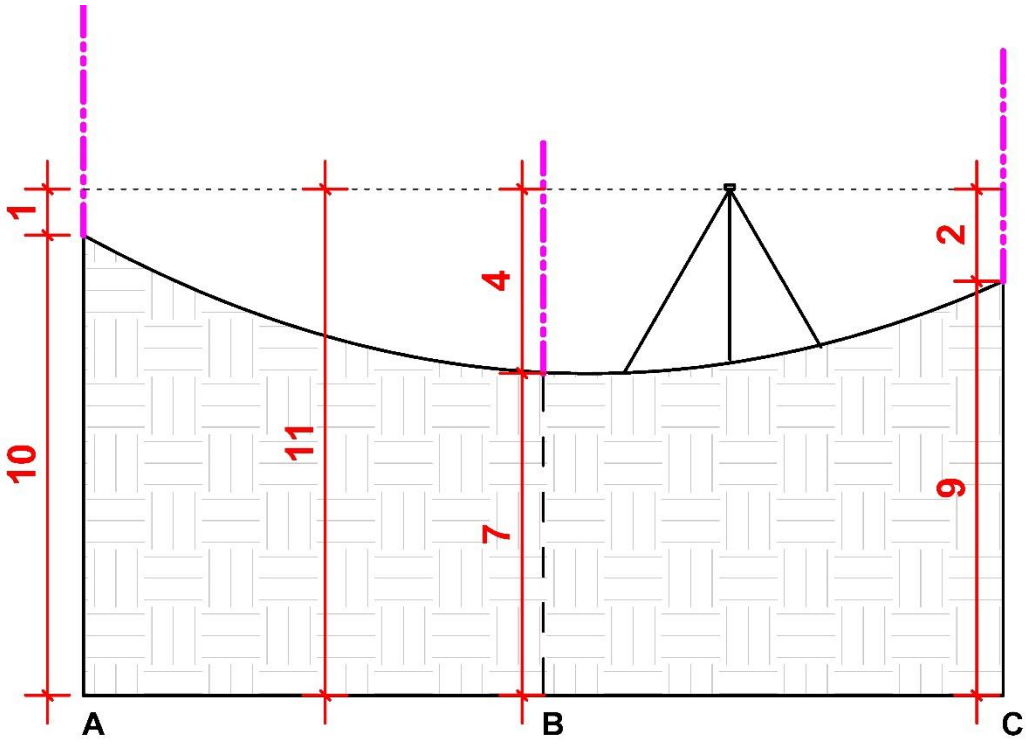
The following list of readings were taken in sequence during a leveling survey:

1.00, 4.00, 2.00

If the elevation of the first point is 10 m, compute the real level of each point using:

1- Height of instrument method. 2- rise and fall method.

1- Height of instrument method:



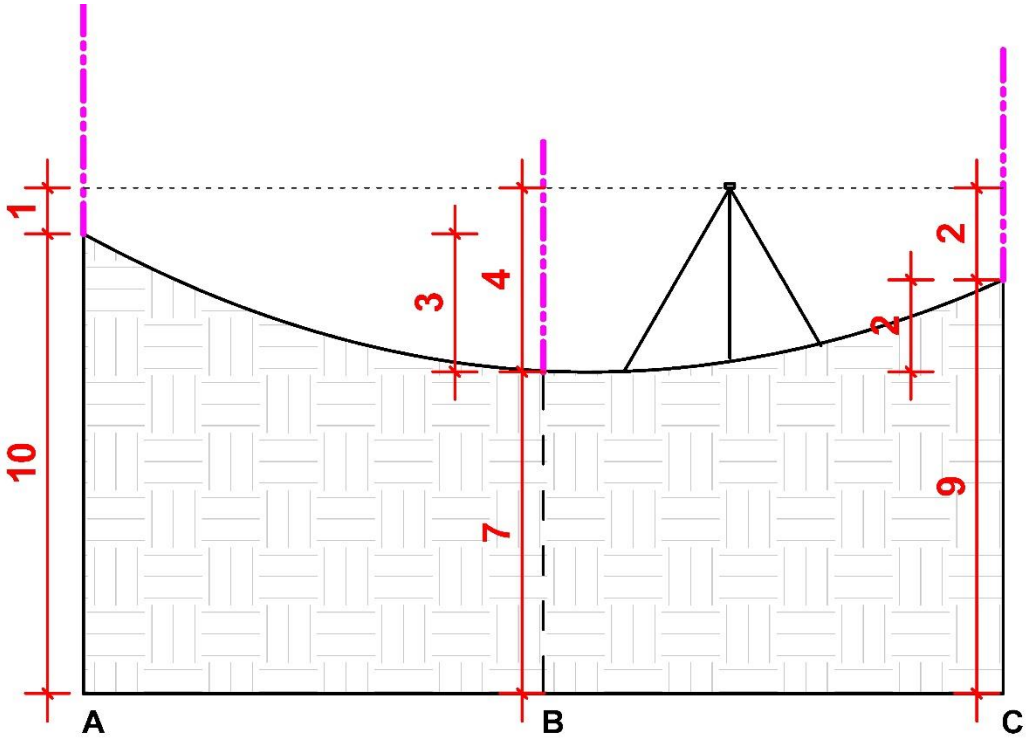
Point	BS	IS	FS	HI	RL	Remarks
A	1			11	10	BM
B		4			7	
C			2		9	LAST

$$\sum BS - \sum FS = -1$$

$$RL_{LAST} - RL_{FIRST} = -1$$

➔ ✓

2- Rise and fall method:



Point	BS	IS	FS	R & F	RL	Remarks
A	1				10	BM
B		4		– 3	7	
C			2	+ 2	9	LAST

$$\sum BS - \sum FS = -1$$

$$RL_{LAST} - RL_{FIRST} = -1$$

➔ ✓

■■■■

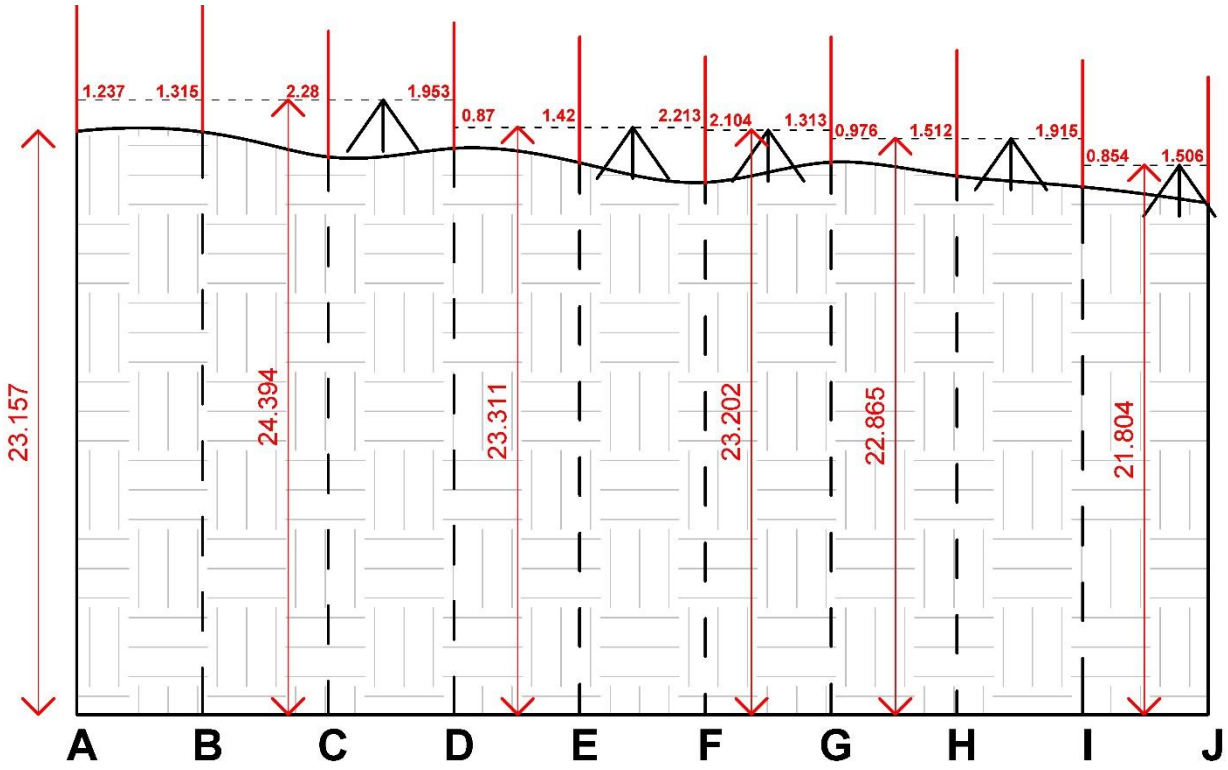
The following list of readings were taken in sequence during a leveling survey:

1.237, 1.345, 2.28, 1.953, 0.87, 1.42, 2.213, 2.104, 1.313, 0.976, 1.512, 1.915, 0.854, 1.506

The level was moved after the forth, seventh, ninth, twelvth, and last readings. If the elevation of the first point is 23.157m, compute the real level of each point using:

1- Height of instrument method. 2- rise and fall method.

