Learning Objectives

Monday, March 2, 2020 9:39 AM

Learning objectives

1.

Homework Assignment 6

Do the following problems from the textbook:
8.1
8.2
8.3
8.4
8.7
8.11
8.12
8.16
8.17
8.21 (See Eq. 8.3)

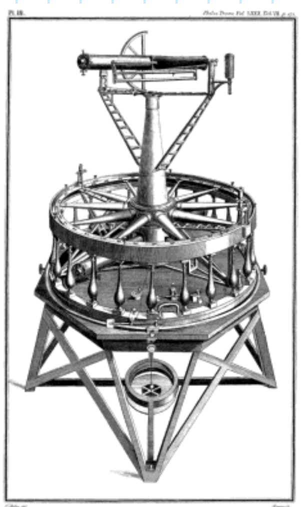
Manual Total Station

Monday, March 2, 2020 9:39 AM

What is a total station?

Total Station – **A combination of an electronic theodolite, electronic distance measuring (EDM) device, and software running on an external computer**, a total station is used to calculate the coordinates of survey points using angles and distances. It may also incorporate **GPS technology** to produce more accurate results.

From <https://www.google.com/search?q=gps+total+station&rlz=1C1SQJL_enUS822US822&oq=&aqs=chrome.0.69i59i450l6.1033651015j0j15&sourceid=chrome&ie=UTF-8>



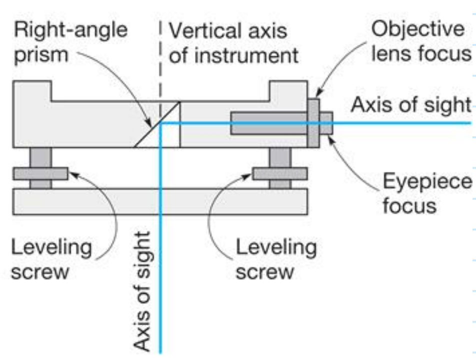
General View of the Instrument.

https://en.wikipedia.org/wiki/Theodolite

Manual Total Station Components

Monday, March 2, 2020 9:39 AM

(a)

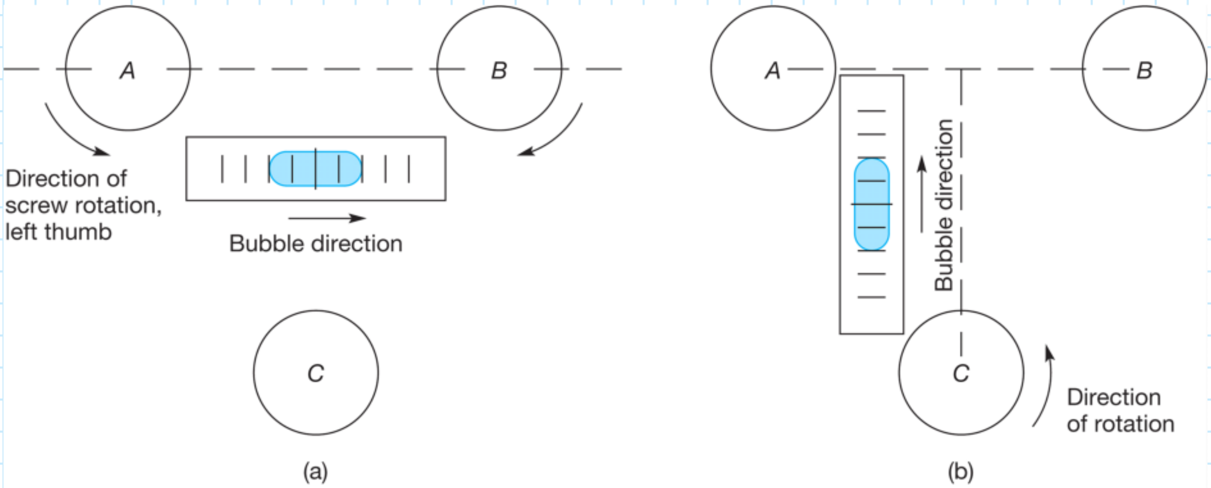


(b)

Manual Total Station Components Leveling

Monday, March 2, 2020 9:39 AM

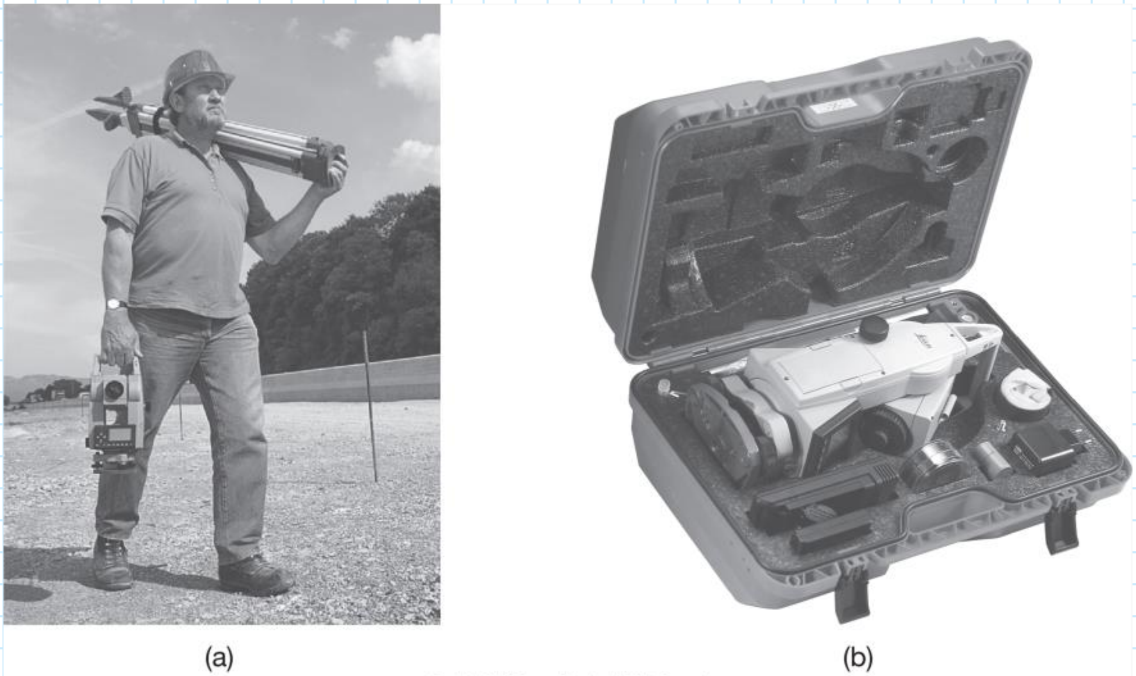
Figure 8.4 Bubble centering with three-screw leveling head.



