Program : **B.Tech**

Subject Name: **Basic Civil Engineering & Mechanics**

Subject Code: **BT-204**

Year: **1st**

Unit 03

Mapping details and contouring, Profile Cross sectioning and measurement of areas, volumes, application of measurements in quantity computations, Survey stations, Introduction of remote sensing and its applications.

Mapping & Sensing

A contour line is an imaginary line which connects points of equal elevation. Such lines are drawn on the plan of an area after establishing reduced levels of several points in the area. The contour lines in an area are drawn keeping difference in elevation of between two consecutive lines constant. For example, Fig. 1 shows contours in an area with contour interval of 1 m. On contour lines the level of lines is also written. For example, the line of intersection of the water surface of a still lake or pond with the surrounding ground represents a contour line. It facilitates depiction of the relief of terrain in a two dimensional plan or map. The process of tracing contour lines on the surface of earth is called contouring. A contour map gives the idea of the altitudes of the surface features as well as their relative positions in a plan.

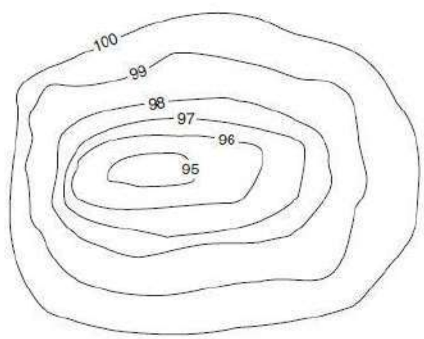


Figure 1: Contours of an area.

Contour interval:

"The vertical distance between any two successive contours on a given map is called the contour interval". Contour intervals usually vary from 25 to 250 cm in engineering work. In rough country, the vertical distance between contours is kept greater while in flat areas 25 to 50 cm contour intervals are used.

The contours have the following characteristics:

1. **Contour lines must close, not necessarily in the limits of the plan.**
2. **Widely spaced contour indicates flat surface.**
3. **Closely spaced contour indicates steep ground.**
4. **Equally spaced contour indicates uniform slope.**
5. **Irregular contours indicate uneven surface.**
6. **Approximately concentric closed contours with decreasing values towards centre (Fig. 1) indicate a pond.**
7. **Approximately concentric closed contours with increasing values towards centre indicate hills.**
8. **Contour lines with U-shape with convexity towards lower ground indicate ridge (Fig. 2).**
9. **Contour lines with V-shaped with convexity towards higher ground indicate valley (Fig. 3).**
10. **Contour lines generally do not meet or intersect each other.**
11. **If contour lines are meeting in some portion, it shows existence of a vertical cliff (Fig. 4).**

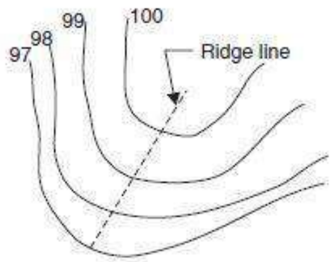


Figure 2: Contours indicating ridge.

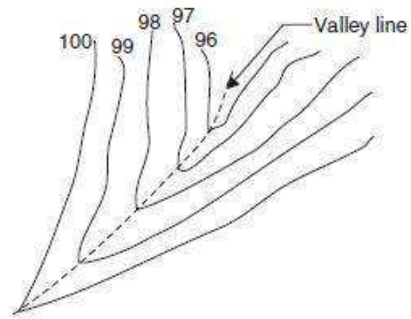


Figure 3: Contours indicating valley.

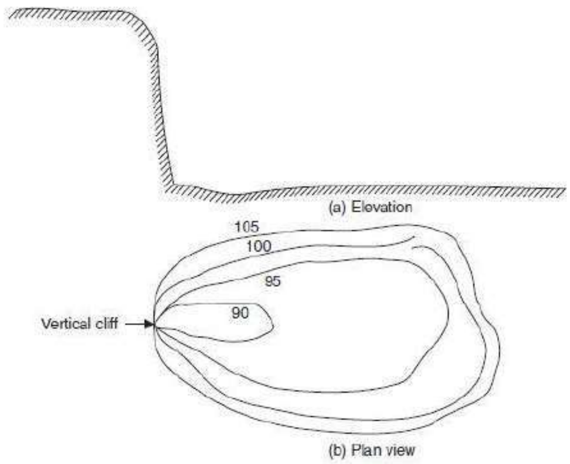


Figure 4: Contours indicating vertical cliff.

