Getting to the Point

Unit Topic:	Navigation
Grade Level:	7th grade (with suggestions to scale for grades 6 to 8)
Lesson No.	6 of 10
Lesson Subject(s):	Finding position by triangulation
Key Words:	Triangulation, Compass, Bearing

Lesson Abstract —

In this lesson, students learn how to determine location by triangulation. We describe the process of triangulation and practice finding your location on a worksheet, in the classroom, and outdoors.

The activities include:

- Classroom Triangles – Students will make compass measurements in the classroom to find their location on a map of the room.
- Topo Triangulation – Students will use triangulation on a topographic map to find a location given example measurements to landmarks shown on the map.
- Topos, Compasses, and Triangles, Oh My! – students will learn how to do actual triangulation using a compass, topographical (topo) map and view of outside landmarks.

Lesson Opening Topics / Motivation —

Ask the students how they would figure out their location if they were hiking along a trail in the middle of Rocky Mountain National Park. (Possible Answers: Look at a map, use a GPS receiver or a compass.) A map gives you information about an area, but it is up to you to figure out how your actual location matches up with what is shown on the map. You can use visual landmarks to help you figure out your approximate location on the map. You can also use a compass to help narrow down where you are on the map. Ask the students to think about how the compass can be used to find your location. (Answer: You will have to make measurements to landmarks.)

Imagine that you are out in the wilderness and you come to the top of a ridge. How can you identify the ridge on the topo map? How can you figure out where you are along the ridge? In this lesson, we will explore how to use triangulation to answer these questions.

Lesson Desired Student Outcomes —

Students will understand how to use a map and compass to do triangulation and determine their location.

Science: Students should be able to:

- Predict (hypothesize). (1)
- Describe how using and understanding maps and compasses can help determine your location. (5)

Math: Students should be able to:

- Draw a line at a specific angle
- Using a compass to measure both possible bearing angles of the line.

Colorado State Standards Met —

- Science Standard 1, 5.
- Math Standard 4, 5.

Lesson Background & Concepts for Teachers —

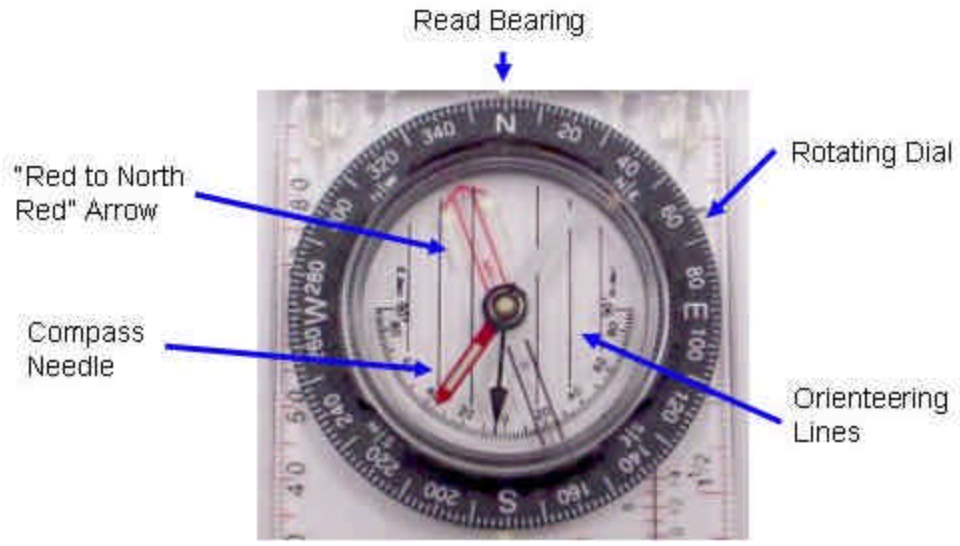
Overview

The following topics are discussed:

- Brief review of bearing measurements,
- Basic triangulation,
- Correcting for magnetic declination, and
- Using an orienteering compass with a topographical map.

Bearing Measurements

Details on using a compass to measure bearing were discussed in Lesson 5. As a reminder, a bearing is the direction to something measured as an angle relative to north. It increases as you turn toward the east, with north=0 degrees, east=90 degrees, south=180 degrees, and west=270 degrees.