Instrument Transport and Care

Monday, March 2, 2020 9:39 AM

Figure 8.6 (a) A proper method of transporting a total station in the field. (b) Total station in open case. (Courtesy Leica Geosystems AG.)

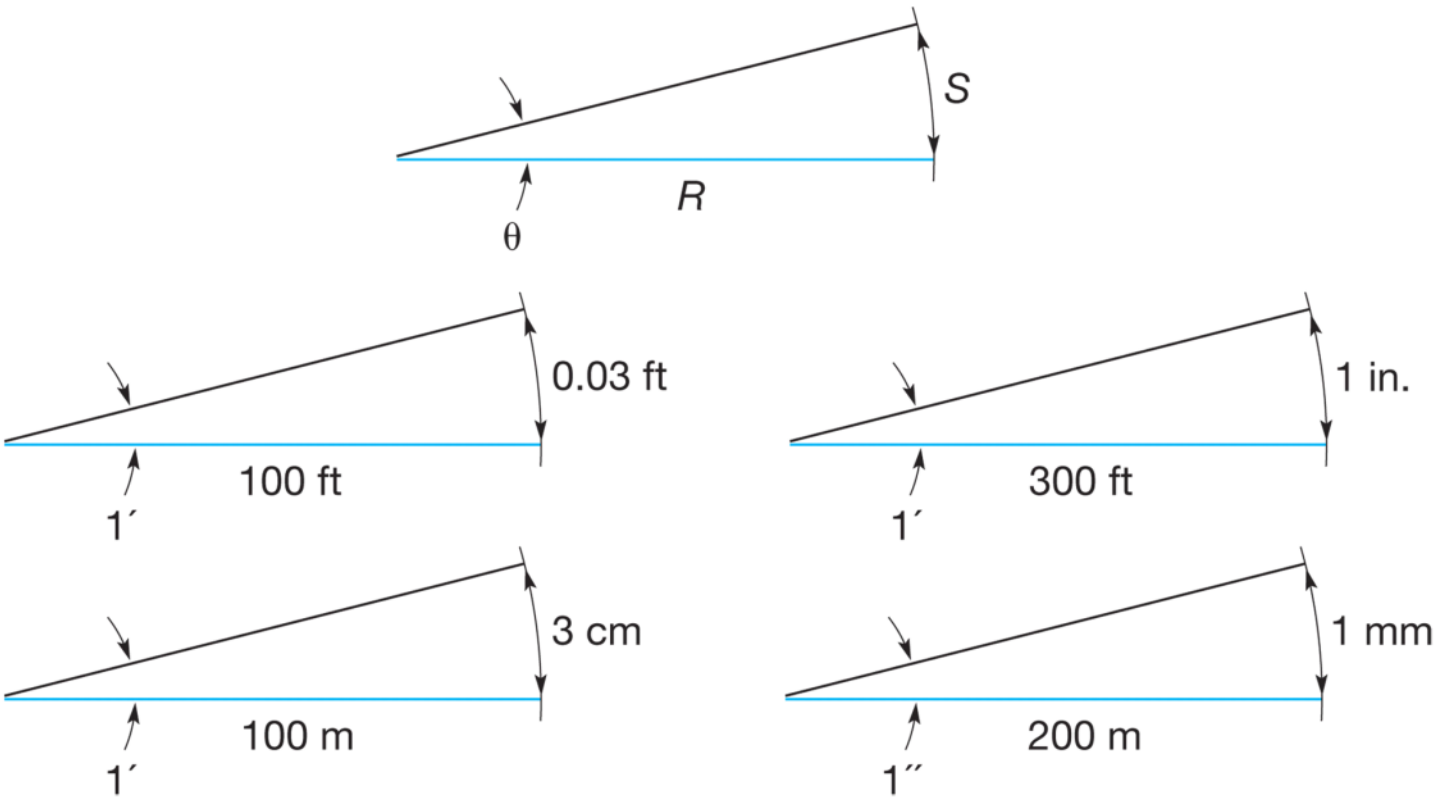


Transportation in the field		Transportation to and from the field

Angle and Distance Relations

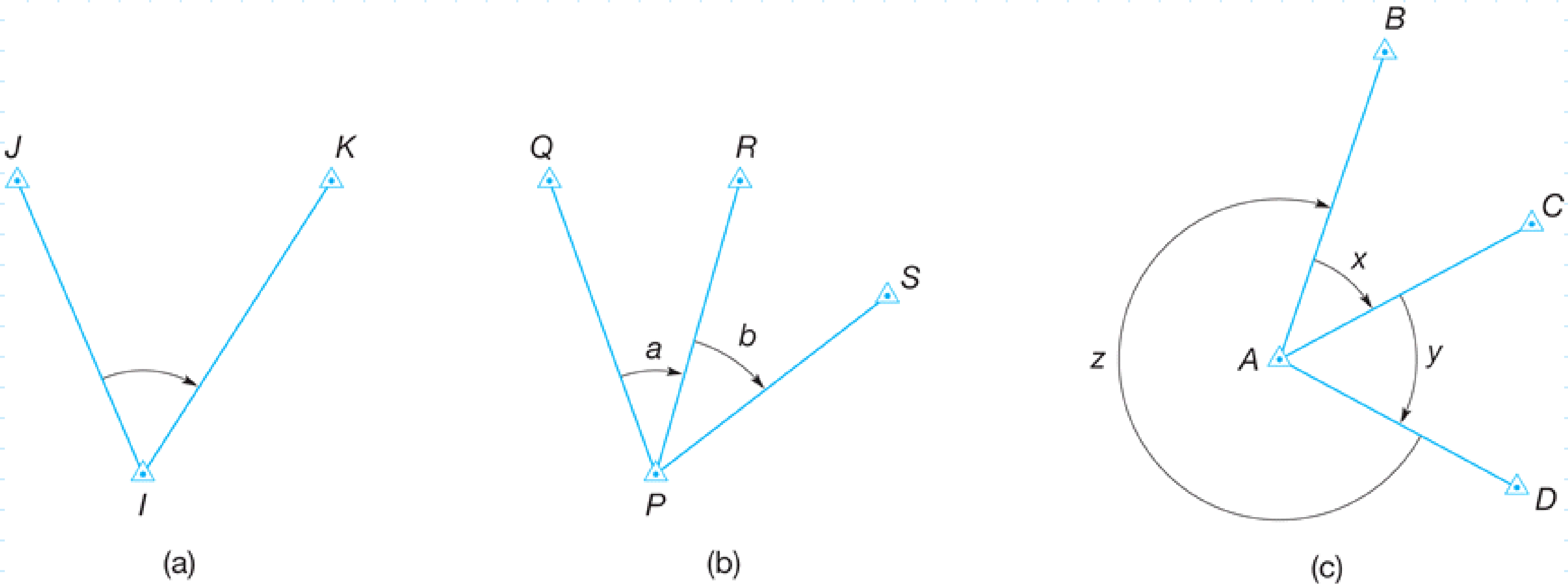
Monday, March 2, 2020 9:39 AM

Figure 8.8 Angle and distance relationships.



