Subject Name: **Advance surveying & remote sensing**

Subject Code: **CE-3004**

Semester: **3rd**

Unit II

Theodolite Traversing & Types: Digital levels and theodolites, Electronic Distance measurement (EDM), Total Station and Global Positioning Systems (GPS), Digital Planimeter.

Digital levels and theodolite:

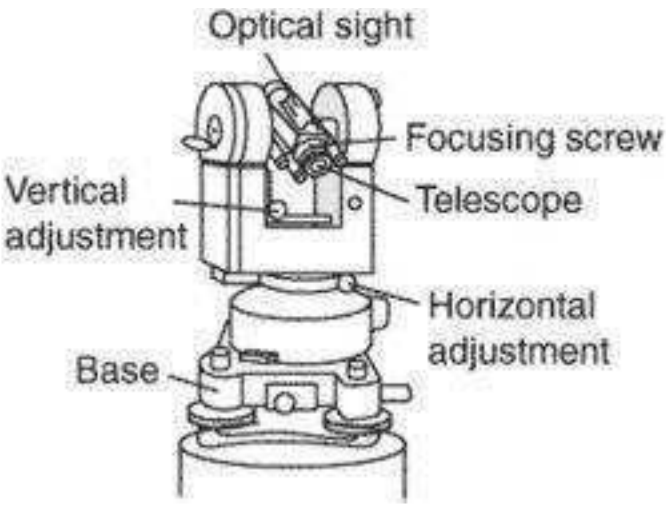
Digital automatic levels are a precise instruments used for precise leveling. Operation of digital levels is based on the digital processing of video indications of a coded staff. At the beginning of measurement a visual pointing of the instrument into the surface of leveling meter is performed.

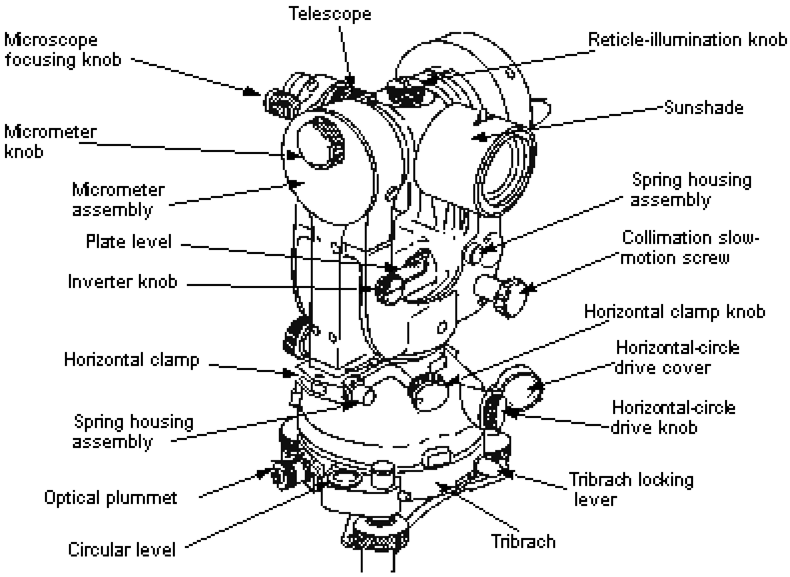
A theodolite is a precision instrument for measuring angles in the horizontal and vertical planes. Theodolites are used mainly for surveying applications, and have been adapted for specialized purposes such as meteorology and rocket launch.

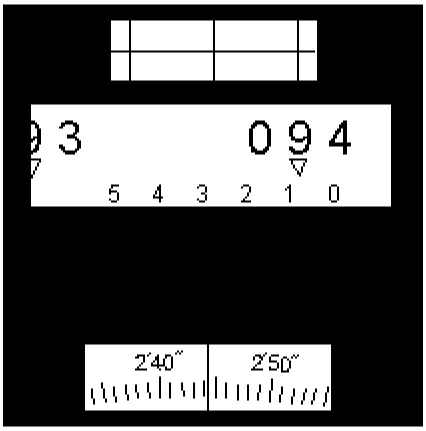
A modern theodolite consists of a movable telescope mounted within two perpendicular axes: the horizontal or trunnion axis and the zenith axis. A theodolite measures vertical angles as angles between the zenith, forwards or plunged—typically approximately 90 and 270 degrees. When the telescope is pointed at a target object, the angle of each of these axes can be measured with great precision, typically to seconds of arc.