- First reading is always BS of the first point.
- Last reading before the level relocation is always FS. And the reading after that is BS of the same point.
- Readings between BS and FS is always IS.
- HI = RL $_{\text{first point}}$ + BS $_{\text{first point}}$
- RL $_{\text{any point}}$ = HI – (FS or IS) $_{\text{any point}}$
- R&F $_{\text{any point}}$ =
    - BS $_{\text{previous point}}$ – IS
    - BS $_{\text{previous point}}$ – FS
    - IS $_{\text{previous point}}$ – FS
    - IS $_{\text{previous point}}$ – IS
- RL $_{\text{any point}}$ = RL $_{\text{previous point}}$ + R&F $_{\text{any point}}$



- Height of instrument method

Point	BS	IS	FS	HI	RL	Remarks
A	1.237			24.394	23.157	BM
B		1.315			23.079	
C		2.28			22.114	
D	0.87		1.953	23.311	22.441	TP
E		1.42			21.891	
F	2.104		2.213	23.202	21.098	TP
G	0.976		1.313	22.865	21.889	TP
H		1.512			21.353	
I	0.854		1.915	21.804	20.95	TP
J			1.506		20.298	LAST
TOTAL	6.041		8.9			

$\sum BS - \sum FS = -2.859$ $RL_{LAST} - RL_{FIRST} = -2.859$ ➔ ✓

- Rise and fall method

Point	BS	IS	FS	R&F	RL	Remarks
A	1.237				23.157	BM
B		1.315		– 0.078	23.079	
C		2.28		– 0.965	22.114	
D	0.87		1.953	+ 0.327	22.441	TP
E		1.42		– 0.55	21.891	
F	2.104		2.213	– 0.793	21.098	TP
G	0.976		1.313	+ 0.791	21.889	TP
H		1.512		– 0.536	21.353	
I	0.854		1.915	– 0.403	20.95	TP
J			1.506	– 0.652	20.298	LAST
TOTAL	6.041		8.9	– 2.859		

$\sum BS - \sum FS = -2.859$ $RL_{LAST} - RL_{FIRST} = -2.859$ $\sum R\&F = -2.859$ ➔ ✓

■■■■

The following list of readings were taken in sequence during a leveling survey:

Readings (m): 2.20 1.80 2.40 2.00 2.20 1.80 2.20 2.40 2.70 1.60

The level was moved after the fourth, seventh and last readings.

Fill in the leveling table below and find the RLs of all points.

(RL of the first observed point = 600.00m). Use R & F method and check using HI method. Apply arithmetic check in both cases.

- Rise and fall method

Point	BS	IS	FS	R&F	RL	Remarks
1	2.2				600.0	BM
2		1.8		+ 0.4	600.4	
3		2.4		– 0.6	599.8	
4	2.2		2.0	+ 0.4	600.2	TP
5		1.8		+ 0.4	600.6	
6	2.4		2.2	– 0.4	600.2	
7		2.7		– 0.3	599.9	TP
8			1.6	+ 1.1	601.0	Last Point
TOTAL	6.8		5.8	1.0		

$\sum BS - \sum FS = +1$ $RL_{LAST} - RL_{FIRST} = +1$ $\sum R\&F = +1$ ➔ ✓

- Height of instrument method

Point	BS	IS	FS	HI	RL	Remarks
1	2.2			602.2	600.0	BM
2		1.8			600.6	
3		2.4			599.8	
4	2.2		2.0	602.4	600.2	TP
5		1.8			600.6	
6	2.4		2.2	602.6	600.2	
7		2.7			599.9	TP
8			1.6		601.0	Last Point
TOTAL	6.8		5.8			

$\sum BS - \sum FS = +1$ $RL_{LAST} - RL_{FIRST} = +1$ ➔ ✓

■■■■

Staff points were chosen to be 50m apart along the ground surface of the center line of a proposed roadway. The following list of readings were taken in sequence:

Readings (m): 4.0, 1.5, 3.0, 1.0, 0.5, 2.0, 3.0, 2.5, 3.5, 1.5

The level was moved after the fourth and last readings.

Use scale 1:2500 for horizontal distances and 1:100 for reduced levels to plot the longitudinal section of the existing ground surface along the proposed road center line.

The highway engineer proposed the following data for the formation level to be constructed:

Road level at the starting point = 621.50m, sloping downwards to the other end with 0.25% rate.

Plot the proposed centerline of the road on the same plot of the existing ground surface plot.

Point	Distance	BS	IS	FS	HI	RL	Remarks
1	0.0	4.0			624.0	620.0	BM
2	50		1.5			622.5	
3	100		3.0			621.0	
4	150	0.5		1.0	623.5	623.0	TP
5	200		2.0			621.5	
6	250		3.0			620.5	
7	300		2.5			621.0	
8	350		3.5			620.0	
9	400			1.5		622.0	LAST
TOTAL		4.5		2.5			

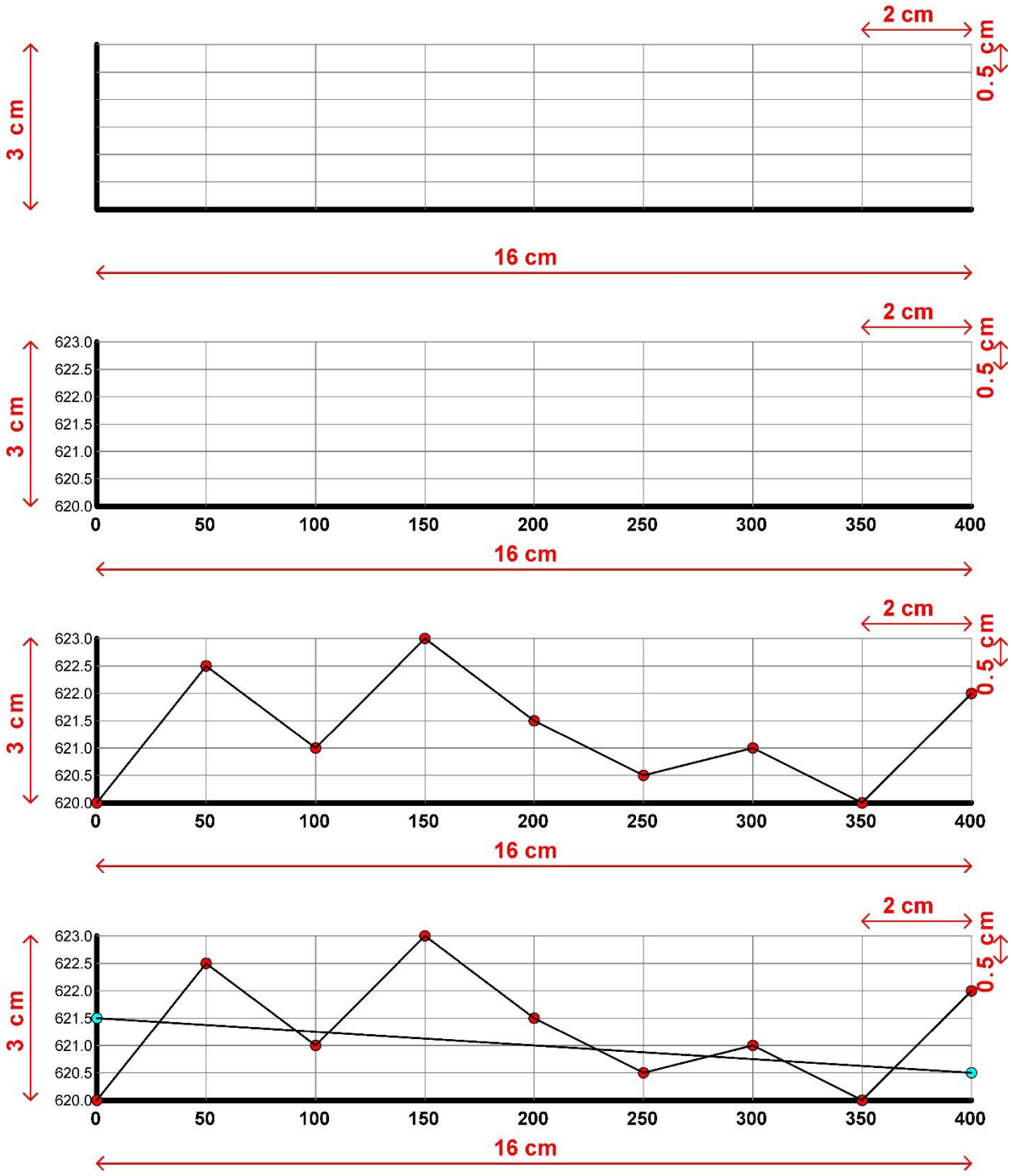
$\sum BS - \sum FS = +2$ $RL_{LAST} - RL_{FIRST} = +2$ ➔ ✓