Measurement of Horizontal Angles

Monday, March 2, 2020 9:39 AM



Estimating Horizontal Angles by Repetition

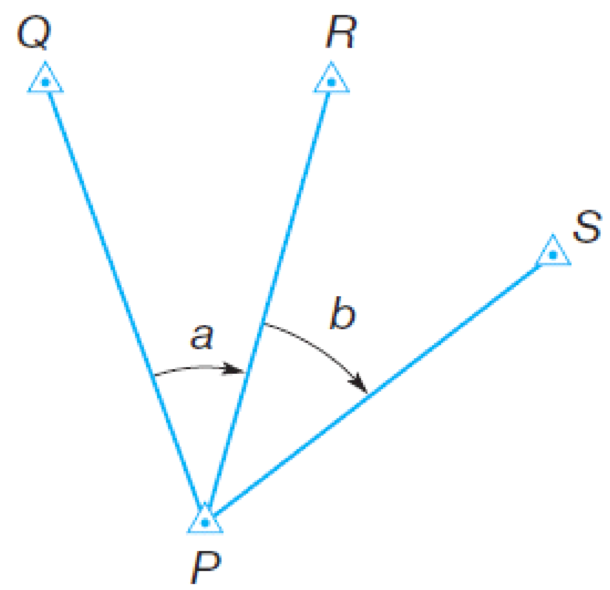
Monday, March 2, 2020 9:39 AM

HORIZONTAL ANGLE MEASUREMENT

(1)	(2)	(3)	(4)	(5)	
Angle	Face			Mean	
		° ′ ″	° ′ ″	° ′ ″	
JIK	I	66 37 40	66 37 42		
	II	66 37 40	66 37 48	66 37 40	

Field Notes for Measuring Directions

Monday, March 2, 2020 9:39 AM



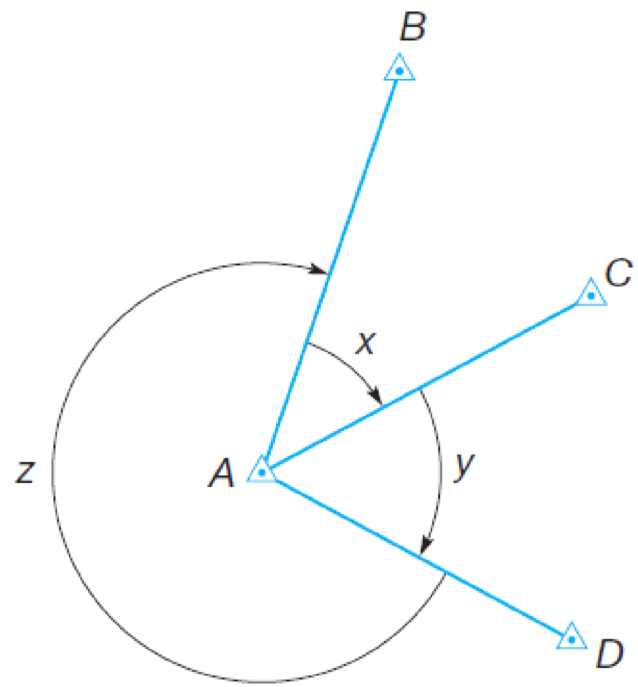
(b)

DIRECTIONS OBSERVED FROM STATION P

Repetition No.	Station Sighted	Reading Direct	Reading Reverse	Mean	Angle
(1)	(2)	(3)	(4)	(5)	(6)
		° ′ ″	° ′ ″	° ′ ″	° ′ ″
1	Q	0 00 00	0 00 00	0 00 00	
	R	37 30 27	37 30 21	37 30 24	37 30 24
	S	74 13 42	74 13 34	74 13 38	36 43 14
2	Q	0 00 00	0 00 00	0 00 00	
	R	37 30 32	37 30 28	37 30 30	37 30 30
	S	74 13 48	74 13 42	74 13 46	36 43 16
3	Q	0 00 00	0 00 00	0 00 00	
	R	37 30 26	37 30 26	37 30 26	37 30 26
	S	74 13 36	74 13 40	74 13 38	36 43 12
4	Q	0 00 00	0 00 00	0 00 00	
	R	37 30 34	37 30 30	37 30 32	37 30 32
	S	74 13 48	74 13 44	74 13 46	36 43 14

Field Notes for Measuring Directions

Monday, March 2, 2020 9:39 AM

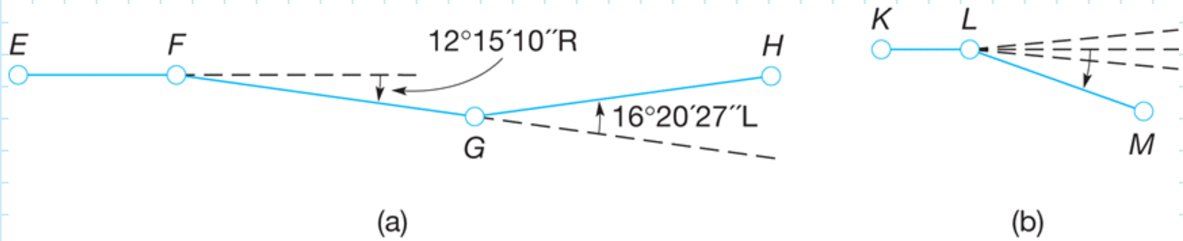


CLOSING THE HORIZON
AT STATION A

Position No.	Station Sighted	Reading Direct	Reading Reverse	Mean	Angle
(1)	(2)	(3)	(4)	(5)	(6)
		° ′ ″	° ′ ″	° ′ ″	° ′ ″
1	B	0 00 00	0 00 00	0 00 00	
	C	42 12 12	42 12 14	42 12 13	42 12 13
	D	102 08 26	102 08 28	102 08 27	59 56 14
	B	0 00 02	0 00 02	0 00 02	257 51 35
				Sum	360 00 02
2	B	0 00 00	0 00 00	0 00 00	
	C	42 12 12	42 12 14	42 12 13	42 12 13
	D	102 08 28	102 08 28	102 08 28	59 56 15
	B	0 00 04	0 00 04	0 00 04	257 51 36
				Sum	360 00 04
3	B	0 00 00	0 00 00	0 00 00	
	C	42 12 14	42 12 12	42 12 13	42 12 13
	D	102 08 28	102 08 26	102 08 27	59 56 14
	B	0 00 04	0 00 00	0 00 02	257 51 35
				Sum	360 00 02
4	B	0 00 00	0 00 00	0 00 00	
	C	42 12 14	42 12 12	42 12 13	42 12 13
	D	102 08 32	102 08 28	102 08 30	59 56 17
	B	0 00 04	0 00 04	0 00 04	257 51 34
				Sum	360 00 04