A theodolite may be either transit or non-transit. In a transit theodolite, the telescope can be inverted in the vertical plane, whereas the rotation in the same plane is restricted to a semi-circle in a non-transit theodolite. Some types of transit theodolites do not allow the measurement of vertical angles.

The builder's level is sometimes mistaken for a transit theodolite, but it measures neither horizontal nor vertical angles. It uses a spirit level to set a telescope level to define a line of sight along a horizontal plane.



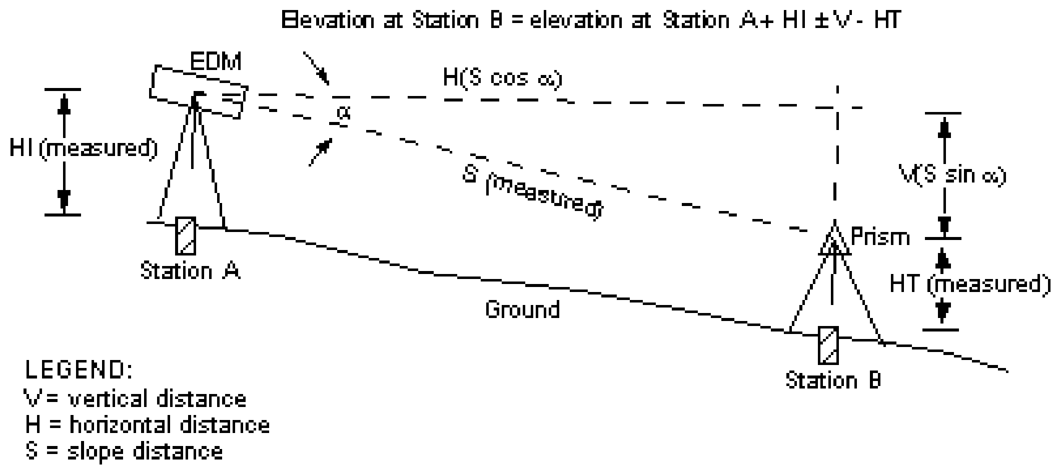




Vertical angle = 94°12'44"

Electronic Distance measurement:

Electronic distance measurement (EDM) is a method of determining the length between two points, using phase changes, that occur as electromagnetic energy waves travels from one end of the line to the other end. The distance between two points can be horizontal, slope, or vertical. A tape measure or an EDM device can measure horizontal and slope distances. In surveying, horizontal-distance measurements are always required. A distance measured on a slope can be trigonometrically converted to its horizontal equivalent by using the slope angle or vertical DE.



Electronic distance measurement (EDM) is a method of determining the length between two points, using phase changes, that occur as electromagnetic energy waves travels from one end of the line to the other end. As a background, there are three methods of measuring distance between two points:

DDM or Direct distance measurement – This is mainly done by chaining or taping.

ODM or Optical distance measurement – This measurement is conducted by tacheometry, horizontal subtense method or telemetric method. These are carried out with the help of optical wedge attachments.

EDM or Electromagnetic distance measurement – The method of direct distance measurement cannot be implemented in difficult terrains. When large amount of inconsistency in the terrain or large obstructions exist, this method is avoided.

Types of Electronic Distance Measurement Instrument

EDM instruments are classified based on the type of carrier wave as

1. **Microwave instruments**
2. **Infrared wave instruments**
3. **Light wave instruments.**

1. Microwave Instruments

These instruments make use of microwaves. Such instruments were invented as early as 1950 in South Africa by Dr. T.L. Wadley and named them as Tellurometers. The instrument needs only 12 to 24 V batteries. Hence they are light and highly portable. Tellurometers can be used in day as well as in night.

The range of these instruments is up to 100 km. It consists of two identical units. One unit is used as master unit and the other as remote unit. Just by pressing a button, a master unit can be converted into a remote unit and a remote unit into a master unit. It needs two skilled persons to operate. A speech facility is provided to each operator to interact during measurements.

2. Infrared Wave Instruments

In this instrument amplitude modulated infrared waves are used. Prism reflectors are used at the end of line to be measured. These instruments are light and economical and can be mounted on theodolite. With these instruments accuracy achieved is ± 10 mm. The range of these instruments is up to 3 km.