To sketch the profile, first find the map distances corresponding to ground data.

- Maximum ground horizontal distance = 400 m (1:2500)
- Maximum ground reduced level difference = 3.0 m (1:100)

➔ Required map distance for horizontal spacing = 400/2500 = 0.16 m = 16 cm

➔ Required map distance for reduced levels = 3/100 = 0.03 m = 3 cm


2 cm
0.5 cm
3 cm
16 cm
623.0
622.5
622.0
621.5
621.0
620.5
620.0
0
50
100
150
200
250
300
350
400

■■■■

Exam Question: *The following list of readings were taken in sequence during leveling along a proposed road center line. The level was moved after the 8th reading and the last reading.*

1.37, 1.53, 1.67, 1.73, 1.9, 2.05, 2.22, 1.6, 1.8, 2.27, 2.37, 2.57, 2.77, 3.0.

1- Tabulate the data in a levelling table and compute the levels of all observed points if the level of the first point is 1.5m.

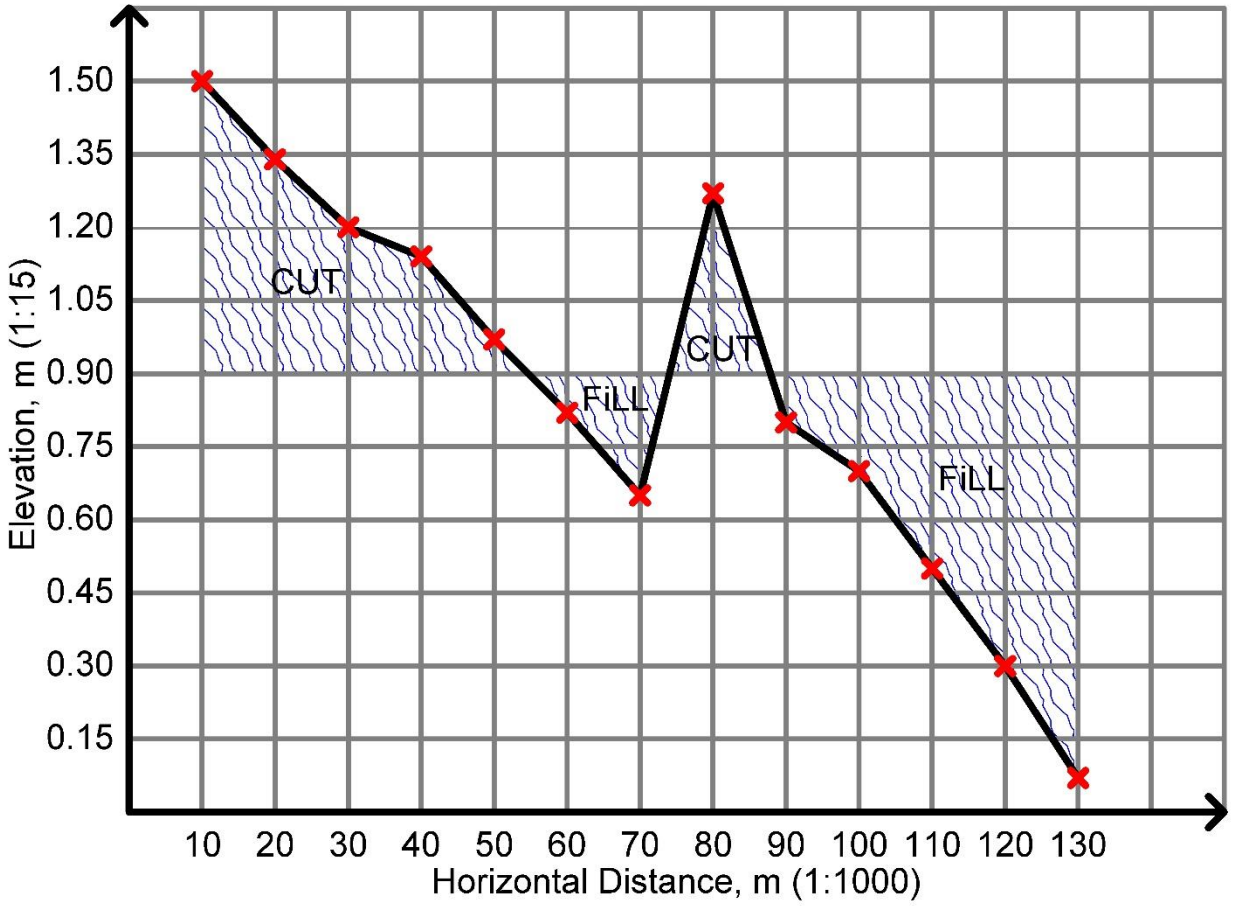
2- Check if your calculations are right.

3- If the distance between consecutive points is 10 m, plot the longitudinal section of the road center line with 1:1000 and 1:15 scales for horizontal distances and elevations, respectively.

4- Indicate on the sketch the cut and fill areas if the road is to be levelled to 0.90 m.

