The Ames Instrument Student Compass

User's Manual

171 Otsego Road, Canajoharie, NY 13317

The Ames Instrument Student Compass

Introduction:

In response to many requests for a more affordable but fully functional instrument for educational purposes, Ames Instrument Company is pleased to introduce the Student Model Compass.

The Student Model is our modern interpretation of an instrument known in the 1700s and 1800s in America as a "Plain Compass" or "Circumferentor". The Plain Compass filled the needs of a rapidly expanding nation, applying the best technology of the times to the need for legally defined boundaries and borders.

Using basic arithmetic and simple geometry along with the plain compass, the land surveyor of earlier times was able to perform his duties with acceptable precision. Those same qualities make it an admirable tool for instruction in the basic principles of geometry.

Your Student Model compass is sturdily constructed from aluminum and brass and is carefully machined to assure precision equal to or exceeding most instruments of the colonial and early Federal eras.

*In keeping with surveying tradition, the standard degree ring is divided into 90-degree quadrants and is graduated to single degree accuracy. The "E" and "W" cardinal points are transposed on the compass face, facilitating the taking and recording of compass readings. **

You'll find that it's an excellent tool to take outdoors for work in the field and it's equally at home in a classroom environment.

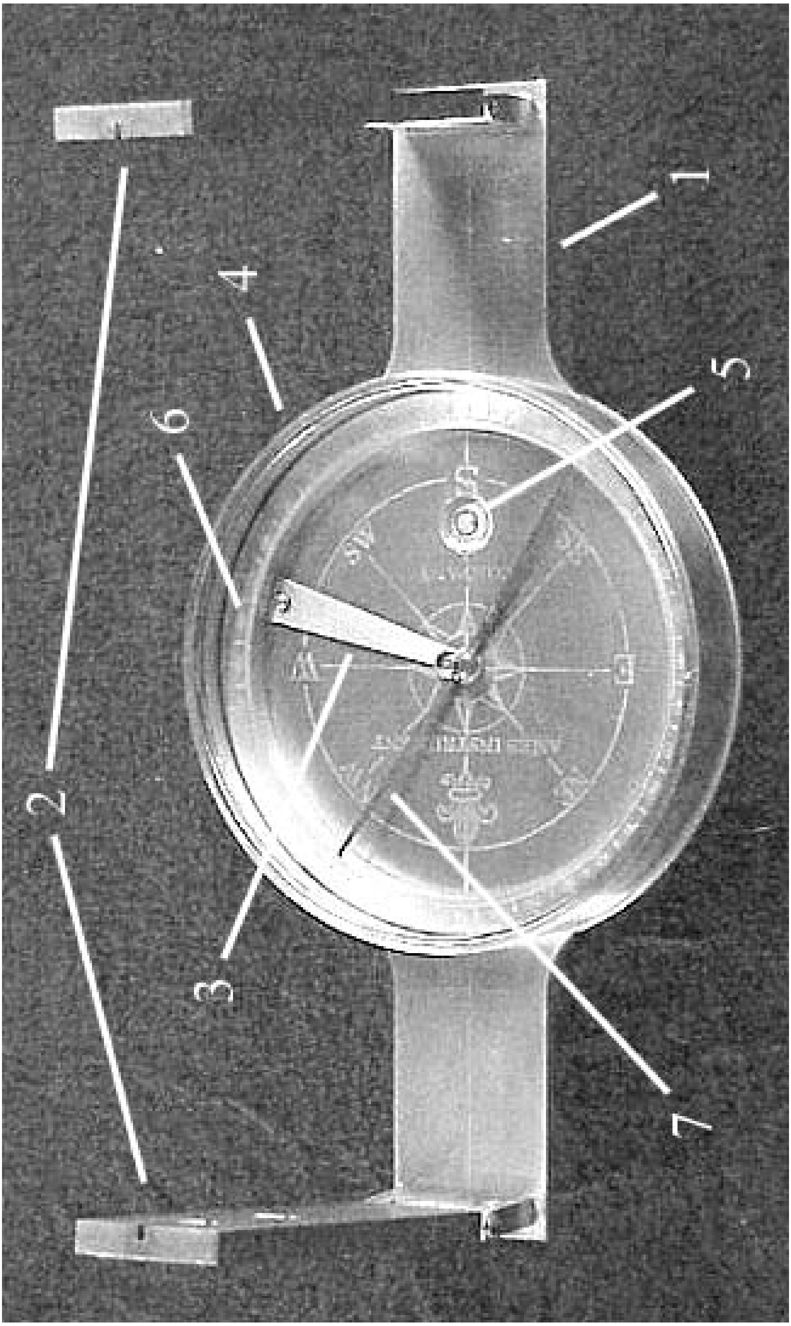
The following sections will explain how to use and care for your Student Model Compass.