These instruments are useful for most of the civil engineering works. These instruments are available in the trade names DISTOMAT DI 1000 and DISTOMAT DI 55.

3. Visible Light Wave Instruments

These instruments rely on propagation of modulated light waves. This type of instrument was first developed in Sweden and was named as Geodimeter. During night its range is up to 2.5 km while in day its range is up to 3 km. Accuracy of these instruments varies from 0.5 mm to 5 mm/km distance. These instruments are also very useful for civil engineering projects.

Operations of Electronic Distance Measurement Instruments

It is essential to know the fundamental principle behind EDM to work with it. The electromagnetic waves propagate through the atmosphere based on the equation

$$V = f.\lambda = (\frac{1}{T}\lambda)$$

$$f = 1/T;\ (T = \text{Time in seconds})$$

Where 'v' is the velocity of electromagnetic energy in meters per second(m/sec); f is the modulated frequency in hertz (Hz) and λ is, the wavelength measured in meters. Mainly the waves that are propagated can be represented like a sine wave as shown in figure below.

Another property of wave called as phase of wave $\emptyset$, is a very convenient method of small fraction of wavelength during measurement in EDM. The points A, B, C etc. represents various phase points

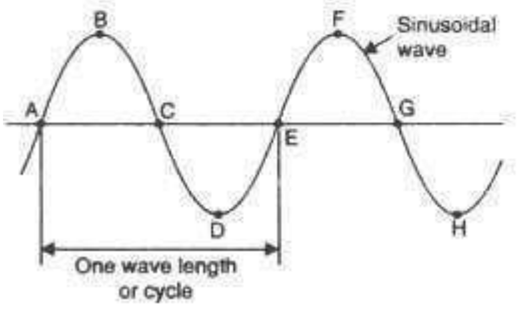


Fig. Sinusoidal Waves

Point →	A	B	C	D	E	F	G	H
Phase φ°	0	90	180	270	360 (or 0)	90	180	270

Fig. Corresponding phase values

Say AB is the survey line to me measured, having a length of D. The EDM equipment is placed at ends A and B. A transmitter is placed at A and a receiver is placed at B. the transmitter lets propagation of electromagnetic waves towards B. A timer is also placed. At the instant of transmission of wave from A the timer at B starts and stops at the instant of reception of incoming wave at B. This enable us to know the transit time for the wave from the point A to B.

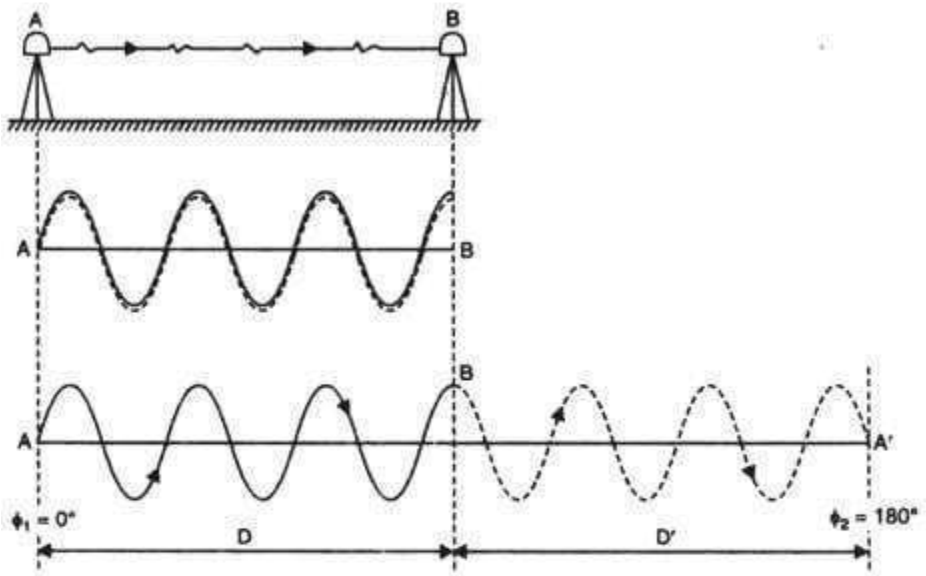


Fig. Transit Time Measurement Demonstration

From the transit time and known velocity, the distance can be easily measured. Now to solve the problem arise due to difficulty in starting the timer at B, a reflector can be placed as shown below instead of a receiver at B.