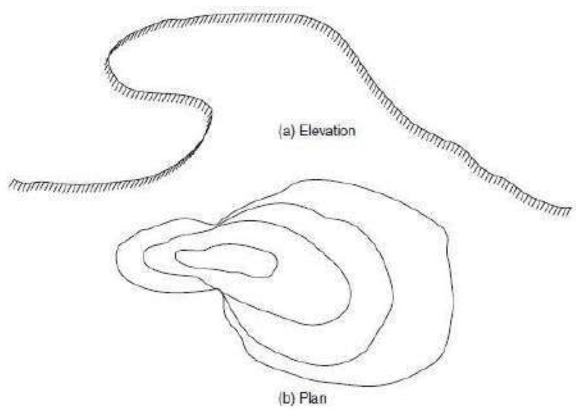


Figure 5: Contours indicating overhanging cliff.

Uses of Contour Maps:

Contour maps are extremely useful for various engineering works:

1. **A civil engineer studies the contours and finds out the nature of the ground to identify.**
2. **Suitable site for the project works to be taken up.**
3. **By drawing the section in the plan, it is possible to find out profile of the ground along that line. It helps in finding out depth of cutting and filling, if formation level of road/railway is decided.**
4. **Cost estimates can be made with the help of the contour maps.**
5. **Intervisibility of any two points can be found by drawing profile of the ground along that line.**
6. **The routes of the railway, road, canal or sewer lines can be decided so as to minimize and balance earthworks.**
7. **Catchment area and hence quantity of water flow at any point of nalla or river can be found. This study is very important in locating bunds, dams and also to find out flood levels.**
8. **Contours may be used to determine area of the catchments and the capacity of the reservoir.**
9. **In agricultural work, contours maps are useful as guide lines in planning land improvement project. The tile drainage system can be conveniently planned whit contour maps.**

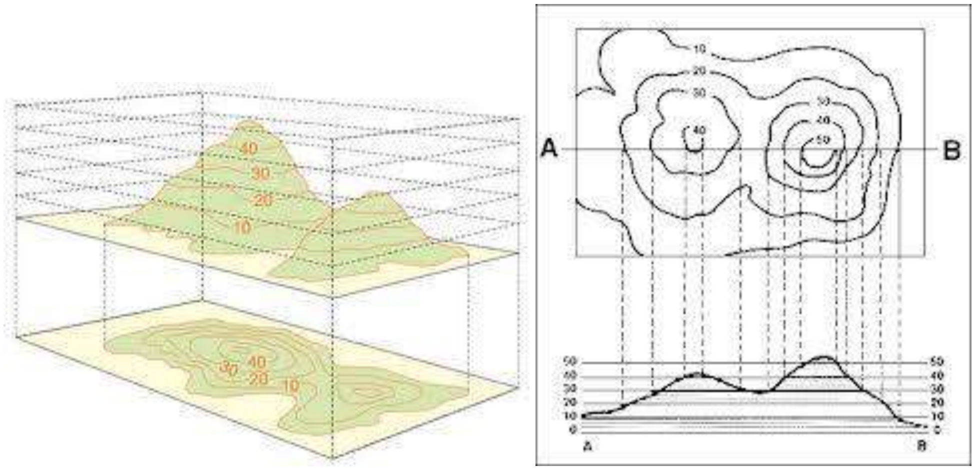


Figure 6: Uses of Contours.

Characteristic of Contour Lines:

1. **All points on a contour line have same elevation.**
2. **Contour line close to each other on s plan view; represent very steep ground. Contour lines for apart indicate relatively flat land.**
3. **On uniform slopes the contour lines are spaced uniformly .along plane surfaces these lines are straight and parallel to one another.**
4. **Contour lines Crosse ridge lines or valley lines at right angles valley contour are convex towards the stream.**
5. **Contour lines cannot and anywhere, but close on themselves. Either within or outside the limits of map they cannot merge or cross one another.**
6. **A series of closed contour on the map indicate a depression or a summit, depending whether the successes contour have lower or higher values inside**
7. **At ridge line the contour lines form carves of U shape .At Valley lines they farm sharp curves of shape**

REMOTE SENSING

Remote Sensing is the collection of information relating to objects without being in physical contact with them. Thus our eyes and ears are remote sensors, and the same is true for cameras and microphones and for many instruments used for all kinds of applications Or, said another way: Remote sensing is the process of acquiring data/information about objects/substances not in direct contact with the sensor, by gathering its inputs using electromagnetic radiation or acoustical waves that emanate from the targets of interest. An aerial photograph is a common example of a remotely sensed (by camera and film, or now digital) product.