* see page 5 for more detail

<u>A Note for the middle school instructor:</u>

At a minimum, Middle School students will require a basic understanding of the following study areas in order to receive maximum benefit from surveying-themed instruction using the Student Model Compass:

- simple four function arithmetic
- basic geometric principles
    - angles and angle measurement in degrees
    - basic knowledge of simple plane geometric figures, including how to calculate area
        - polygons
        - triangles
        - circles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Understanding your Ames Student Compass and Tripod:

The compass:

1 - compass platform – the compass platform forms the foundation for the instrument. On the base of the foundation, you'll find the socket for the mounting spindle and the brass knob for the needle lifter.

2 - sight vanes – the sight vanes are a part of the foundation and are hinged for improved transport and storage. When erected, they are used to align the instrument.

3 - needle lifter – even with the jeweled bearing, continued rotation of the needle will eventually cause wear to the pivot pin, increasing friction and decreasing needle response and accuracy. The needle lifter is used to "lift" the needle off the pivot when the instrument is not in use, prolonging needle pivot life. Turning the lifter screw clockwise raises the needle while a counterclockwise turn releases it.

4 - compass "box" – the compass "box" surrounds the internal parts of the compass itself. The box is covered at the top by a glass that is held in place by a threaded bezel ring that may be unscrewed for compass maintenance. Within the compass box, you'll find:

5 - bulls-eye level – this integral level at the south end of the compass face simplifies the leveling of the instrument platform prior to taking a reading. In practice, the tripod legs are adjusted until the bubble is centered in the level.

6 - degree ring or "chapter" ring – the degree ring has a circular scale calibrated in degrees. There are two calibration options available: the Quadrant Format (standard) and the optional Azimuth Format.

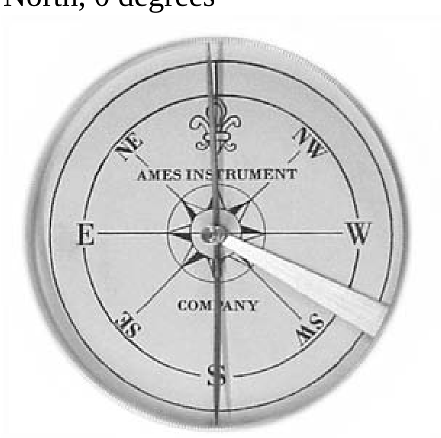
The Quadrant Format is divided into four 90-degree quadrants. The Azimuth Format is laid out in a 360-degree circle. An explanation of how to use the quadrant format in taking a bearing will be found on Page 9.

compass rose/face with directions – the compass rose is that part that most people associate with a compass. It's divided into the eight cardinal points with a traditional "Fleur-de-Lis" delineating the North point.

Why are E & W reversed?

Newcomers to the plain compass are surprised to find the East and West markers in what appears to be reversed positions. There's a simple explanation: it's a feature that actually makes it easier to take a reading from your compass.