Deflection Angles

Monday, March 2, 2020 9:39 AM



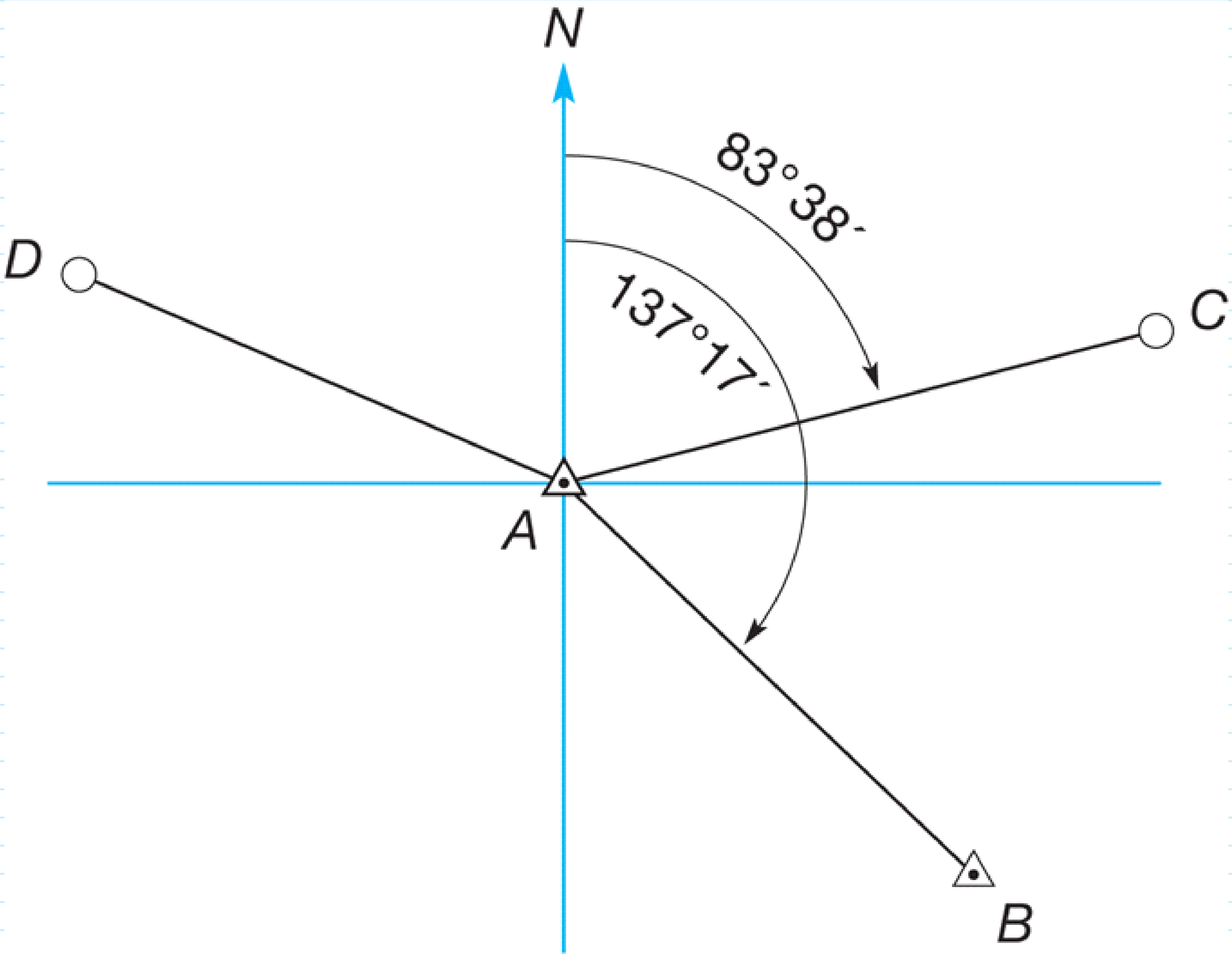
A deflection angle is a horizontal angle observed from the prolongation of the preceding line, right or left, to the following line. In Figure 8.13(a) the deflection angle at *F* is 12°15′10″ to the right (12°15′10″R), and the deflection angle at *G* is 16°20′27″L.

DEFLECTION ANGLES

Sta	BS/FS Sta	Reps	Circle Rdg	Mean	Right/Left
			° ′ ″	° ′ ″	
F	E	1	12 15 12		
		2	12 15 10		
		3	12 15 10		
	G	4	12 15 08	12 15 10	R
G	F	1	16 20 28		
		2	16 20 26		
		3	16 20 26		
	H	4	16 20 28	16 20 27	L

Orientation by Azimuths

Monday, March 2, 2020 9:39 AM



Observing Vertical Angles

Monday, March 2, 2020 9:39 AM

A vertical angle is the difference in direction between two intersecting lines measured in a vertical plane. Vertical angles can be observed as either altitude or zenith angles. An altitude angle is the angle above or below a horizontal plane through the point of observation. Angles above the horizontal plane are called

plus angles, or *angles of elevation*. Those below it are *minus angles*, or *angles of depression*. Zenith angles are measured with zero on the vertical circle oriented toward the zenith of the instrument and thus go from 0° to 360° in a clockwise circle about the horizontal axis of the instrument.

Most total station instruments are designed so that zenith angles are displayed rather than altitude angles. In equation form, the relationship between altitude angles and zenith angles is

$$\text{Direct mode} \qquad \alpha = 90^\circ - z \tag{8.2a}$$

$$\text{Reverse mode} \qquad \alpha = z - 270^\circ \tag{8.2b}$$

where z and α are the zenith and altitude angles, respectively. With a total station, therefore, a reading of 0° corresponds to the telescope pointing vertically upward. In the direct mode, with the telescope horizontal, the zenith reading is 90°, and if the telescope is elevated 30° above horizontal, the reading is 60°. In the reverse mode, the horizontal reading is 270°, and with the telescope raised 30° above the horizon it is 300°. Altitude angles and zenith angles are observed in trigonometric leveling and in EDM work for reduction of observed slope distances to horizontal.