Introduction: The sun is a source of energy or radiation, which provides a very convenient source of energy for remote sensing. The sun's energy is either reflected, as it is for visible wavelengths, or absorbed and then reemitted, as it is for thermal infrared wavelengths.

There are two main types of remote sensing: Passive remote sensing and Active remote sensing.

Passive remote sensing: Passive sensors detect natural radiation that is emitted or reflected by the object or surrounding area being observed. Reflected sunlight is the most Passive 1-Passive sensors detect natural radiation that is emitted or reflected by the object or surrounding area being observed. Reflected sunlight is the most common source of radiation measured by passive sensors. Examples of passive remote sensors include film photography, infrared, and radiometers.

Active remote sensing: It is on the other hand, emits energy in order to scan objects and areas whereupon a sensor then detects and measures the radiation that is reflected or backscattered from the target. RADAR is an example of active remote sensing where the time delay between emission and return is measured, establishing the location, height, speeds and direction of an object.

Overview

Remote sensing makes it possible to collect data on dangerous or inaccessible areas. Remote sensing applications include monitoring deforestation in areas such as the Amazon Basin, the effects of climate change on glaciers and Arctic and Antarctic regions, and depth sounding of coastal and ocean depths. Military collection during the cold war made use of stand-off collection of data about dangerous border areas. Remote sensing also replaces costly and slow data collection on the ground, ensuring in the process that areas or objects are not disturbed.

Principles and Process of Remote Sensing

Remote sensing actually done from satellites as Landsat or airplane or on the ground. To repeat the essence of the definition above, remote sensing uses instruments that house sensors to view the spectral, spatial and radiometric relations of observable objects and materials at a distance. Most sensing modes are based on sampling of photons corresponding frequency in the electromagnetic (EM) spectrum.

In much of remote sensing, the process involves an interaction between incident radiation and the targets of interest. This is exemplified by the use of imaging systems where the following seven elements are involved. Note, however that remote sensing also involves the sensing of emitted energy and the use of non-emitted sensors.

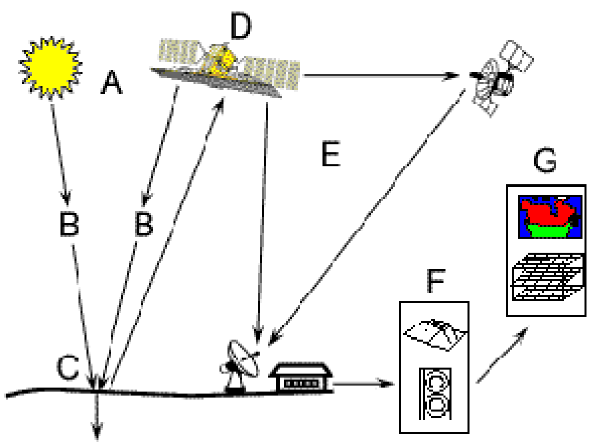


Figure 7: Principles of remote sensing.

i. Energy Source or Illumination (A) - The first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.

ii. Radiation and the Atmosphere (B) - As the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.

iii. Interaction with the Target (C) - Once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.

iv. Recording of Energy by the Sensor (D) - After the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation.

v. Transmission, Reception, and Processing (E) - The energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed.

vi. Interpretation and Analysis (F) - The processed image is interpreted, visually and/or digitally or electronically, to extract information about the target, which was illuminated.

vii. Application (G) - The final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

Applications of Remote Sensing

There are probably hundreds of applications - these are typical:

1. **Meteorology - Study of atmospheric temperature, pressure, water vapour, and wind velocity.**
2. **Oceanography: Measuring sea surface temperature, mapping ocean currents, and wave energy spectra and depth sounding of coastal and ocean depths Glaciology- Measuring ice cap volumes, ice stream velocity, and sea ice distribution. (Glacial)**
3. **Geology- Identification of rock type, mapping faults and structure.**
4. **Geodesy- Measuring the figure of the Earth and its gravity field.**
5. **Topography and cartography - Improving digital elevation models.**
6. **Agriculture Monitoring the biomass of land vegetation**
7. **Forest- monitoring the health of crops, mapping soil moisture**
8. **Botany- forecasting crop yields.**
9. **Hydrology- Assessing water resources from snow, rainfall and underground aquifers.**
10. **Disaster warning and assessment - Monitoring of floods and landslides, monitoring volcanic activity, assessing damage zones from natural disasters.**
11. **Planning applications - Mapping ecological zones, monitoring deforestation, monitoring urban land use.**
12. **Oil and mineral exploration- Locating natural oil seeps and slicks, mapping geological structures, monitoring oil field subsidence.**
13. **Military- developing precise maps for planning, monitoring military infrastructure, monitoring ship and troop movements**
14. **Urban- determining the status of a growing crop**
15. **Climate- the effects of climate change on glaciers and Arctic and Antarctic Regions**
16. **Sea- Monitoring the extent of flooding**
17. **Space program- is the backbone of the space program**

Profile Cross sectioning

Survey Station: Survey stations are of two kinds

Main Stations, Subsidiary or tie

<u>Main Stations</u>: Main stations are the end of the lines, which command the boundaries of the survey, and the lines joining the main stations re called the main survey line or the chain lines.