The following figure shows a compass face. The needle is pointing north and the user is looking north with the south end of the compass face nearest his eye. He will read his bearings from the degree ring and from the compass rose beneath the tip of the needle… in this case, he can record that bearing as North, 0 degrees



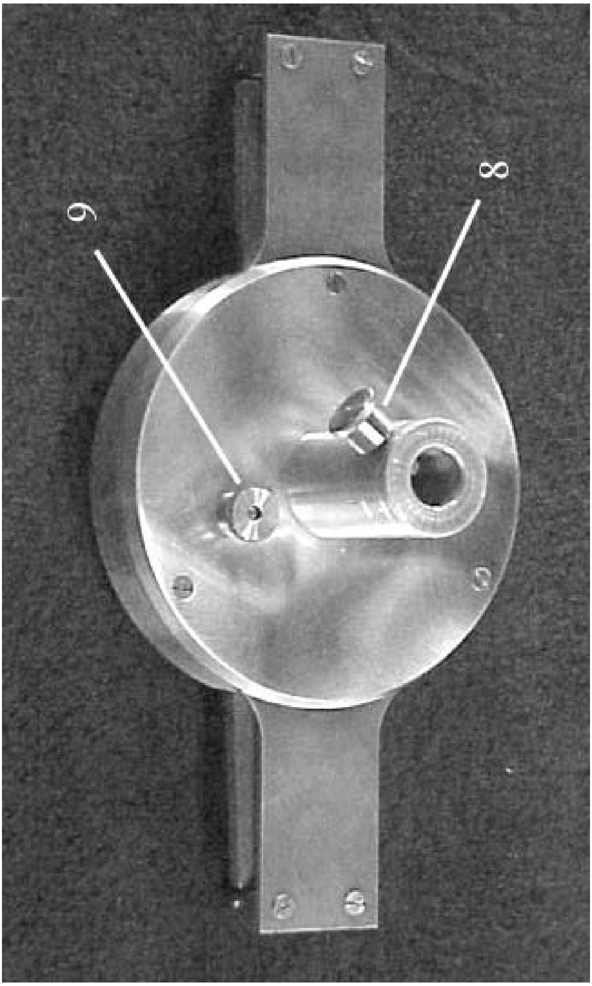
Now, let's assume that he wants to turn the platform and sights of the compass so we are looking northwest… that means we'll need to rotate the compass platform counterclockwise 45 degrees as in this figure.

Note that when we do so, the needle doesn't rotate, keeping its northerly alignment (that's what compass needles do!) The illustration shows that the reversal of E & W places the correct direction (northwest in this example) under the needle.

7 - the needle and it's features – the needle is also a familiar part of a compass. Made of magnetized steel, it is attracted to the earth's magnetic pole.

- Counterweight – you'll notice that one end of the needle has a small wrapping of copper wire. The wire is there as a counterweight, allowing the needle to be balanced to correct for magnetically induced "needle dip". Magnetic needles not only point North they dip toward the North. The amount of dip varies with location. You should assure that the needle is level within the compass when the bulls-eye level indicates that the compass platform is level.

<u>the jeweled bearing</u> – at the central point of the needle is a jeweled bearing that provides a super hard surface to ride on the needle-like point of the compass pivot. This bearing will prolong the life of the pivot point and reduce friction.



8 - spindle and spindle setscrew – your Ames Student Compass sits on the tripod spindle. Once aligned, the setscrew may be tightened to maintain the alignment.

9 - needle lifter screw – this screw controls the needle lifter.

- provision to hang a plumb bob – beneath the spindled you'll find a hole for suspension of a plumb bob, should you choose to use one. The plumb bob would be used to assure accurate alignment over a point on the ground.

The Tripod

- tripod legs – the tripod legs are made of Phillipine Mahogany

Putting your Ames Student Compass to work:

You may find some or all of the following accessories useful with your Student Compass:

- a linear measuring device, which may be:
  - a tape measure
  - traditional surveying measuring chains (available from AIC)
- chaining pins (also available from AIC, or make your own from 7/16" dowels. These are aids in marking progress in taking linear measurement.
- stakes for corners, Point of Origin, and Point of Beginning
- a rod (you can make your own from a 6 foot hardware store industrial broom handle)

Understanding Magnetic Deviation and Local Variation

Despite the reliance placed on it for many centuries the magnetic compass has an inherent flaw… it points to the earth's magnetic pole, not the true pole. To compound this issue, the magnetic pole isn't static but moves gradually from year to year… and not always in a predictable direction. [1] While this deviation created issues for surveyors who wished to use a magnetic compass, it is of little importance for those using the Ames Student Compass for instruction in geometry.