Example 8.1

A zenith angle was read twice direct giving values of 70°00′10″ and 70°00′12″, and twice reverse yielding readings of 289°59′44″ and 289°59′42″. What is the mean zenith angle?

Solution

Two pairs of zenith angles were read, thus $n = 2$. The sum of direct angles is 140°00′22″ and that of reverse values is 579°59′26″. Then by Equation (8.3)

$$\begin{aligned}\bar{z}_D &= \frac{140^\circ 00'22''}{2} + \frac{2(360^\circ) - (140^\circ 00'22'' + 579^\circ 59'26'')}{2 \times 2} \\ &= 70^\circ 00'11'' + 0^\circ 00'03'' = 70^\circ 00'14''\end{aligned}$$

Note that the value of 03″from the latter part of Equation (8.3) is the index error.

Sights and Marks

Monday, March 2, 2020 9:39 AM

Objects commonly used for sights when total station instruments are being used only for angle observations include prism poles, chaining pins, pencils, plumb-bob strings, reflectors, and tripod-mounted targets. For short sights, a string is preferred to a prism pole because the small diameter permits more accurate sighting. Small red and white targets of thin plastic or cardboard placed on the string extend the length of observation possible. Triangular marks placed on prisms as shown in Figure 8.16(a) provide excellent targets at both close and longer sight distances.

An error is introduced if the prism pole sighted is not plumb. The pole is kept vertical by means of a circular bubble. [The bubble should be regularly checked for adjustment, and adjusted if necessary (see Section 8.19.5)]. The person holding the prism has to take special precautions in plumbing the pole, carefully watching the circular bubble on the pole. Bipods like the one shown in Figure 8.16(b) and tripods have been developed to hold the pole during multiple angle observation sessions.

(a)

Principle of Reversion & Double Centering

Monday, March 2, 2020 9:39 AM

On route surveys, straight lines may be continued from one point through several others. To prolong a straight line from a backsight, the vertical cross wire is aligned on the back point by means of the lower motion, the telescope plunged, and a point, or points, set ahead on line. In plunging the telescope, a serious error can occur if the line of sight is not perpendicular to the horizontal axis. The effects of this error can be eliminated, however, by following proper field procedures. The procedure used is known as the *principle of reversion*. The method applied, actually double reversion, is termed *double centering*. Figure 8.17 shows a simple use of the principle in drawing a right angle with a defective triangle. Lines OX and OY are drawn with the triangle in "normal" and "reverse" positions. Angle XOY represents twice the error in the triangle at the 90° corner, and its bisector (shown dashed in the figure) establishes a line perpendicular to AB.

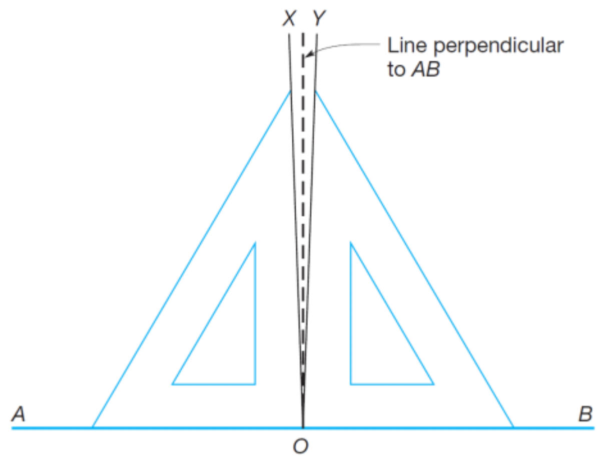


Figure 8.17 Principle of reversion.

To prolong line AB of Figure 8.18 by double centering with a total station whose line of sight is not perpendicular to its horizontal axis, the instrument is set up at B. A backsight is taken on A with the telescope in the direct mode, and by plunging the telescope into the reverse position the first point C' is set. The horizontal circle lock is released, and the telescope turned in azimuth to take a second backsight on point A, this time with the telescope still plunged. The telescope is plunged again to its direct position and point C'' placed. Distance $C'C''$ is bisected to get point C, on line AB prolonged. In outline form, the procedure is as follows:

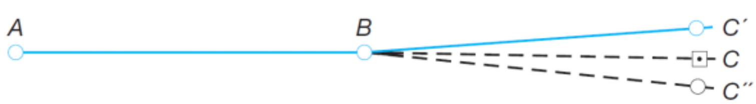


Figure 8.18 Double centering.

1. Backsight on point A with the telescope direct. Plunge to the reverse position and set point C'.
2. Backsight on point A with the telescope still reverse. Plunge to a direct position and set point C''.
3. Split the distance $C'C''$ to locate point C.

Traversing

Monday, March 2, 2020 9:39 AM

Closed Traverse

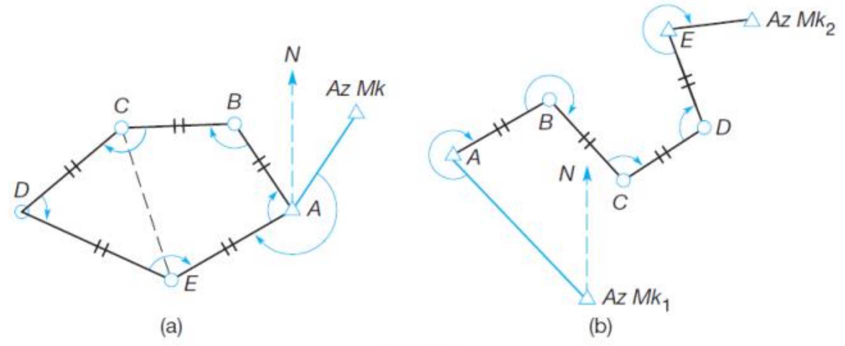


Figure 9.1
Examples of closed traverses.

Open Traverse

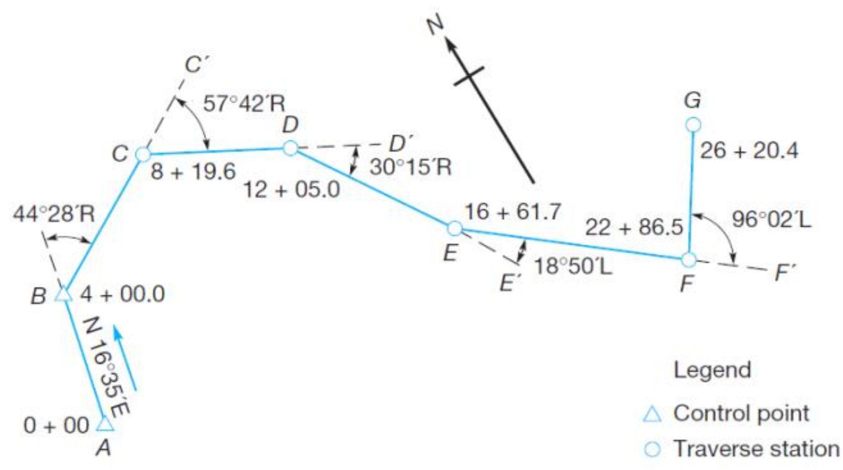


Figure 9.2
Open traverse.