Error in Electronic Distance Measurement Instruments

Personal Errors

- Inaccuracy in initial setups of EDMs and the reflectors over the preferred stations
- Instrument and reflector measurements going wrong
- Atmospheric pressures and temperature determination errors

Instrumental Errors

- Calibration errors
- Chances of getting maladjusted time to time generating frequent errors
- Errors shown by the reflectors

Natural Errors

- Atmospheric variations in temperature, pressure as well as humidity. Micro wave EDM instruments are more susceptible to these.
- Multiple refraction of the signals.

The advantage of using EDM instruments is the speed and accuracy in measurement. Several obstacles to chaining are automatically overcome when these instruments are used.

Total station

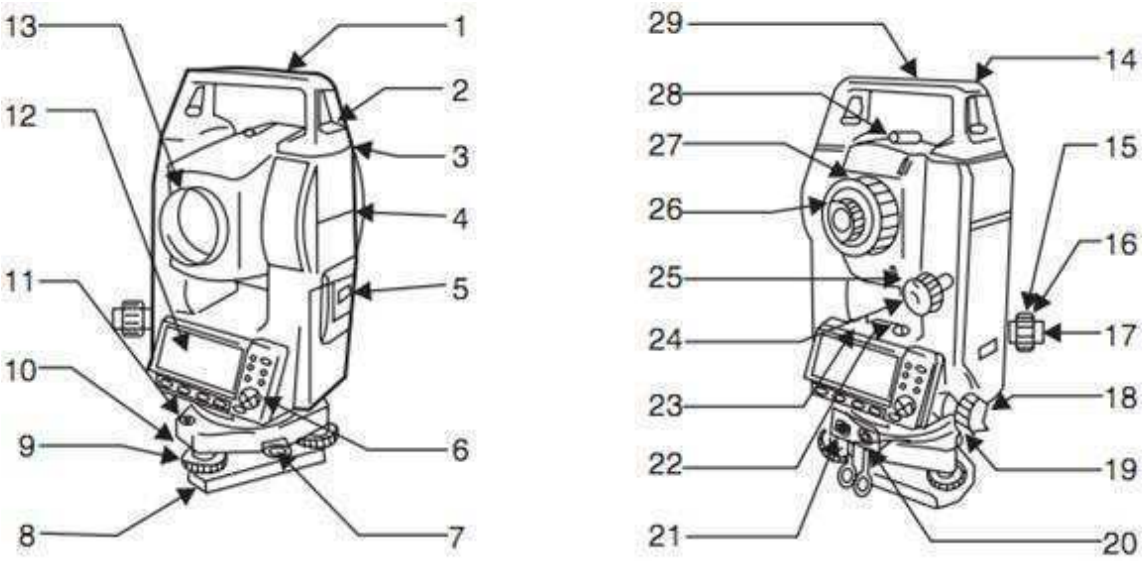
Total station is a surveying equipment combination of Electromagnetic Distance Measuring Instrument and electronic theodolite. It is also integrated with microprocessor, electronic data collector and storage system. The instrument can be used to measure horizontal and vertical angles as well as sloping distance of object to the instrument.

Capability of a Total Station:

Microprocessor unit in total station processes the data collected to compute:

1. Average of multiple angles measured.
2. Average of multiple distance measured.
3. Horizontal distance.
4. Distance between any two points.
5. Elevation of objects and
6. All the three coordinates of the observed points.

Data collected and processed in a Total Station can be downloaded to computers for further processing.