Should you wish to demonstrate the difference between "true north" and magnetic north, you'll find two methods based on simple observation in the appendix at the end of this manual.

Local variation is an influence on the compass needle caused by local forces… perhaps a high iron content in the soil. Theses variations may be so localized that they affect only a single reading in a survey. The following section describes a simple check for local variation.

General operation: Taking a bearing with your Ames Instrument Student compass

Reading a Compass Bearing

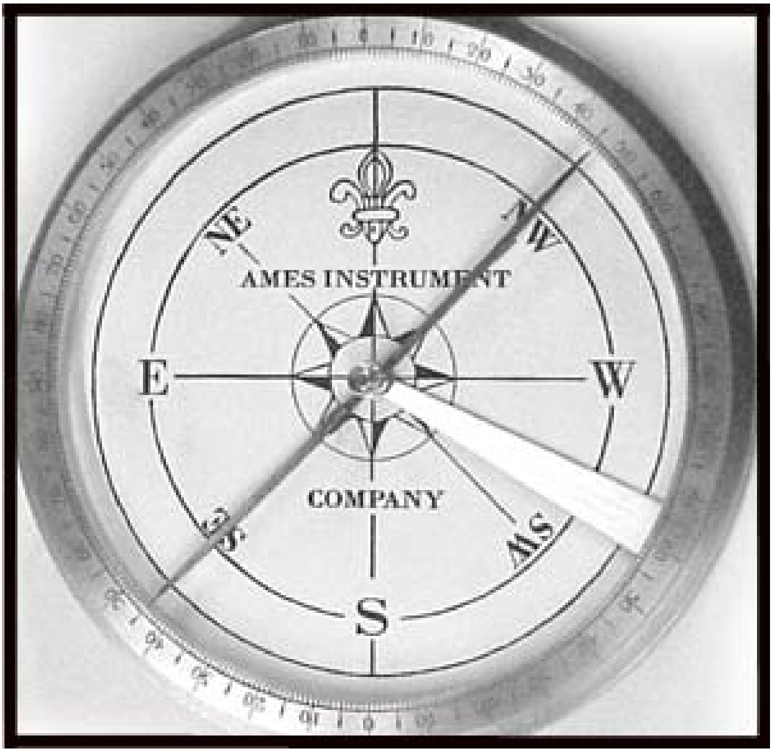
In taking bearings with your Ames Student Compass you should form a habit of doing so with the same end of the compass nearest your eye. Most choose to have the South end of the face nearest them. If you've chosen to keep the South end of the compass face closest to your eye, you'll always take your bearing reading from the North end of the

[1] At present the magnetic pole is located in northern Canada. It's heading generally northwards at an average of about 10 kilometers per year, but it's accelerating. In a few decades the magnetic pole may be in Siberia.