Subsidiary or the tie stations: Subsidiary or the tie stations are the point selected on the main survey lines, where it is necessary to locate the interior detail such as fences, hedges, building etc.

Tie or subsidiary lines: A tie line joints two fixed points on the main survey lines. It helps to checking the accuracy of surveying and to locate the interior details. The position of each tie line should be close to some features, such as paths, building etc.

<u>Base Lines</u>: It is main and longest line, which passes approximately through the centre of the field. All the other measurements to show the details of the work are taken with respect of this line.

Check Line: A check line also termed as a proof line is a line joining the apex of a triangle to some fixed points on any two sides of a triangle. A check line is measured to check the accuracy of the framework. The length of a check line, as measured on the ground should agree with its length on the plan.

<u>Offsets:</u> These are the lateral measurements from the base line to fix the positions of the different objects of the work with respect to base line. These are generally set at right angle offsets. It can also be drawn with the help of a tape.

There are two kinds of offsets:

Perpendicular offsets, and Oblique offsets.

The measurements are taken at right angle to the survey line called perpendicular or right angled offsets. The measurements which are not made at right angles to the survey line are called oblique offsets or tie line offsets.

Procedure in chain survey:

1. Reconnaissance: The preliminary inspection of the area to be surveyed is called reconnaissance. The surveyor inspects the area to be surveyed, survey or prepares index sketch or key plan.
2. Marking Station: Surveyor fixes up the required no stations at places from where maximum possible stations are possible.
3. Then he selects the way for passing the main line, which should be horizontal and clean as possible and should pass approximately through the centre of work.
4. Then ranging roads are fixed on the stations.
5. After fixing the stations, chaining could be started.
6. Make ranging wherever necessary.
7. Measure the change and offset.
8. Enter in the field the book.

Cross Staff Survey

This type of survey is undertaken to locate boundaries of a field or a field or plat and determinations of its area.

Principle: The principle of the survey is to divide the given area in to number of right angled triangles and trapezoids and to calculate and plot the areas of triangles and trapezoids. Instruments/Material Required: Two Chains, arrows taps, ranging rods, cross-staff and drawing material

Procedure: Two chains are usually provided one for measuring distance along the chain line and other for measuring the offsets. The cross staff is used to set out the perpendicular directions for offsets. In this survey, the base line runs through the center of the area, so that the offsets are left or right side of base line are fairly equal. To check accuracy length of the boundary lines may also be measured. After the field work is over, the survey is plotted to a suitable scale.

Measurement of areas

1. **Calculations of Field Area:**

By this method of survey, the field as divided in to right angled triangles and trapezoids are calculated as under:

Area of right -angled triangle = ½ base x Height.

Area of trapezoid= sum of parallel sides/2 x Height.

Add the areas of all the triangles & trapezoids and sum is equal to the total of a field.

The computations for area should be written in a tabular from as given below.

Sl. No.	Figure	Chainage in m.	Base in M.	Offset in M.	Mean offset in m.	Area in m^2 = Col 4 x Col 6

Problem 1:

The following are the details of chain survey. Plot the area for the given details and calculate the area.

65.4 m F
52.4 m 18.50 m E
D 13.50 m 42.00 m
28.00 m 22.00 m C
B 14.5 m 12.00 m
0.0 m A

Solution: Plot the area for the given data.

Tabular column:

Sl. No.	Figure	Chainage in m.	Base in M.	Offset in M.	Mean offset in m.	Area in m^2 = Col 4 x Col 6
1.	A12B	0.0 to 12.0	12.0	0.0 and 14.5	7.25	87.00
2.	A28C	12.0 to 28.0	16.0	0.0 and 22.0	11.0	176.00
3.	12BD42	12.0 to 42.0	30.0	14.5 and 13.5	14.0	420.00
4.	28CE52.4	28.0 to 52.40	24.4	22.0 and 18.5	20.25	494.10
5.	D42F	42.0 to 65.4	23.4	13.5 and 0.0	6.75	157.95
6.	52.4EF	52.4 to 65.4	13.0	18.5 and 0.0	9.25	120.25
	Total area in m^2 (ABDFECA)					1455.30

Problem 2:

The following are the details of chain survey. Plot the area for the given details and calculate the area.