An open traverse (geometrically and mathematically open) (Figure 9.2) consists of a series of lines that are connected but do not return to the starting point or close upon a point of equal or greater order accuracy. Open traverses should be avoided because they offer no means of checking for observational errors and mistakes.

Traversing Field Notes

Monday, March 2, 2020 9:39 AM

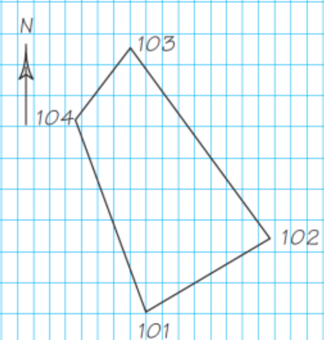
First, each station that is occupied is identified, and the heights of the total station instrument and reflector that apply at that station are recorded. Then horizontal circle readings, zenith angles, horizontal distances, and elevation differences observed at each station are recorded. Notice that each horizontal angle is measured twice in the **direct mode**, and twice in the **reversed mode**. As noted earlier, this practice eliminates instrumental errors and gives repeat angle values for checking.

TRAVERSING WITH A TOTAL STATION INSTRUMENT

Sta. Sighted	D/R	Horiz. Circle	Zenith Angle	Horiz. Dist.	Elev. Diff.
Instrument at sta 101					
h_e=5.3		h_r=5.3			
104	D	0°00′00″	86°30′01″	324.38	+19.84
102	D	82°18′19″	92°48′17″	216.02	−10.58
104	R	180°00′03″	273°30′00″		
102	R	262°18′18″	267°11′41″		
Instrument at sta 102					
h_e=5.5		h_r=5.5			
101	D	0°00′00″	87°11′19″	261.05	+10.61
103	D	95°32′10″	85°19′08″	371.65	+30.43
101	R	180°00′02″	272°48′43″		
103	R	275°32′08″	274°40′50″		
Instrument at sta 103					
h_e=5.4		h_r=5.4			
102	D	0°00′00″	94°40′48″	371.63	−30.42
104	D	49°33′46″	90°01′54″	145.03	− 0.08
102	R	180°00′00″	265°19′14″		
104	R	229°33′47″	269°58′00″		

Topo Control Survey
19 Oct. 2000
Cool, Sunny, 48° F
Pressure 29.5 in.
Total Station #7
Reflector #7A
M.R. Duckett–⊼
N. Dahman –ϕ
T. Ruhren –N

Sketch



M. R. Duckett

Figure 9.6 Example traverse field notes using a total station instrument.

Traverse Misclosure

Monday, March 2, 2020 9:39 AM

9.7 ANGLE MISCLOSURE

The angular misclosure for an interior-angle traverse is the difference between the sum of the observed angles and the geometrically correct total for the polygon. The sum, Σ, of the interior angles of a closed polygon should be

$$\Sigma = (n - 2)180^\circ \tag{9.1}$$

where n is the number of sides, or angles, in the polygon. This formula is easily derived from known facts. The sum of the angles in a triangle is 180°; in a rectangle, 360°; and in a pentagon, 540°. Thus, each side added to the three required for a triangle increases the sum of the angles by 180°. As was mentioned in Section 7.3, if the direction about a traverse is clockwise when observing angles to the right, exterior angles will be observed. In this case, the sum of the exterior angles will be

$$\Sigma = (n + 2)\,180^\circ \tag{9.2}$$

Figure 9.1(a) shows a five-sided figure in which, if the sum of the observed interior angles equals 540°00′05″, the angular misclosure is 5″. Misclosures result from the accumulation of random errors in the angle observations. Permissible misclosure can be computed by the formula

$$\boxed{c = K\sqrt{n}} \tag{9.3}$$

where n is the number of angles, and K a constant that depends on the level of accuracy specified for the survey. The Federal Geodetic Control Subcommittee (FGCS) recommends constants for five different orders of traverse accuracy: *first-order, second-order class I, second-order class II, third-order class I, and third-order class II*. Values of K for these orders, from highest to lowest, are 1.7″, 3″, 4.5″, 10″, and 12″, respectively. Thus, if the traverse of Figure 9.1(a) were being executed to second-order class II standards, its allowable misclosure error would be $4.5''\sqrt{5} = \pm 10''$.

The algebraic sum of the deflection angles in a closed-polygon traverse equals 360°, clockwise (right) deflections being considered plus and counterclockwise (left) deflections, minus. This rule applies if lines do not crisscross, or if they cross an even number of times. When lines in a traverse cross an odd number of times, the sum of right deflections equals the sum of left deflections.

A closed-polygon azimuth traverse is checked by setting up on the starting point a second time, after having occupied the successive stations around the traverse, and orienting by back azimuths. The azimuth of the first side is then obtained a second time and compared with its original value. Any difference is the misclosure. If the first point is not reoccupied, the interior angles computed from the azimuths will automatically check the proper geometric total, even though one or more of the azimuths may be incorrect.

Although angular misclosures cannot be directly computed for link traverses, the angles can still be checked. The direction of the first line may be determined from two intervisible stations with a known azimuth between them, or from a sun or Polaris observation, as described in Appendix C. Observed angles are then applied to calculate the azimuths of all traverse lines. The last line's computed azimuth is compared with its known value, or the result obtained from another sun or Polaris observation. On long traverses, intermediate lines can be checked similarly. In using sun or Polaris observations to check angles on traverses of long east-west extent, allowance must be made for *convergence of meridians*. This topic is discussed in Section 19.12.2.

Trigonometric Leveling

Monday, March 2, 2020 9:39 AM

A set of notes from trigonometric leveling is shown in Figure 8.23. Column (a) lists the backsight and foresight station identifiers and the positions of the telescope [direct (D) and reverse (R)] for each observation; (b) tabulates the backsight vertical distances, (BS+); (c) lists the backsight horizontal distances to the nearest decimeter; (d) gives the foresight vertical distances, (FS−); (e) lists the foresight horizontal distances to the nearest decimeter; and (f) tallies the elevation differences between the stations, computed as the difference of the BS vertical distances, minus the FS vertical distances. The observed elevation difference between stations A and E is 8.405 m.