1. Handle
2. Handle securing screw
3. Data input/output terminal (Remove handle to view)
4. Instrument height mark
5. Battery cover
6. Operation panel
7. Tribrach clamp (SET300S/500S/600S: Shifting clamp)
8. Base plate
9. Levelling foot screw
10. Circular level adjusting screws
11. Circular level
12. Display
13. Objective lens
14. Tubular compass slot
15. Optical plummet focussing ring
16. Optical plummet reticle cover
17. Optical plummet eyepiece
18. Horizontal clamp
19. Horizontal fine motion screw
20. Data input/output connector (Besides the operation panel on SET600/600S)
21. External power source connector (Not included on SET600/600S)
22. Plate level
23. Plate level adjusting screw
24. Vertical clamp
25. Vertical fine motion screw
26. Telescope eyepiece
27. Telescope focussing ring
28. Peep sight
29. Instrument center mark

Figure- Total Station

Brief Description of Important Operations of Total Station:

***Distance Measurement:**

Electronic distance measuring (EDM) instrument is a major part of total station. Its range varies from 2.8 km to 4.2 km. The accuracy of measurement varies from 5 mm to 10 mm per km measurement. They are used with automatic target recognizer. The distance measured is always sloping distance from instrument to the object. Angle Measurements: The electronic theodolite part of total station is used for measuring vertical and horizontal angle. For measurement of horizontal angles any convenient direction may be taken as reference direction. For vertical angle measurement vertical upward (zenith) direction is

taken as reference direction. The accuracy of angle measurement varies from 2 to 6 seconds.

*Data Processing :

This instrument is provided with an inbuilt microprocessor. The microprocessor averages multiple observations. With the help of slope distance and vertical and horizontal angles measured, when height of axis of instrument and targets are supplied, the microprocessor computes the horizontal distance and X, Y, Z coordinates. The processor is capable of applying temperature and pressure corrections to the measurements, if atmospheric temperature and pressures are supplied.

*Display:

Electronic display unit is capable of displaying various values when respective keys are pressed. The system is capable of displaying horizontal distance, vertical distance, horizontal and vertical angles, difference in elevations of two observed points and all the three coordinates of the observed points.

*Electronic Book:

Each point data can be stored in an electronic note book (like compact disc). The capacity of electronic note book varies from 2000 points to 4000 points data. Surveyor can unload the data stored in note book to computer and reuse the note book.

Use of Total Station

The total station instrument is mounted on a tripod and is levelled by operating levelling screws. Within a small range instrument is capable of adjusting itself to the level position. Then vertical and horizontal reference directions are indexed using onboard keys. It is possible to set required units for distance, temperature and pressure (FPS or SI). Surveyor can select measurement mode like fine, coarse, single or repeated.

When target is sighted, horizontal and vertical angles as well as sloping distances are measured and by pressing appropriate keys they are recorded along with point number. Heights of instrument and targets can be keyed in after measuring them with tapes. Then processor computes various information about the point and displays on screen.

This information is also stored in the electronic notebook. At the end of the day or whenever electronic note book is full, the information stored is downloaded to computers.

The point data downloaded to the computer can be used for further processing. There are software like auto civil and auto plotter clubbed with AutoCad which can be used for plotting contours at any specified interval and for plotting cross-section along any specified line.

Advantages of Using Total Stations

The following are some of the major advantages of using total station over the conventional surveying instruments:

1. Field work is carried out very fast.
2. Accuracy of measurement is high.
3. Manual errors involved in reading and recording are eliminated.
4. Calculation of coordinates is very fast and accurate. Even corrections for temperature and pressure are automatically made.
5. Computers can be employed for map making and plotting contour and cross-sections. Contour intervals and scales can be changed in no time.

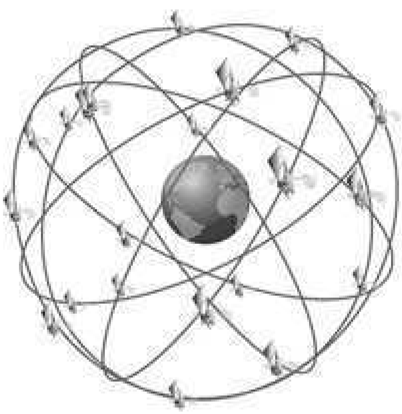
However, surveyor should check the working condition of the instruments before using. For this standard points may be located near survey office and before taking out instrument for field work, its working is checked by observing those standard points from the specified instrument station.

Global Positioning System.

A system of satellites, computers, and receivers that is able to determine the latitude and longitude of a receiver on Earth by calculating the time difference for signals from different satellites to reach the receiver. The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense.GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use.