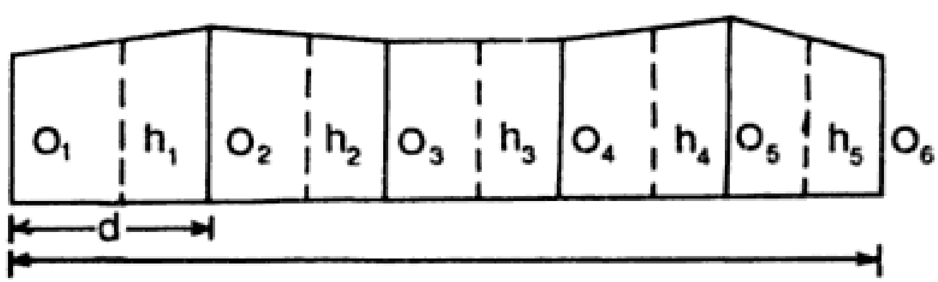
115.4 m G
102.0 m 18.50 m F
E 10.0 m 82.00 m
68.00 m 12.00 m D
C 23.5 m 42.00 m
28.00 m 14.00 m B
0.0 m A

Solution: Plot the area for the given data.

Tabular column:

Sl. No.	Figure	Chainage in m.	Base in M.	Offset in M.	Mean offset in m.	Area in m^2 = Col 4 x Col 6
1.	A42C	0.0 to 42.0	42.0	0.0 and 23.5	11.75	493.50
2.	A28B	0.0 to 28.0	28.0	0.0 and 14.0	7.0	196.00
3.	28BD68	28.0 to 68.0	40.0	14.0 and 12.0	13.0	520.00
4.	42CE82	42.0 to 82.0	40.0	23.5 and 10.0	16.75	670.00
5.	68DF102	68.0 to 102	34.0	12.0 and 18.5	15.25	518.50
6.	E82G	82.0 to 115.4	33.4	18.5 and 0.0	9.25	308.95
	Total area in m^2 (ABDFGECA)					2706.95

2. **Measurement of areas by mid ordinate method:**



L = Length of base line

Let $O_1, O_2, O_3, \ldots, O_n$ = Ordinates at equal intervals.

d = Common distance between ordinates.

L = Length of Base line = d * (n - 1)

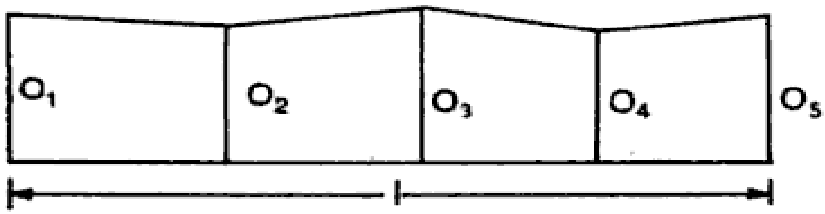
$h_1, h_2, h_3, \ldots, h_n$ = Mid-ordinates

n = Number of ordinates.

$$h_1 = (O_1 + O_2)/2$$
$$h_2 = (O_2 + O_3)/2$$
$$h_3 = (O_3 + O_4)/2$$
$$\ldots\ldots\ldots\ldots$$
$$h_{n-1} = (O_{n-1} + O_n)/2$$

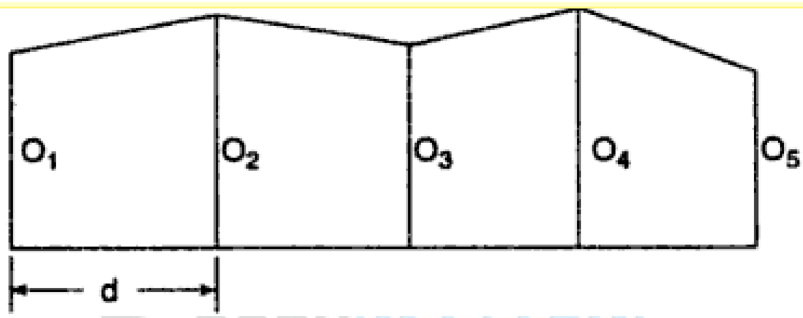
$$\text{Area} = A = d * (h_1 + h_2 + h_3 + \ldots\ldots + h_{n-1})$$