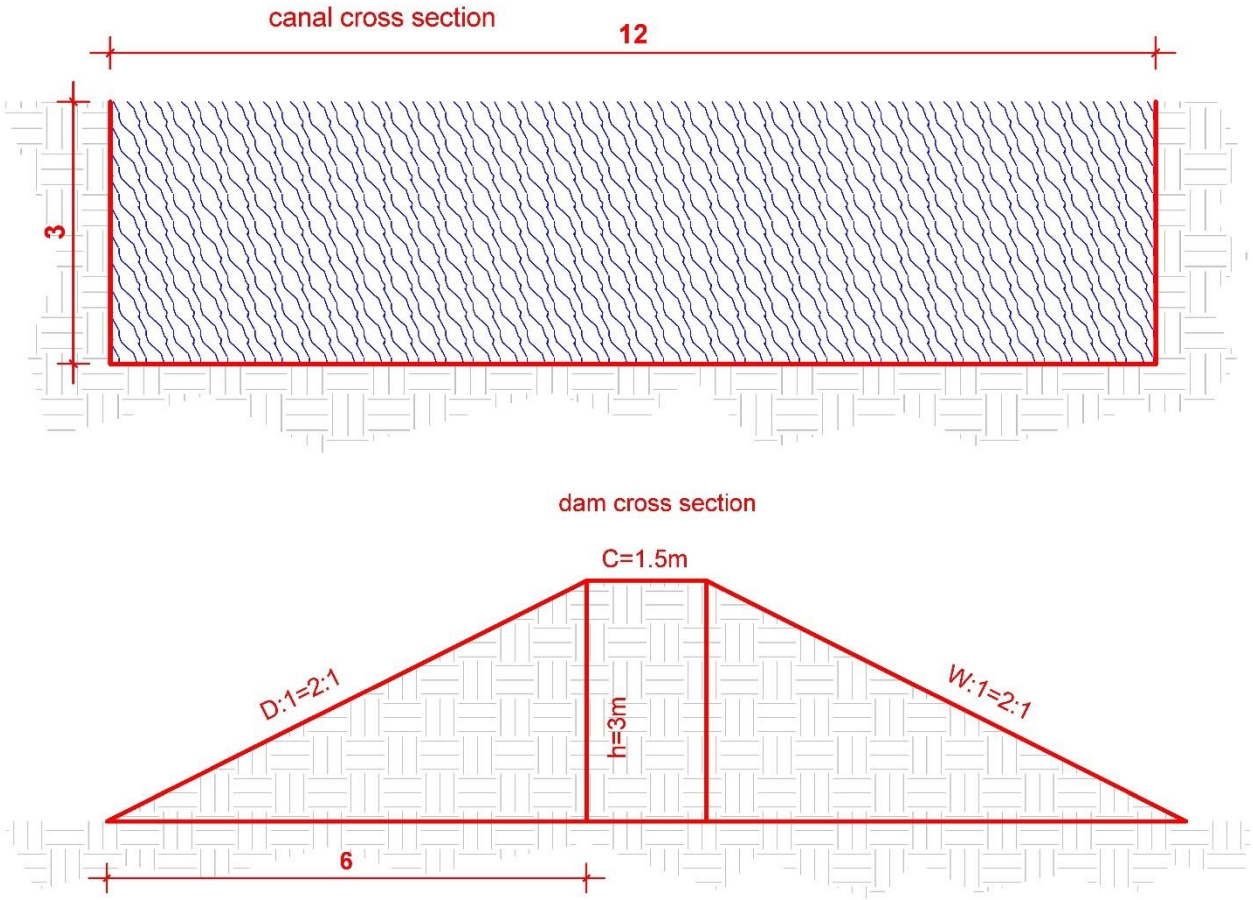
Point No.	Distance	BS	IS	FS	HI	Elevation	Remarks
1	10	1.37			2.87	1.5	BM
2	20		1.53		2.87	1.34	
3	30		1.67		2.87	1.2	
4	40		1.73		2.87	1.14	
5	50		1.9		2.87	0.97	
6	60		2.05		2.87	0.82	
7	70		2.22		2.87	0.65	
8	80	1.8		1.6	3.07	1.27	TP
9	90		2.27		3.07	0.8	
10	100		2.37		3.07	0.7	
11	110		2.57		3.07	0.5	
12	120		2.77		3.07	0.3	
13	130			3	3.07	0.07	Last Point
TOTAL		3.17		4.6			

$\sum BS - \sum FS = -1.43$ $RL_{LAST} - RL_{FIRST} = -1.43$ ➔ ✓


1.50
1.35
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
Elevation, m (1:15)
CUT
FiLL
CUT
FiLL
10 20 30 40 50 60 70 80 90 100 110 120 130
Horizontal Distance, m (1:1000)

■■■■

Exam Question: *An earth dam is to be used to block the water from running in a canal with width of 12m and depth of 3m. Estimate the volume of the earth dam if its crown width is 1.5m. the dam wet and dry slope is 2:1.*



Area of dam cross section, $A = (Ch) + (Dh^2 \div 2) + (Wh^2 \div 2)$

$A = (1.5\times3) + (2\times3^2 \div 2) + (2\times3^2 \div 2) = 22.5\ m^2$

$A = 4.5 + 9 + 9 = 22.5m^2$

Volume of dam = Area of dam cross section x Canal width

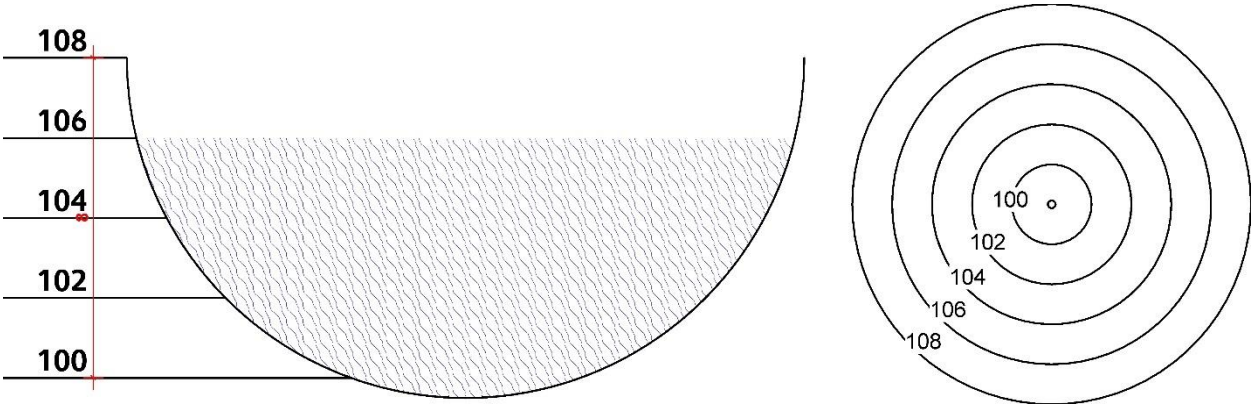
$V = 22.5 \times 12 = 270\ m^3$

■■■■

For a certain reservoir area within contour lines were measured and recorded using a digital planimeter. Draw a sketch to show the reservoir section and compute the volume of water in the reservoir:

1- If the reservoir is filled to level 106m
2- If water level in the reservoir drops to level 103.6m.

Contour above datum (m):	*100*	*102*	*104*	*106*	*108*
Area (m^2):	*20*	*106*	*480*	*1200*	*1840*



1) The reservoir is filled to level 106m

Volume between two contour line = contour interval × average area within contour line

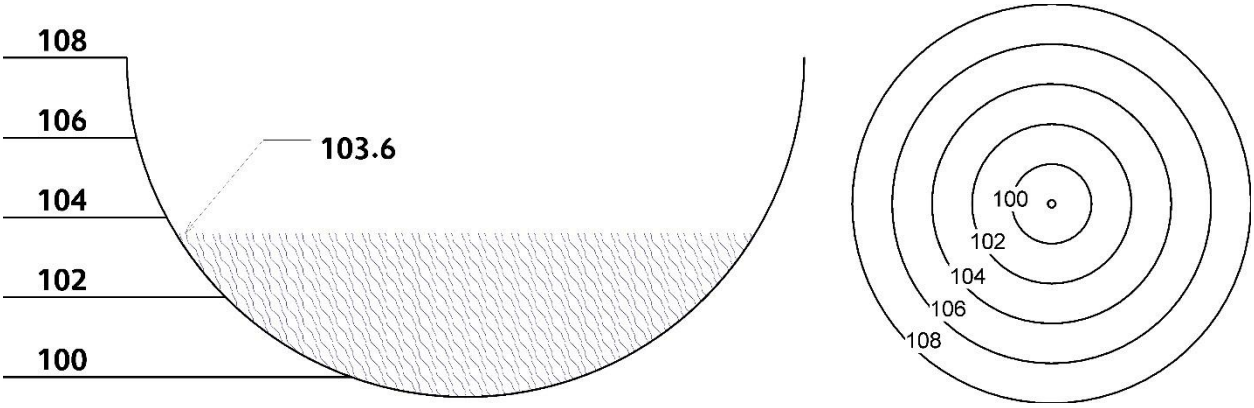
Volume between 106 and 104	= 2 × (1200 + 480)/2	= 1680 m^3
Volume between 104 and 102	= 2 × (480 + 106)/2	= 586 m^3
Volume between 102 and 100	= 2 × (106 + 20)/2	= 126 m^3
Volume from 100 to bottom of lake	= 2 × (20 + 0)/2	= 20 m^3
Total volume	=1680 + 586 + 126 + 20	= 2412 m^3

Alternative solution:

$$Volume = \frac{interval}{2} \times \left[A_n + A_1 + 2\sum(A_2 + A_3 + \cdots + A_{n-1})\right]$$

$$Volume = \frac{2}{2} \times \left[1200 + 0 + 2\sum(106 + 480 + 20)\right] = 2412\ m^2$$

2) Water level in the reservoir drops to level 103.6m



First find the area at level 103.6 m.

Since the ground slope between any two contour lines is assumed to be constant, we can find the area at level 103.6 m by linear interpolation.