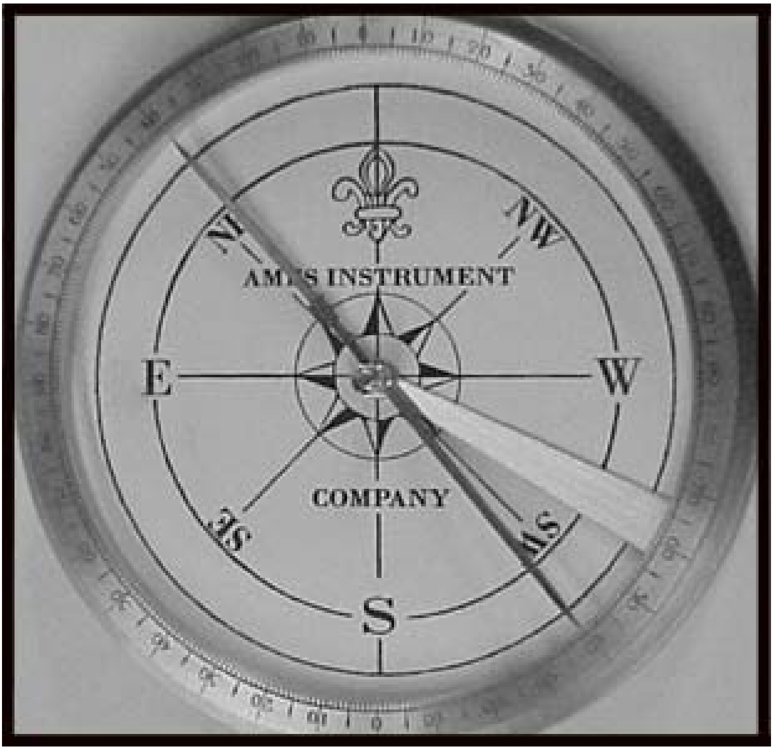
magnetic needle. (You'll recall that the South end of the needle has a counterweight that makes it easy to tell one end from the other.)

In reading the compass bearing, first notice whether the North end of the needle lies within the northern or southern hemisphere of the compass face. Record that information as "N" or "S". Next record the numeric bearing indicated by the position of the North end of the needle along the degree ring. For example let's say it points to "47 ½ °". Finally, note whether the North end of the needle is in the eastern or western quadrant and record that. Such a reading might be N 47 ½ ° W.

The examples on the following pages should make reading a quadrant type bearing clear.



If you have taken your bearings with the S end of the compass nearest your eye, you will read your results from the N end of the needle. Remember that the counterweight is on the S end of the needle. In the example above, the N end of the needle is in the northern hemisphere of the compass face, so we record the first part of the bearing as “N”. Next we note that the needle is pointing at the 45 degree mark on the degree ring, so we add the 45 to our recorded bearing. Finally we note that the N end of the needle is in the western quadrant of the hemisphere, so we complete our recorded bearing by adding a W. The end result is N 45 W. Bearings may be recorded to a ¼ of a degree with a bit of estimation.



In this example, note that the N end of the needle lies in the southern hemisphere and is pointing toward the 40 degree mark on the degree ring, and is in the western quadrant, therefore our bearing is S 40 W.

1. Making a simple traverse survey with your Student Compass

A traverse survey is one that proceeds around the periphery of the figure to be measured and/or laid out, measuring each angle and distance in turn. A traverse survey typically proceeded clockwise around the boundaries, although there is no requirement that it be done so.

The process begins by locating a “point of beginning” (POB) that is usually one of the corners of the figure you intend to lay out. You should mark this spot with a small stake or any object that will serve the purpose.

In accomplishing a survey, the surveyor would set up his compass over the POB, often using a plumb bob to assure that the compass was indeed over the mark. He’d also make sure the compass was level by using the integral bull’s-eye level as an indicator.

Having determined the direction to proceed he would sight through the vanes of his compass to the next “station” and record the compass bearing to that point in hemispherical notation. (see pg. 9). E.g. northeast would be recorded as North 45E East, ...i.e., 45E east of north and would be written as “N 45 E.” (Note: if you have chosen the “azimuth” compass face, hemispherical readings are unnecessary and the direct reading should be recorded.)