3. **Measurement of areas by average ordinate method:**



Let O_1, O_2, O_3,…., O_n = Ordinates at equal intervals.
d = Common distance between ordinates.
L = Length of Base line = d * (n - 1)
n = Number of ordinates.
Area = A = L * (O_1 + O_2 + O_3 + …….. + O_n)/n

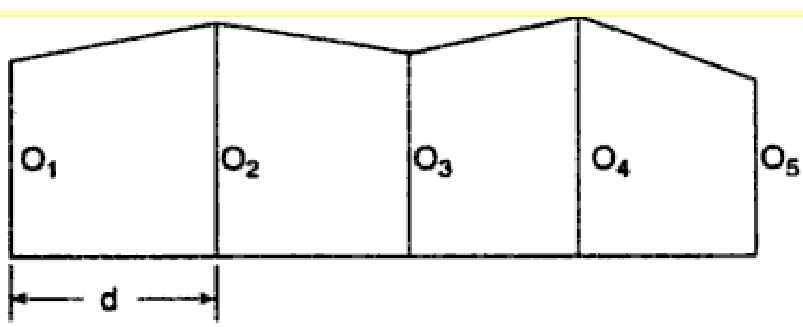
4. **Measurement of areas by Trapezoidal rule.**



Let O_1, O_2, O_3,…., O_n = Ordinates at equal intervals.
d = Common distance between ordinates.
n = Number of ordinates.

Area = A = d * [(O_1 + O_n)/2 + (O_2 + …….. + O_{n-1})]

5. **Measurement of areas by Simpson's rule.**
In this rule, the boundaries between the end of ordinates are assumed to form an arc of parabola. Hence Simpson's rule is some times called as parabolic rule.



Let O_1, O_2, O_3,…., O_n = Ordinates at equal intervals.
d = Common distance between ordinates.
n = Number of ordinates.

Area = A

$= (d/3) * [(O_1 + O_n)/2 + 2*(O_2 + O_4 + O_6 + ...) + 4 *(O_3 + O_5 + O_7 + ...)]$

Problem 01: The following perpendicular offsets were taken from chain line to an irregular boundary:

Chainage	0.0	10.0	25.0	42.0	60.0	75.0 m
Offset	15.5	26.2	31.8	25.6	29.0	31.5

Calculate the area between the chain line, the boundary and the end offsets.

1. **Area by mid ordinate method:**

n = 06.

d = 10.0 m.

$h_1 = (O_1 + O_2)/2 = (15.5 + 26.2)/2 = 20.85$

$h_2 = (O_2 + O_3)/2 = (26.2 + 31.8)/2 = 29.00$

$h_3 = (O_3 + O_4)/2 = (31.8 + 25.6)/2 = 28.70$

$h_4 = (O_4 + O_5)/2 = (25.6 + 29.0)/2 = 27.30$

$h_5 = (O_5 + O_6)/2 = (29.0 + 31.5)/2 = 30.25$

Area $= A = d * (h_1 + h_2 + h_3 + ... + h_{n-1})$

$= 10.0 * (20.85 + 29.0 + 28.7 + 27.3 + 30.25)$

$= 1361.00\ m^2$.

2. **Area by average ordinate method:**

n = 06.

d = 10.0 m.

L = Length of Base line = d * (n - 1) = 10 * (6-1) = 50.0 m.

Area $= L * (O_1 + O_2 + O_3 + ... + O_n)/n$

$= 50.0 * (15.5 + 26.2 + 31.8 + 25.6 + 29.0 + 31.5)/6$

$= 1330.00\ m^2$.

3. **Area by Trapezoidal rule:**

n = 06.

d = 10.0 m.

Area $= d * [(O_1 + O_n)/2 + (O_2 + ... + O_{n-1})]$

$= 10.0 * [(15.5 + 31.5)/2 + 26.2 + 31.8 + 25.6 + 29.0]$

$= 1361.00\ m^2$.

4. **Area by Simpson's rule:**

n = 06.

d = 10.0 m.

Area $= (d/3) * [(O_1 + O_n)/2 + 2*(O_2 + O_4 + O_6 + ...) + 4 *(O_3 + O_5 + O_7 + ...)]$

$= (10.0/3) * [(15.5 + 31.5)/2 + 2 * (26.2 + 25.6) + 4 * (31.8 + 29.0)]$

$= 1234.33\ m^2$.

Problem 02:

The following perpendicular offsets were taken from a chain line to a hedge:

Chainage:	**0.0**	**15.0**	**30.0**	**45.0**	**60.0**	**75.0**	**90.0**	**105.0**	**120.0**	**135.0 m.**
Offset:	**7.6**	**8.5**	**10.7**	**12.8**	**10.6**	**9.5**	**8.3**	**7.9**	**6.4**	**4.4 m.**

Calculate the area by mid ordinate, average ordinate, Trapezoidal rule and Simpson's rule.