At level 104 ➔ area = 480 m^2

At level 102 ➔ area = 106 m^2

At level 103.6 ➔ area = x m^2

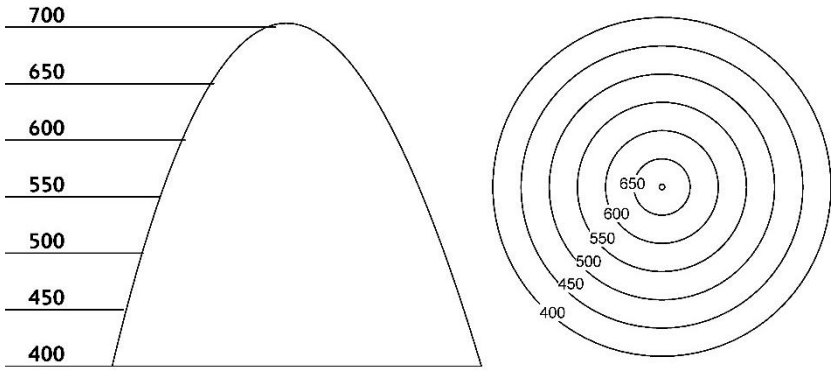
$$\frac{104-102}{103.6-102}=\frac{480-106}{x-106} \qquad \rightarrow x = 405.2\ m^2$$

Volume between 103.6 and 102	= 1.6 × (405.2 + 106)/2	= 409 m^3
Volume between 102 and 100	= 2 × (106 + 20)/2	= 126 m^3
Volume from 100 to bottom of lake	= 2 × (20 + 0)/2	= 20 m^3
Total volume	= 409 + 126 + 20	= 555 m^3

■■■■

Exam Question: *A small hilly area contoured from 400m to 700m, contour interval is 50m. Areas within each contour line are measured using a planimeter and given in the table below. Compute the volume of cut to level the area to 400m.*

Contour, m	*400*	*450*	*500*	*550*	*600*	*650*	*700*
Enclosed area, m^2	*1500*	*1250*	*1100*	*650*	*250*	*50*	*Peak*



Contour interval = 50m

400 – 450 ➔ v = 50 × (1500+1250)/2 = 68750 m^3

450 – 500 ➔ v = 50 × (1250+1100)/2 = 58750 m^3

500 – 550 ➔ v = 50 × (1100+650)/2 = 43750 m^3

550 – 600 ➔ v = 50 × (650+250)/2 = 22500 m^3

600 – 650 ➔ v = 50 × (250+50)/2 = 7500 m^3

650 – 700 ➔ v = 50 × (50+0)/2 = 1250 m^3

Total cut volume = 202500 m^3

Alternative solution:

$$Volume = \frac{interval}{2} \times \left[A_n + A_1 + 2\sum(A_2 + A_3 + \cdots + A_{n-1})\right]$$

$$Volume = \frac{50}{2} \times \left[0 + 1500 + 2\sum(1250 + 1100 + 650 + 250 + 50)\right] = 202500\ m^3$$

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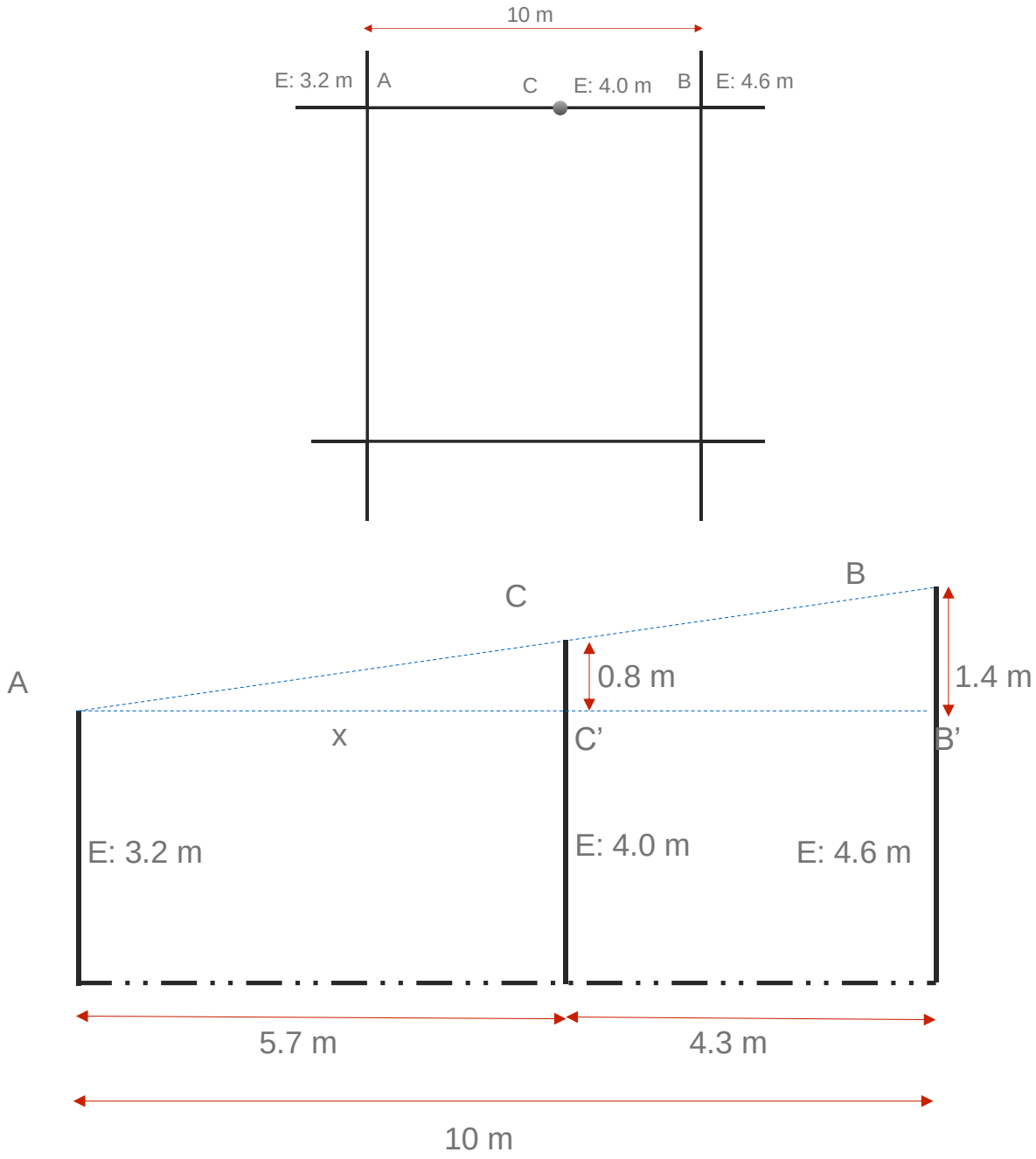
Assume two neighboring grid corners, A and B of levels 3.2m and 4.6m respectively. Horizontal ground distance between A and B is 10m. Locate position of point C of level 4.0m.



1) level B – level A= 4.6 – 3.2 = 1.4m.

2) Level C – level A = 4.0 – 3.2 = 0.8m.

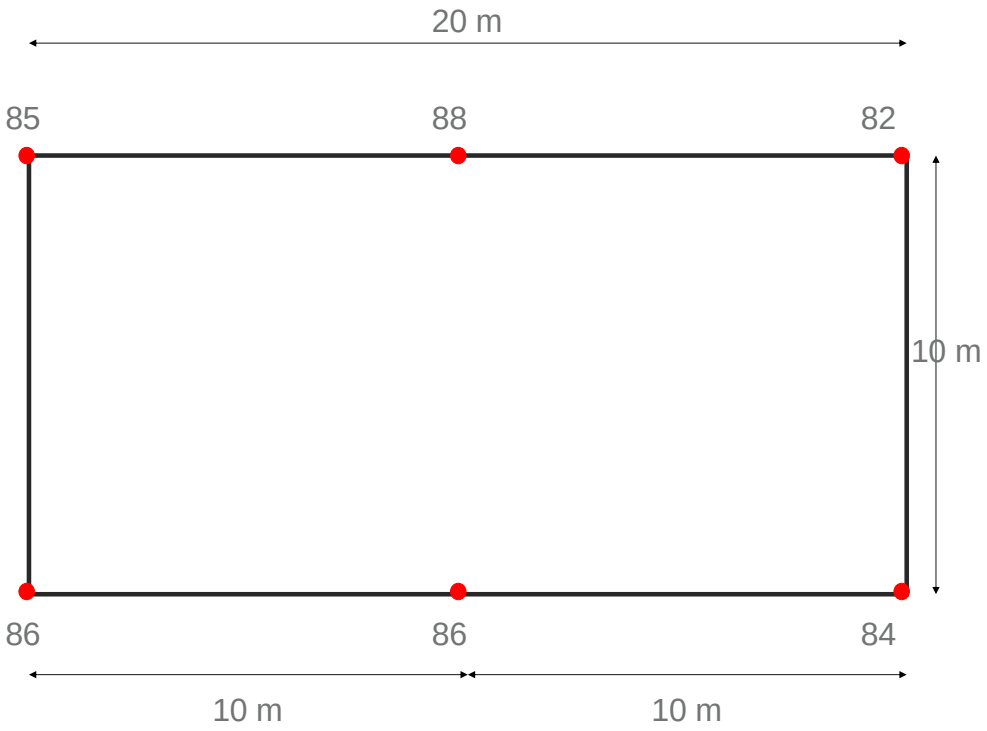
From similar triangles ACC' and ABB': x = 5.7 m