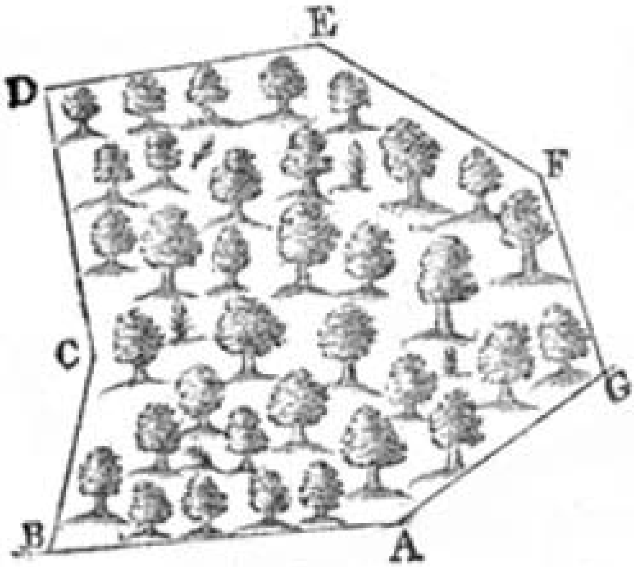
Although it’s not a common occurrence, an important task while using any magnetic compass is to check for local magnetic anomalies that might affect your readings. You can do this by setting the instrument up at the second station and sighting back to the first station. If there are no magnetic anomalies, this “backsight” reading will be a reciprocal of the first. [2]

Once the presence or absence of a magnetic anomaly is determined, the next task is to determine distance between the stations or along a line. Historically, the “chain crew” was equipped with a chain of known length and a set of 10 “chaining pins” or “arrows”. The chain in most common use was a 66-foot chain of 100 links, or its 33-foot, 50 link variant. This chain’s main recommendation was that a 66-foot square area equals 1/10 of an acre. Therefore, land measured in units of a 66 foot chain and links was easily “cast up” into acreage.

The process of taking bearings and measuring distances and descriptions of each corner or “station” continued until the figure was “closed” by returning to the beginning.

Note: For any polygonal figure bordered with straight lines, a quick check for angular closure can be made by totaling the included angles. They should total the number of sides minus 2 multiplied by 180 degrees… e.g. a quadrilateral figure should have angles totaling (4 – 2) X 180 degrees, or 360 degrees.

[2] If a magnetic anomaly is found, the surveyor had to find which station was affected and by how much and make corrections accordingly. It might be that the entire area would be subject to disorienting magnetic anomalies to the point that the compass wasn’t usable.

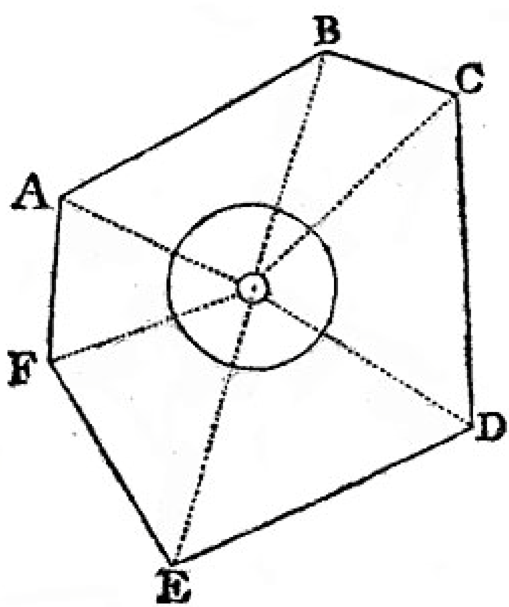


A “Traverse Survey” from an illustration in John Love’s 1768 edition of *Geodaesia* . The surveyor would have begun at station A then proceeded to B and so on until he had returned to his starting point.

2. Making a radial survey from a single point when you can see all corners of the field

Not all surveys were carried out as traverse surveys. In some cases other methods were easier due to difficulties imposed by terrain.

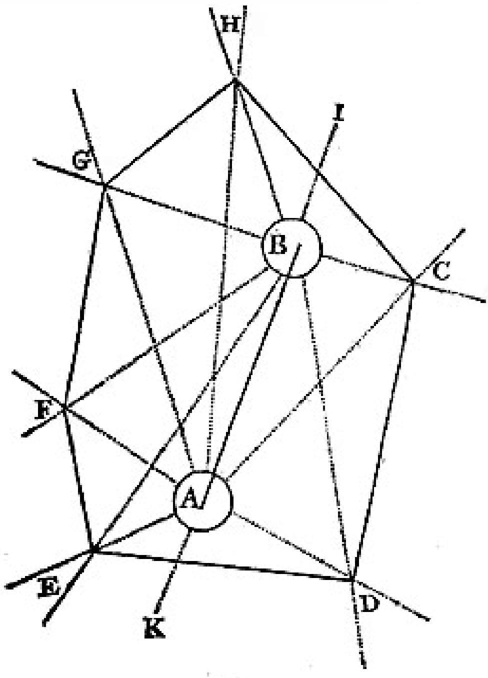
One such alternate method is a radial survey in which all bearings are taken from a single central point. Recording the bearings and the distances from the central point to each station provides sufficient information for a map of the property to be drawn to scale. The measurements around the perimeter can then be taken off by scale or by trigonometry.