1. **Area by mid ordinate method:**
   n = 10.
   d = 15.0 m.

$h_1 = (O_1 + O_2)/2 = (7.6 + 8.5)/2 = 8.05$

$h_2 = (O_2 + O_3)/2 = (8.5 + 10.7)/2 = 9.60$

$h_3 = (O_3 + O_4)/2 = (10.7 + 12.8)/2 = 11.75$

$h_4 = (O_4 + O_5)/2 = (12.8 + 10.6)/2 = 11.70$

$h_5 = (O_5 + O_6)/2 = (10.6 + 9.5)/2 = 10.05$

$h_6 = (O_6 + O_7)/2 = (9.5 + 8.3)/2 = 8.90$

$h_7 = (O_7 + O_8)/2 = (8.3 + 7.9)/2 = 8.10$

$h_8 = (O_8 + O_9)/2 = (7.9 + 6.4)/2 = 7.15$

$h_9 = (O_9 + O_{10})/2 = (6.4 + 4.4)/2 = 5.40$

Area = $A = d * (h_1 + h_2 + h_3 + \ldots\ldots + h_{n-1})$
$= 15.0 * (8.05 + 9.60 + 11.75 + 11.70 + 10.05 + 8.90 + 8.10 + 7.15 + 5.40)$
$= 1210.50\ m^2$.

2. **Area by average ordinate method:**
   n = 10.
   d = 15.0 m.
   L = Length of Base line = d * (n - 1) = 15 * (10-1) = 135.0 m.
   Area = $L * (O_1 + O_2 + O_3 + \ldots\ldots + O_n)/n$
   $= 135.0 * (7.6 + 8.5 + 10.7 + 12.8 + 10.6 + 9.5 + 8.3 + 7.9 + 6.4 + 4.4)/10$
   $= 1170.45\ m^2$.
3. **Area by Trapezoidal rule:**
   n = 10.
   d = 15.0 m.
   Area = $d * [(O_1 + O_n)/2 + (O_2 + \ldots\ldots + O_{n-1})]$
   $= 15.0 * [(7.6 + 4.4)/2 + 8.5 + 10.7 + 12.8 + 10.6 + 9.5 + 8.3 + 7.9 + 6.4]$
   $= 1210.50\ m^2$.
4. **Area by Simpson's rule:**
   n = 10.
   d = 15.0 m.

Area = $(d/3) * [(O_1 + O_n)/2 + 2*(O_2 + O_4 + O_6 + \ldots\ldots) + 4 *(O_3 + O_5 + O_7 + \ldots\ldots)]$
$= (15.0/3) * [(7.6 + 4.4)/2 + 2 * (8.5 + 12.8 + 9.5 + 7.9) +$
$4 * (10.7 + 10.6 + 8.3 + 6.4)]$
$= 1137.00\ m^2$.

Measurement of Volume

1. **Volume by Trapezoidal rule:**

Let $A_1, A_2, A_3, \ldots, A_n$ = Areas at equal intervals.
d = Common distance between areas.
n = Number of areas.

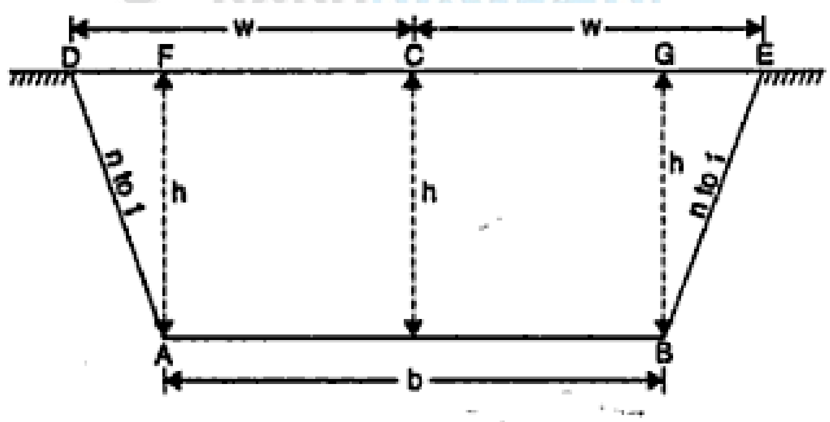
Volume = $V = d * [(A_1 + A_n)/2 + (A_2 + \ldots\ldots + A_{n-1})]$

2. **Volume by Simpson's rule:**

Let $A_1, A_2, A_3, \ldots, A_n$ = Areas at equal intervals.
d = Common distance between areas.
n = Number of areas.