■■■■

Exam Question: *A rectangular piece of land 10m×20m is divided into two squares, each 10m×10m. after performing levelling, the reduced levels of the corner of the grid are shown in the figure below in meters.*

Draw contour lines 83, 85, 87m.

The land is to be levelled to elevation 85m. Compute the volumes of cut and fill.



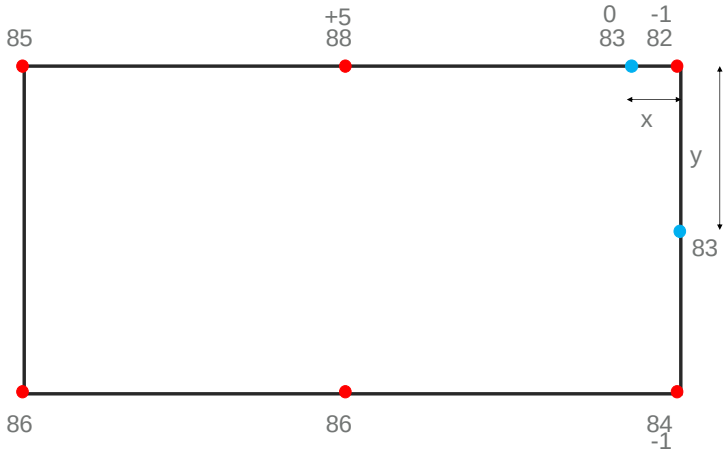
Points of contour line 83

$$\frac{88-82}{10}=\frac{83-82}{x}$$

$$x=1.667m$$

$$\frac{84-82}{10}=\frac{83-82}{y}$$

$$y=5m$$



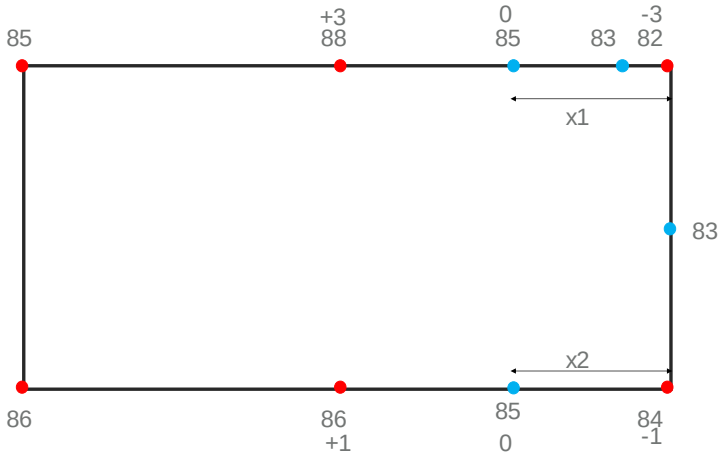
Points of contour line 85

$$\frac{88-82}{10}=\frac{85-82}{x_1}$$

$$x_1 = 5m$$

$$\frac{86-84}{10}=\frac{85-84}{x_2}$$

$$x_2 = 5m$$



Points of contour line 87

$$\frac{88-82}{10}=\frac{88-87}{x_1}$$

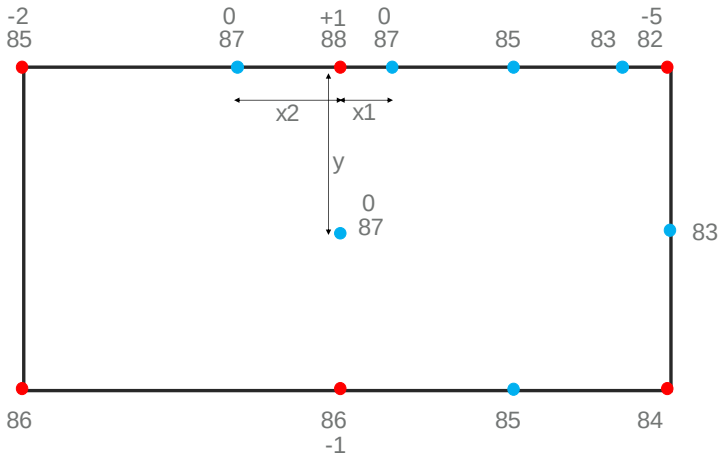
$$x_1 = 1.667m$$