An illustration of a radial survey from the 1768 edition of John Love's *Geodaesia*. The surveyor would have set his instrument in the center of the field.

3.Making a radial survey from two points, requiring only a single measurement – triangulation

Occasionally, it isn't possible to see all the corners of a tract of land from a single point or intervening terrain may make it difficult to measure the distance on the ground. In such a case, the tract may be mapped to scale by taking bearings from two points that are a known distance apart and then "triangulating" those stations that can be viewed from both. Those stations that can be "triangulated" don't need to have their distances measured on the field, as they can be determined from the scale drawing.



A radial survey with two centers from *Geodaesia*. In this illustration all stations can be triangulated to scale as long as distance A – B and all bearings are known.

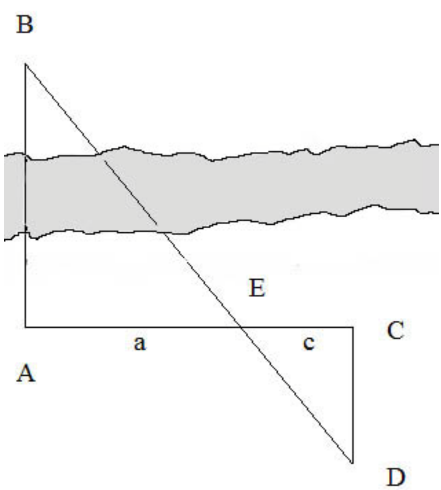
4. Measuring an impassible distance by means of Euclid's theory of equivalent triangles without the use of trigonometry.

Euclid, Book Six, Proposition Four

In equiangular triangles the sides about the equal angles are proportional where the corresponding sides are opposite the equal angles.

Occasionally an impassible object intervenes in a tract survey. Usually the distance can be ascertained by use of triangulation and a scaled drawing. Alternatively, the distance can be determined in the field by use of Euclid's theory of equivalent triangles.

In the following drawing, a river separates points A and B, however, the distance between them is desired.



In resolving this problem, we begin by creating a line, A-C that lies at a 90-degree angle to line A-B. Then measuring along that line any distance to point E, where a stake is driven. Then continue along the line toward C. At some point on C, another stake is placed and a 90-degree bearing is taken in the opposite direction toward D.

Walking along the line C-D a third stake is placed where point B can be viewed in line with point E. We have now established two equivalent triangles, within which line A-E is to Line C-E as line A-B (our desired distance) is to line C-D.

NOTE: if line C-E is intentionally made some simple fraction of line A-E, (e.g. ½ or ⅓) the calculation of the proportion of line A -B to line C – D will be made easier.

<u>"Content of Ground"</u>

When all the field measurements had been taken, the surveyor drew up a map (know as a "plat") that included all the data and a written description of each corner, adjoining properties, orientation, and the area enclosed. The enclosed area was called "the content of ground".

If your survey has enclosed a regular figure such as a triangle or a square, your students should have little difficulty in calculating the area. But many surveys contained irregular, multi-sided tracts of land. The surveyor of early times would have calculated the area of these difficult shapes by dividing the plat into triangles, then calculating the areas of each and adding the results.

To accomplish this, your students will need to be able to take scaled measurements from a scaled map.

Appendix: Simple methods for calculating True North

The Equal Angle method –
One method used by the early surveyors was still in use by air force navigators well into the 20th century.