TRIGONOMETRIC LEVELING NOTES

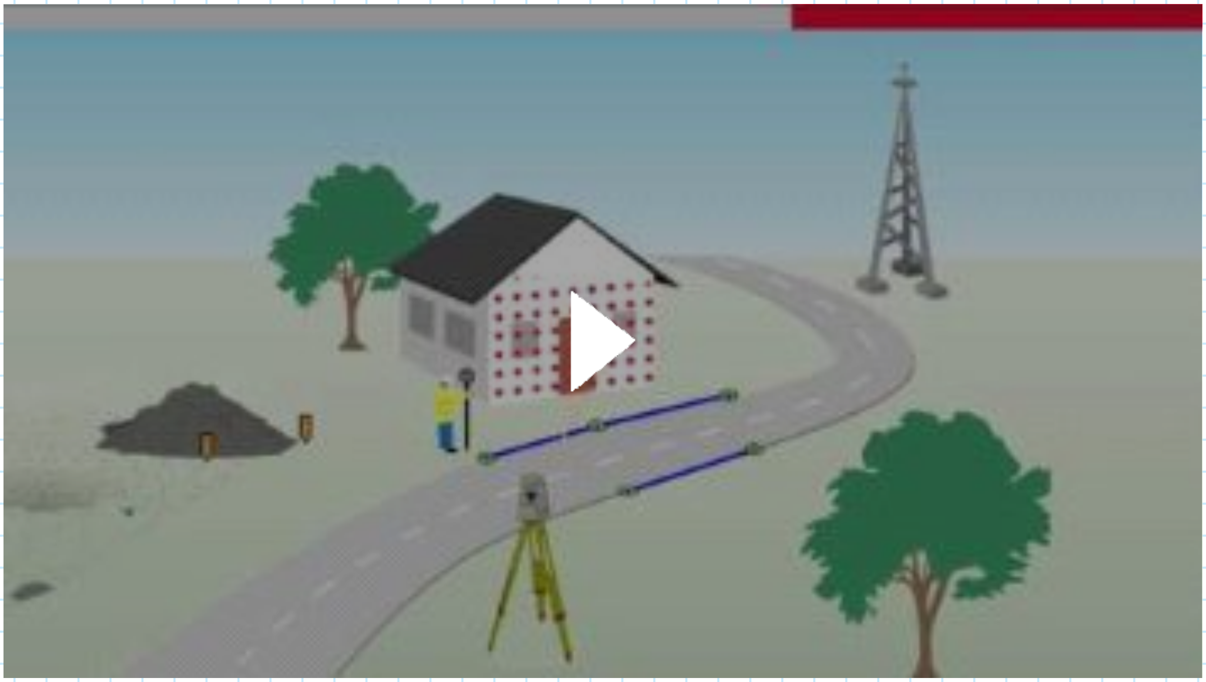
(a) Sta/Pos	(b) BS(+)	(c) BD	(d) FS(−)	(e) FD	(f) ΔElev
A					
D	1.211	98.12	1.403	86.34	
D	1.210		1.403		
R	1.211		1.404		
R	1.211		1.403		
Mean	1.2108		1.4033		−0.192
B					
D	−5.238	101.543	−9.191	93.171	
D	−5.236		−9.191		
R	−5.238		−9.193		
R	−5.237		−9.192		
Mean	−5.2373		−9.1918		3.954
C					
D	4.087	73.245	−3.849	97.392	
D	4.088		−3.851		
R	4.086		−3.849		
R	4.087		−3.849		
Mean	4.0870		−3.8495		7.936
D					
D	3.214	89.87	6.507	97.392	
D	3.214		6.507		
R	3.214		6.508		
R	3.215		6.507		
Mean	3.2143		6.5072		−3.293
E					
				Sum	8.405

Figure 8.23
Trigonometric leveling field notes.

Robotic Total Station - Introduction

Monday, March 2, 2020 9:39 AM

[Introduction to robotic total stations]



https://www.laserinst.com/focus-35-robotic-total-station/?sku=SUMR-35003

GPS Technology

Monday, March 2, 2020 9:39 AM

• **GPS** receiver-based systems are ideal for larger jobsites, and accuracy requirements of 8 millimeters (0.03 feet). Since they depend on satellite signals they work best on sites with a reasonably unobstructed view of the sky. They can be used on a pole or mounted on a vehicle. As a pole mounted system, GPS systems are ideal for moving about on the job site collecting a lot of data—grade checking, measuring volumes, doing as-builts and more. As a vehicle mounted system, GPS systems provide supervisors with a view of the job site and the job progress comparable to what the operator using machine control sees. Today's GPS receivers typically track all the major satellite constellations—GPS, GLONASS, Galileo and Compass—and are referred to as "GNSS receivers". Because they are tracking more satellite constellations, GNSS receivers can provide better coverage and performance even in tough environments—near buildings, under tree canopy or in deep cuttings or mines—than a GPS only receiver.

From <https://www.constructionequipment.com/blog/site-positioning-gps-or-total-stations>

How to Use GPS for Land Surveying

Land surveying involves gathering information about the positions of certain points as well as the angles and distance between them. Through the use of certain instruments, surveyors can create maps, establish property lines, and gather important information for architects, engineers, and developers.
The accuracy of land surveying measurements is dependent on the quality of the instruments used to gather the data. With the invention of GPS technology, land surveyors are now able to make complex calculations more quickly and accurately than ever before.

What Is GPS and How Is It Used in Land Surveying?
GPS stands for global positioning system, and it uses signals from satellites to pinpoint a location on the Earth's surface. In addition to transmitting information about location, GPS can provide data about velocity and time synchronization for various forms of travel. GPS uses at least 24 separate satellites in a system that consists of six Earth-centered orbital planes, each having four satellites.
Generally speaking, GPS has five key uses:

1. Determining a position (location)
2. Moving from one place to another (navigation)
3. Monitoring the movement of a person or object (tracking)
4. Creating a map of an area (mapping)
5. Making precise time measurements (timing)

GPS Survey Equipment (cont.)

Monday, March 2, 2020   9:39 AM

The Global Positioning System was originally developed for military use but has been readily available for civilian use since the 1990s. In addition to its use in mobile devices and car navigation systems, GPS is used for land surveying.

Surveying was one of the first commercial adaptations of GPS technology. It can provide accurate latitudinal and longitudinal location information regardless of weather conditions and without the need for measuring angles and distances between points. Though GPS makes surveying possible in nearly any location, it does have its limits.

What Are the Best GPS Instruments for Land Surveying?