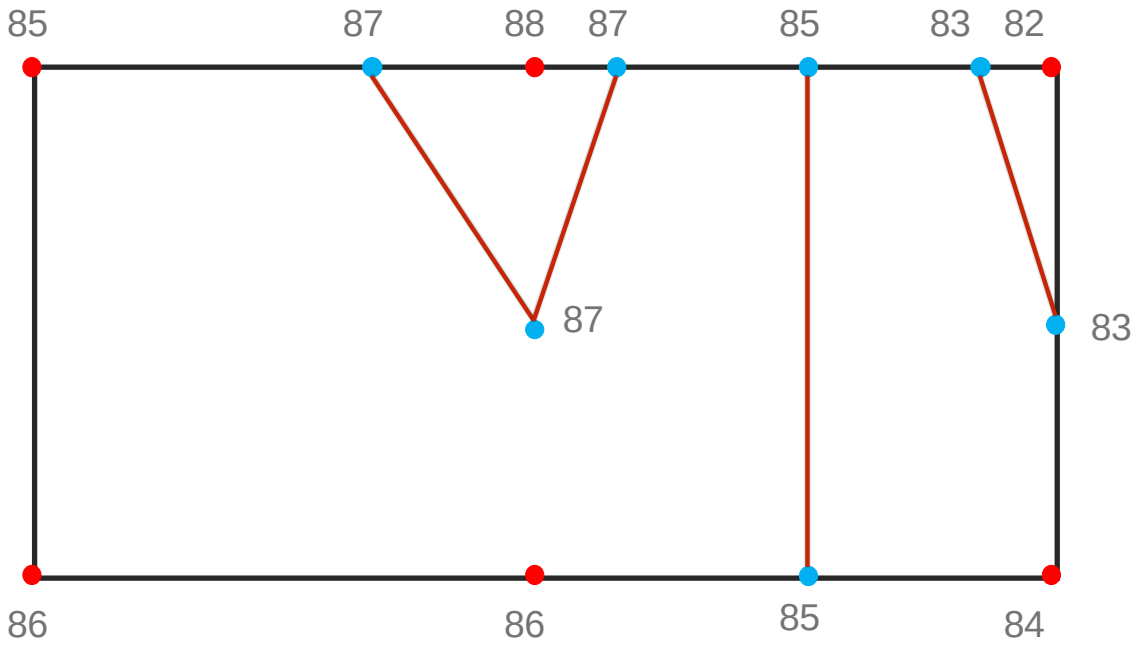
$$\frac{88-85}{10}=\frac{88-87}{x_2}$$

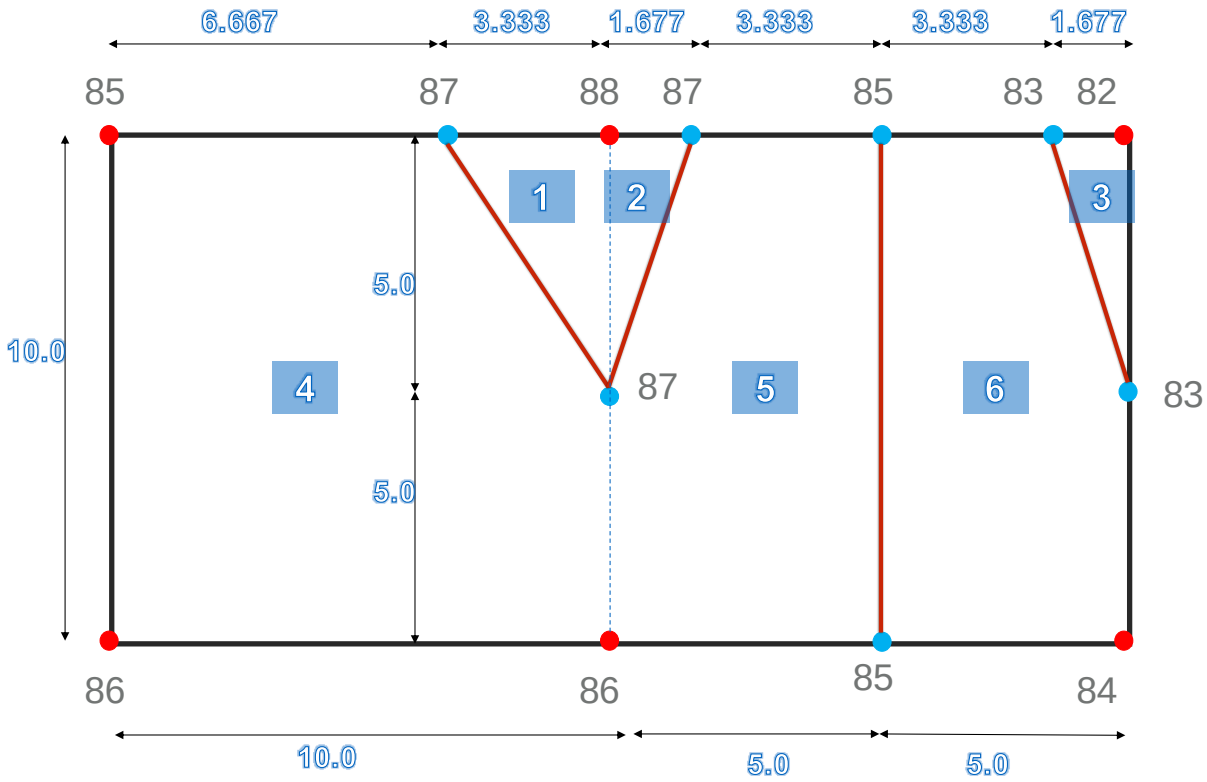
$$x_2 = 3.333m$$

$$\frac{88-86}{10}=\frac{88-87}{y}$$

$$y = 5m$$







levelled to elevation 85 m.

Calculate areas:

A1 = 0.5 × 3.333 × 5 = 8.333 m^2

A2 = 0.5 × 1.667 × 5 = 4.175 m^2

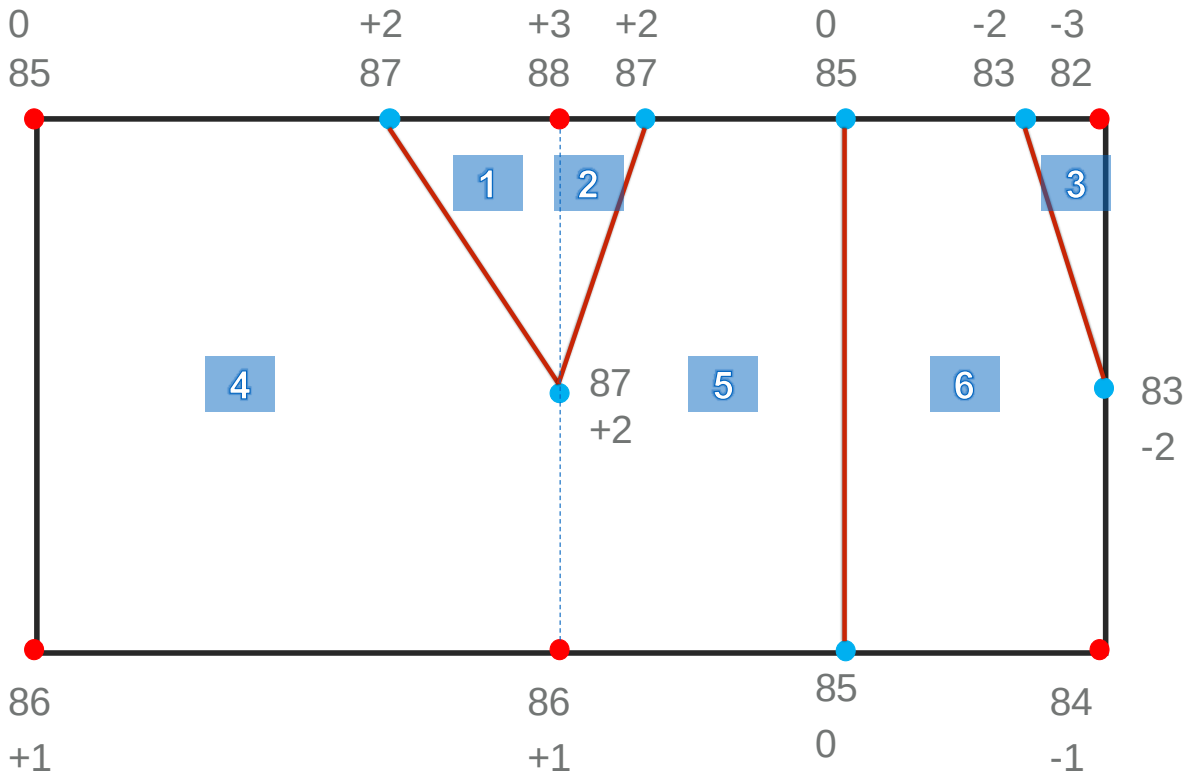
A3 = 0.5 × 1.667 × 5 = 4.175 m^2

A4 = (10 × 10) – (A1) = 100 – 8.333 = 91.667 m^2

A5 = (5 × 10) – (A2) = 50 – 4.175 = 45.825 m^2

A6 = (5 × 10) – (A3) = 50 – 4.175 = 45.825 m^2

Determine difference in level



Determine average height

h1 = (2 + 3 + 2)/3	= + 2.333	m
h2 = (3 + 2 + 2)/3	= + 2.333	m
h3 = (– 2 – 3 – 2)/3	= – 2.333	m
h4 = (0 + 2 + 2 + 1 + 1)/5	= + 1.2	m
h5 = (2 + 0 + 0 + 1 + 2)/5	= + 1.0	m
h6 = (0 – 2 – 2 – 1 + 0)/5	= – 1.0	m