Given that the earth's rotational speed is for all practical purposes a constant, if the observer has not made a major change in location, the elevation of the sun in the sky an hour before noon will be exactly equal to its elevation an hour after noon. In turn the shadows cast by any object will be equal in length at these times. This is known as the "equal angle rule".

Suppose that the surveyor has erected a vertical stake at some time around 10:00 a.m., about 2 hours before noon. At that time he noted the length of the shadow, marking the end of its extent and using the shadow's length as a radius to draw a semicircle around the stake.

About 2 hours after noon, as the sun proceeds on its passage across the sky, the shadow will again attain the same length, its tip again touching the circle. If the surveyor will mark this second tangent point, a line drawn between the two points of equal sun angle will be found to be a true east-west line. A perpendicular to this line will therefore be a true north-south line.

The advantage of this method is that it can be accomplished in daylight and can be done with a minimum of observation.

Observation of the North Star – I
Locating the North Star, or Polaris, is a well-known method of determining north. However, this method is imprecise as Polaris is not directly above the North Pole. Its apparent variation from true north causes it to rotate in a small circle with a radius of about 44 minutes of 1 degree from the

celestial pole, a total side-to-side deviation of 1 degree and 34 minutes.

Early surveying manuals suggest hanging a plumb line and observing the maximum east and west movements of Polaris in its circle, then taking the average of the two as being true north. This same result can be obtained by observing and noting the highest or lowest elevations, these both appearing when Polaris is true north of the observer.

The disadvantage of both methods is that they require considerable time spent in observation.

Observation of the North Star – II

Given the rotation of Polaris around the celestial pole described above and the time required for definitive measurement, surveyors sought shortcuts. One such shorter method of observation was to note when Polaris was in vertical alignment with one of the more prominent stars in the constellation Cassiopeia: “Ruchbah” or “d Cassiopeiae”. This star is at the bottom of the larger side of the “W”. When Polaris is thus aligned it is on the true north meridian. Once more a plumb line, or some other indicator of verticality would be required.

Solar observation – a daylight method

Most people realize that for the few moments when the Sun reaches its highest point in the sky, it’s due south of the observer. This is the basis of the daily “noon sight” in navigation. Continued angle measurements are needed to determine the exact time that the sun is at its highest elevation.

Of course any shadows cast when the sun is at its highest elevation will be the shortest of any time during the day. A surveyor could track the shadow of any object, or he might erect a stake for the purpose. A line drawn along the shortest shadow would be a true meridian line. This method, like the others, required considerable time spent in observation or required special equipment such as an octant or sextant.

The instructor may find determination of true north to be an interesting exercise for students.

A Table of Units of Measure & Conversions

Linear measure based on a Surveyor's Chain:
1 chain = 66 feet
1 chain = 4 "poles" of 16 ½ feet each
    - a pole = 25 links
1 chain = 100 links,
    - each link is 7.92"
80 chains = 1 mile = 5,280 feet

Square measure based on a Surveyor's Chain:
1 square chain = 1/10 of an acre = 4,356 square feet
1 square pole, called a "perch" = 1/160 of an acre
1 acre = 10 square chains = 43,560 square feet
- 1 acre = 100,000 square links
- 1 acre = 160 square poles, or perches

Care of your Ames Instrument Student Compass

Your Ames Instrument Student Compass is sturdily built and should give you years of service if given a bit of care.

- After every outing, we recommend that you wipe off the compass with a damp cloth and then dry it and store it in a safe place until it's needed again
.
- While being stored or transported the needle lifter should be engaged to lift the needle off its pivot and the sight vanes should be folded down to protect the glass. Inserting a piece of cardboard or similar material between the vanes and the glass will provide a bit of extra protection.

Compass Specifications:

Height of the compass: 8 inches.
Height with sights folded: 3-1/2 inches.
Outside dimensions: 10 inches long by 5 inches across.
Weight: approximately 2 lbs.
Height on tripod: from floor to glass: 50 to 52 inches depending on the set-out of the tripod legs.
Compass material: aluminum
Needle: 4 inch with jeweled hub bearing

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