Area = A
$= (d/3) * [(A_1 + A_n)/2 + 2*(A_2 + A_4 + A_6 + \ldots\ldots) + 4 *(A_3 + A_5 + A_7 + \ldots\ldots)]$

Area of trapezium:



Area of trapezium = $b * h + 2((1/2) \times n * h * h) = (b + n*h)h$
$= b*h + n*h^2$.

Where b = Top width of embankment or Bottom width of cutting
n = side slope as 1 in n or n to 1

Problem 01:

A railway embankment is 12 m wide. The ground is level in the direction transeverse to the centre line. Calculate the volume contained in a 120 m length by trapezoidal and prismoidal rule, if the side slope is 1.5:1. The centre height at 20 m interval are 3.7 m, 2.6 m, 4.0 m, 3.4 m, 2.8 m, 3.0 m, 2.2 m.

Solution:

If h is the height of embankment, then the area is given by the equation

$A = 12 \times h + 2((1/2) \times 1.5h \times h) = (b + nh)h$

$= 12h + 1.5h^2$.

Point No.	Chainages	Centre height	Area in m^2.
0	0.0	3.70	54.6675
1	20.0	2.60	36.2700
2	40.0	4.00	60.0000
3	60.0	3.40	49.4700
4	80.0	2.80	39.4800
5	100.0	3.00	42.7500
6	120.0	2.20	30.0300

Volume by trapezoidal formula

Volume = (20)[{54.6675 + 30.0300}/2 +{36.27 +60.00 + 49.47 + 39.48 + 42.75 }]
= 5406.375 m^3.
Volume by Prismoidal formula
Volume = (20/3)[{54.6675 + 30.0300} + 2 x {36.27 + 49.47 + 42.75 } + 4 x {60.00 + 39.48 }]
= 4648.325 m^3.

Problem 02:
A railway embankment 400 m long is 12 m wide at the formation level and has the side slope 2:1. The ground levels across the centre line are as under:

Chainage: 0.0 100.0 200.0 300.0 400.0 m.

Offset: 203.6 204.2 205.7 206.1 207.3 m.

The formation level at zero chainage is 207.00 and the embankment has a rising gradient of 1:100. The ground is level across the centre line. Calculate the volume of earthwork.

Solution:

If h is the height of embankment, then the area is given by the equation
A = 12 x h + 2((1/2) x 1.5h x h) = (b + sh)h
$= 12h + 1.5h^2$.
In this problem, side slope n = 2, b = 12.0 m.
Formation level at 0.0 m chain age is 207.0.
The longitudinal gradient is 1 in 100.
Therefore formation level at 100.0 m chain age is 207.0 + 1.0 = 208.00. The results are shown in the following table.

Chainage in m.	Existing ground level (GL)	Formation level (FL)	Depth of filling (FL – GL)	Area in m^2. ($b*h + n*h^2$)
0.0	203.6	207.0	3.4	63.92
100.0	204.2	208.0	3.8	74.48
200.0	205.7	209.0	3.3	61.38
300.0	206.1	210.0	3.9	77.22
400.0	207.3	211.0	3.7	71.78

Volume by trapezoidal formula

Volume = (100)[{63.92 + 71.78}/2 + {74.48 +61.38 + 77.22 }]
= 28093.00 m^3.

Volume by Prismoidal formula

Volume = (100/3)[{63.92 + 71.78} + 2 x {74.48 + 77.22 } + 4 x {61.38 }]
= 20559.00 m^3.

Problem 03:

The areas within the contour line at the site of reservoir and the face of the proposed Dam are as follows:

Contour	Area in m^2.	Contour	Area in m^2.
101	1000	106	1350000
102	12800	107	1985000
103	95200	108	2286000
104	147600	109	2512000
105	872500	110	3517000

Taking 101 as the bottom level of the reservoir and 110 as the top level, calculate the capacity of the reservoir.

Solution:

Volume by trapezoidal formula

Volume = (1.0)[{1000 + 3517000}/2 + {12800+95200+ 147600 + 872500 + 1350000 + 1985000 + 2286000 + 2512000}]
= 1,10,20,100.00 m^3.

Volume by Prismoidal formula

Volume = (100/3)[{ 1000 + 3517000} + 2 x {12800+ 147600 + 1350000 + 2286000} + 4 x {95200+ 872500 + 1985000 + 2512000}]
= 1,04,03,533.33 m^3.