GPS survey equipment makes it possible to obtain location, distance, and height measurements almost instantaneously – the only requirement is that the instrument has a clear view of the sky to receive signals from GPS satellites clearly. When used properly, GPS for land surveying offers the highest level of accuracy and is much faster than conventional surveying techniques.

Different types of GPS land survey equipment are used for different purposes, though there are three methods of GPS measurement used most often by surveyors:

1. **Static GPS Baseline** – This method is used to determine the coordinates for survey points by simultaneously recording GPS observations over both a known and unknown survey point for at least 20 minutes. The data is then processed to determine coordinates within 5mm accuracy.
2. **Real-Time Kinematic (RTK) Observations** – In this method, one receiver remains open over a known point (the Base Station) while another receiver moves between different positions (the Rover Station). Using a radio link, the position of the Rover Station can be calculated within a few seconds, ensuring a similar level of accuracy to baseline measurements as long as they are within 10km of the Base Station.
3. **Continuously Operating Reference Stations (CORS)** – In this system, a survey grade GPS receiver is permanently installed in a particular location as a starting point for any GPS measurements in the area. GPS survey equipment can collect field data and combine it with CORS data to accurately calculate positions.

Certain instruments are required for proper implementation of GPS land surveying methods. Here is a quick summary of the most common GPS land survey instruments:>

GPS Survey Equipment (cont)

Monday, March 2, 2020 9:39 AM

- **GPS Receiver** – This instrument is required to receive signals from GPS satellites in order to make calculations. These instruments come with a variety of optional features such as multiple band channels, built-in Bluetooth and Wi-Fi technology, and OLED displays.
    - **GPS Rover Rods** – These instruments can be used to extend the rover's reach. They can be made from a variety of durable materials and come in different lengths.
    - **GPS Poles** – Used to mount GPS surveying equipment, these poles are typically lightweight but durable and come in different lengths.
    - **GPS Bipods/Tripods** – For greater stability in mounting GPS equipment, bipods and tripods come in adjustable lengths and numerous sizes.
    - **GPS Antennae** – This piece of equipment makes it possible for GPS systems to receive signals from satellites. Many systems come with an internal antenna, but you can purchase external antennas to boost the signal.
    - **Total Station** – A combination of an electronic theodolite, electronic distance measuring (EDM) device, and software running on an external computer, a total station is used to calculate the coordinates of survey points using angles and distances. It may also incorporate GPS technology to produce more accurate results.

The cost of a GPS land surveying system varies depending on the type and number of receivers you choose. A GPS receiver ranges from $4,000 to over $10,000, and the software itself costs upwards of $400. Additional equipment such as rover rods, poles, and tripods may increase the overall cost.

GPS Survey Equipment (cont)

Monday, March 2, 2020 9:39 AM

The Pros and Cons of GPS for Land Surveying

The Global Positioning System changed the world of land surveying in many ways, most of them good. There are, however, some downsides to this type of equipment. Here is a quick summary of the pros and cons for GPS land surveying:

Pros

- It offers a higher level of accuracy than conventional surveying methods
- Calculations are made very quickly and with a high degree of accuracy
- GPS technology is not bound by constraints such as visibility between stations
- Land surveyors can carry GPS components easily for fast, accurate data collection
- Some GPS systems can communicate wireless for real-time data delivery

Cons

- GPS land surveying equipment requires a clear view of the sky to receive satellite signal
- Interference from dense foliage and other structures can limit function and communication
- All GPS survey equipment is subject to failure from dead batteries and system malfunction
- Special equipment may be required and can be costly

The world of land surveying is constantly changing as new technology replaces old. Commercial survey equipment has made leaps and bounds over the past few decades and, with the help of GPS technology, will only become faster and more accurate over time.

Used properly, GPS for land surveying offers the highest level of accuracy and is much faster than conventional surveying techniques. We break down the details.

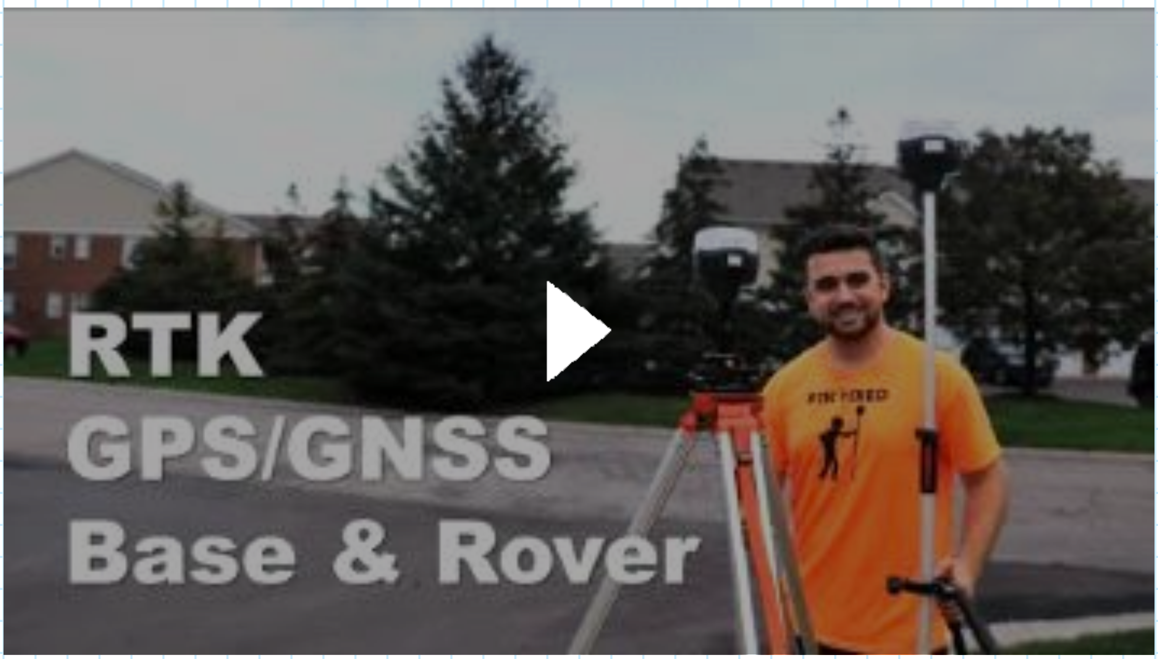
From <https://www.baselineequipment.com/gps-land-surveying-equipment>

How Does GPS/GNSS Work

Monday, March 2, 2020 9:39 AM

[What is GPS/GNSS]

[RTK GPS/GNSS with Base and Rover]



Mapping & Surveying with RTK Drones

Monday, March 2, 2020 9:39 AM

[Drone Surveying for Beginners]

WEB ODM

Monday, March 2, 2020 9:39 AM