Satellite Network

The GPS satellites transmit signals to a GPS receiver. These receivers passively receive satellite signals; they do not transmit and require an unobstructed view of the sky, so they can only be used effectively outdoors. Early receivers did not perform well within forested areas or near tall buildings but later receiver designs such as SiRFStarIII, MTK etc have overcome this and improved performance and sensitivity markedly. GPS operations depend on a very accurate time reference, which is provided by atomic clocks on board the satellites.



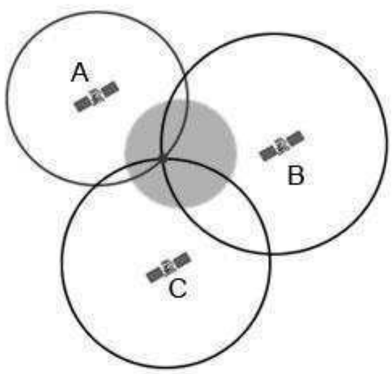
The Navstar GPS Constellation

Each GPS satellite transmits data that indicates its location and the current time. All GPS satellites synchronize operations so that these repeating signals are transmitted at the same instant. The signals, moving at the speed of light, arrive at a GPS receiver at slightly different times because some satellites are further away than others. The distance to the GPS satellites can be determined by estimating the amount of time it takes for their signals to reach the receiver. When the receiver estimates the distance to at least four GPS satellites, it can calculate its position in three dimensions.

There are at least 24 operational GPS satellites at all times plus a number of spares. The satellites, operated by the US DoD, orbit with a period of 12 hours (two orbits per day) at a height of about 11,500 miles traveling at 9,000mph (3.9km/s or 14,000kph). Ground stations are used to precisely track each satellite's orbit.

Determination of Position

A GPS receiver "knows" the location of the satellites because that information is included in the transmitted Ephemeris data. By estimating how far away a satellite is, the receiver also "knows" it is located somewhere on the surface of an imaginary sphere centred at the satellite. It then determines the sizes of several spheres, one for each satellite and therefore knows the receiver is located where these spheres intersect.



Digital Plannimeter

A planimeter, also known as a platometer, is a measuring instrument used to determine the area of an arbitrary two-dimensional shape.

The area of the shape is proportional to the number of turns through which the measuring wheel rotates. The polar planimeter is restricted by design to measuring areas within limits determined by its size and geometry. The images show the principles of a linear and a polar planimeter.

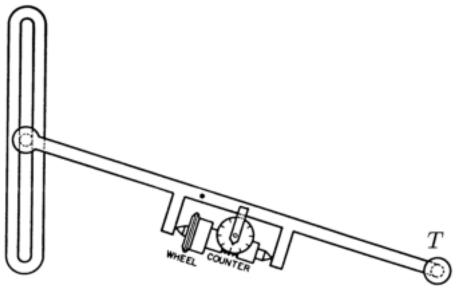


Fig-Linear Planimeter

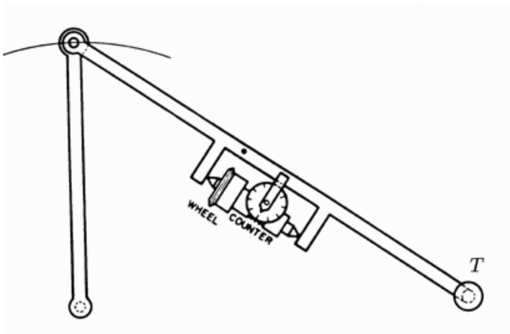


Fig-Polar Planimeter

There are basically two types of the planimeter. One is the mechanical while the other one is the digital. It basically consists of two arms. One arm is free and is can easily be moved from one point to another. This arm is moved at the boundary of the irregular image. Another arm is fixed and is connected to the weight that prevents its free movement. The movement of the arms helps in measuring the area of the contour.

The accuracy is certainly the most important attribute when it comes to measurement for the engineering application. To attain the highest degree of accuracy, the world is turning towards digital instruments. The digital planimeter is widely used, nowadays, as it helps in providing the most accurate results. These devices are based on advanced technology. These work on the computer algorithms that help in calculating the area of the 2D figures.The working principle of the algorithm used in the digital planimeter is based on the green theorem. This theorem helps in calculating the area. The basic fundamental involved in this is the integral calculus. In this, the whole figure is sub-divided into different segments. The area of these segments is calculated and then added up in order to measure the whole area.