Calculate volume = area × average height

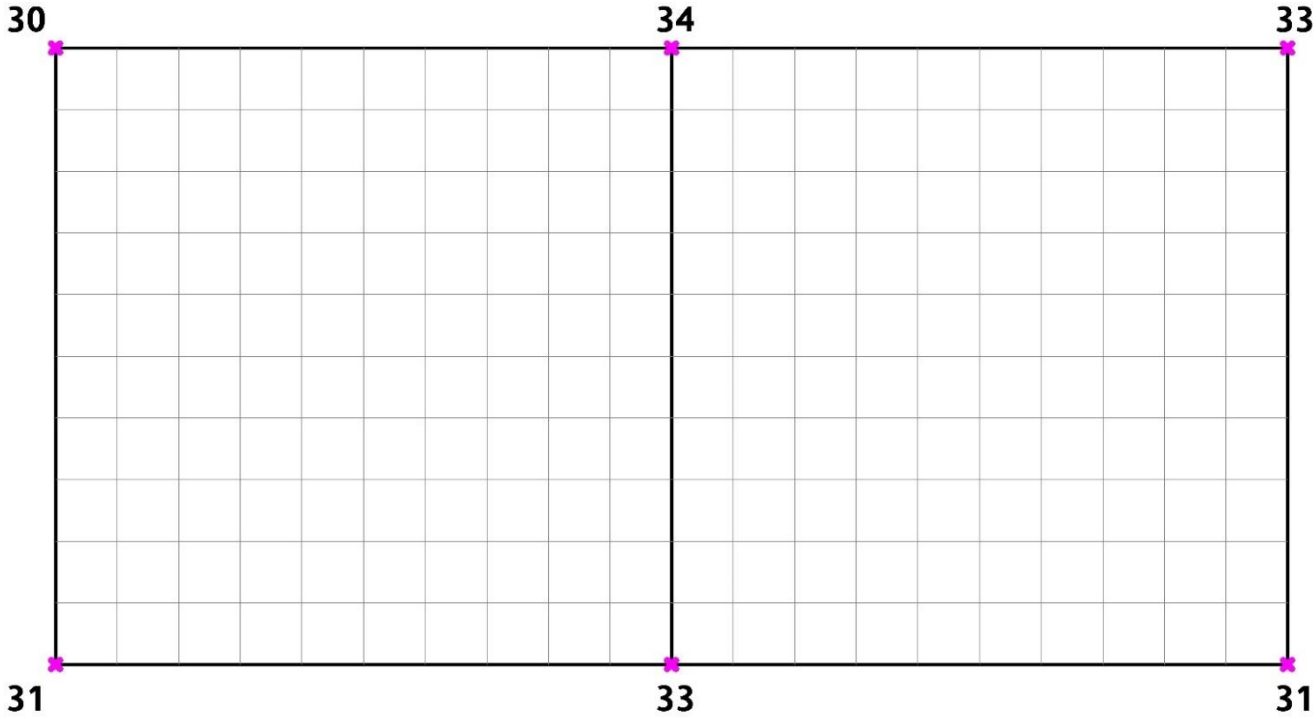
v1 =	8.333 × (+ 2.333)	= +19.444	m^3
v2 =	4.175 × (+ 2.333)	= +9.742	m^3
v3 =	4.175 × (– 2.333)	= –9.742	m^3
v4 =	91.667 × (+ 1.2)	= +110.0	m^3
v5 =	45.825 × (+ 1.0)	= +45.825	m^3
v6 =	45.825 × (– 1.0)	= –45.825	m^3

Calculate total cut and fill volume

Fill volume = v3 + v6	= 55.567	m^3
Cut volume = v1 + v2 + v4 + v5	= 185.011	m^3

■■■■

Exam Question: *The plot represents two square pieces of land 10×10m. After performing levelling, the reduced levels of the corners are shown in the plot in meters. Each square grid of the plot represents 1×1m.*
1) Draw on the same plot contour lines 31, 32, 33m.
2) Estimate the volume of cut and fill if the land is to be levelled to elevation 32m.



Location of contour intersection points:

$$\frac{34-30}{10}=\frac{31-30}{x1}\rightarrow x1=2.5m$$

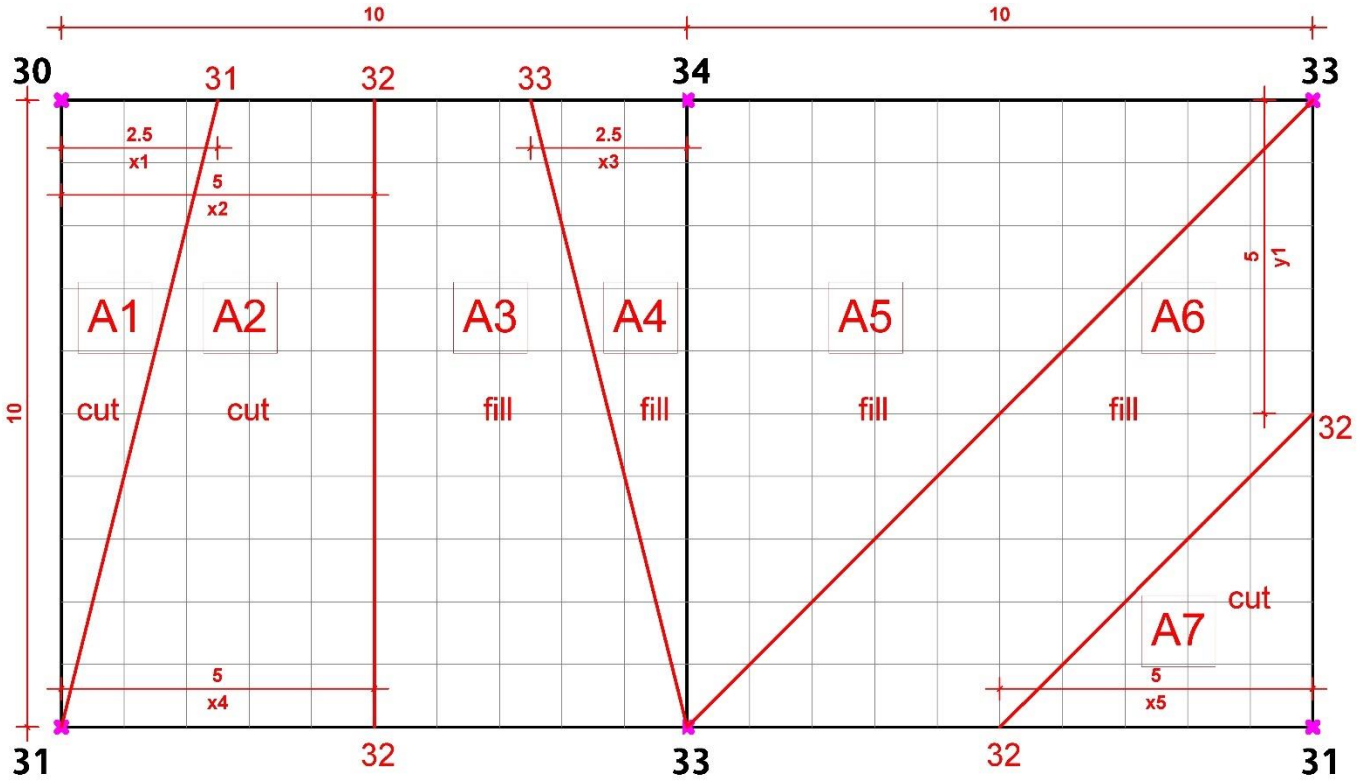
$$\frac{34-30}{10}=\frac{32-30}{x2}\rightarrow x2=5m$$

$$\frac{34-30}{10}=\frac{34-33}{x3}\rightarrow x3=2.5m$$

$$\frac{33-31}{10}=\frac{32-31}{x4}\rightarrow x4=5m$$

$$\frac{33-31}{10}=\frac{32-31}{x5}\rightarrow x5=5m$$

$$\frac{33-31}{10}=\frac{33-32}{y1}\rightarrow y1=5m$$



Areas:

A1 = 0.5 × 2.5 × 10 = 12.5 m^2

A2 = 10 × (5 + 2.5)/2 = 37.5 m^2

A3 = 10 × (5 + 2.5)/2 = 37.5 m^2

A4 = 0.5 × 2.5 × 10 = 12.5 m^2

A5 = 0.5 × 10 × 10 = 50 m^2

A7 = 0.5 × 5 ×5 = 12.5 m^2

A6 = (0.5 × 10 × 10) – (0.5 × 5 × 5) = 37.5 m^2

Average heights to level 32m:

h1= (–2 –1 –1)/3	= – 1.333 m
h2= (–1 + 0 + 0 –1)/4	= – 0.250 m
h3= (0 + 1 + 1 + 0)/4	= + 0.250 m
h4= (1 + 2 + 1)/3	= + 1.333 m
h5= (2 + 1 + 1)/3	= + 1.333 m
h6= (1 + 0 + 0 + 1)/4	= + 0.250 m
h7= (0 – 1 + 0)/3	= – 0.333 m

Volumes:

	Fill	Cut
v1= 12.5 × (– 1.333)	= – 16.667 m^3	
v2= 37.5 × (– 0.25)	= – 9.375 m^3	
v3= 37.5 × (+ 0.25)		= + 9.375 m^3
v4= 12.5 × (+ 1.333)		= + 16.667 m^3
v5= 50 × (+ 1.333)		= + 66.667 m^3
v6= 37.5 × (+ 0.25)		= + 9.375 m^3
v7= 12.5 × (– 0.333)	= – 4.167 m^3	
total cut volume	= – 30.209 m^3	
total fill volume		= + 102.08 m^3

■■■■

Exercise*: Draw in contour lines at the following elevations. All numbers are given in meters above mean sea level. Contour interval is 50 m.*