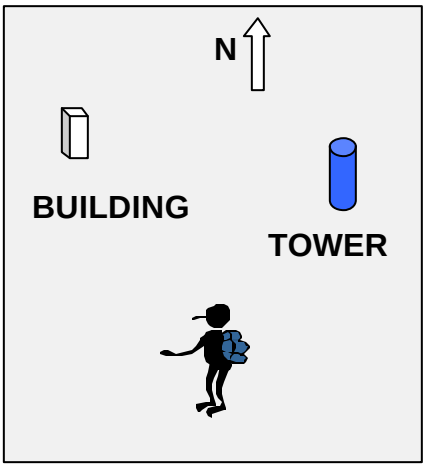
Source: Image created by M. Lippis, University of Colorado, Boulder, 2003.

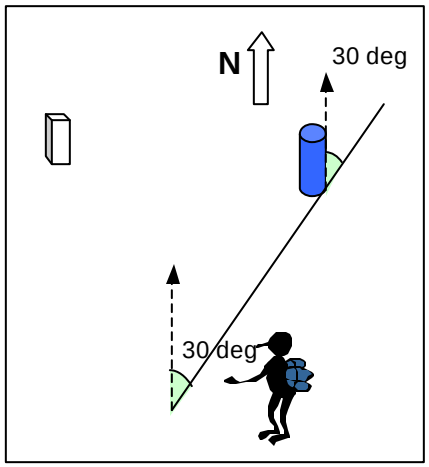
In this image, the black dial shows the bearing angle markings. The bearing will only read out correctly if you have the "N" on the dial aligned with the red arrow of the compass needle. After discussing the basics of triangulation, we will discuss a little about correcting for magnetic declination.

Basic Triangulation

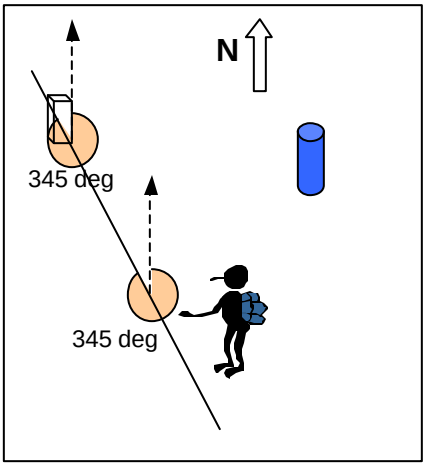
Triangulation is based on finding an unknown location using angle measurements to two known locations. Mathematically, the two known positions define the two vertices (and length of the one side) of a triangle and the two bearing measurements define two of the angles of the triangle. These three things fix the size and orientation of the triangle; thus putting the unknown position at the third vertex of the triangle. In practice, triangulation can be done easily on a map.

Imagine there are two landmarks, a building and a tower, at known locations (as illustrated at right). A lost pedestrian, named Fred, measures the bearing to the tower to be 30 degrees and the bearing to the building to be 345 degrees. To find his position on the map using triangulation, Fred would draw two lines, one through each of the landmarks. The line through the tower should be at an angle of 30 degrees relative to north (as shown below), and the line through the building should be drawn at an angle of 345 degrees. His location lies at the intersection of these two lines.

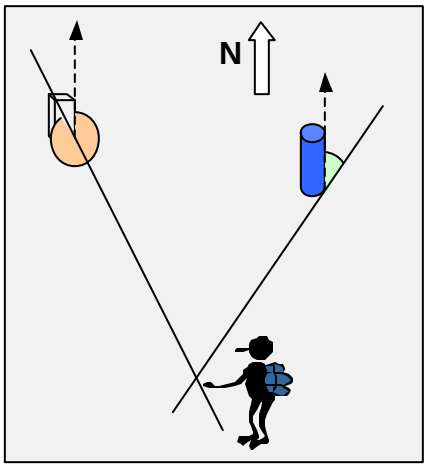




Fred reads a bearing of 30 degrees to the tower. He draws a line on the map through the tower at an angle of 30 degrees.

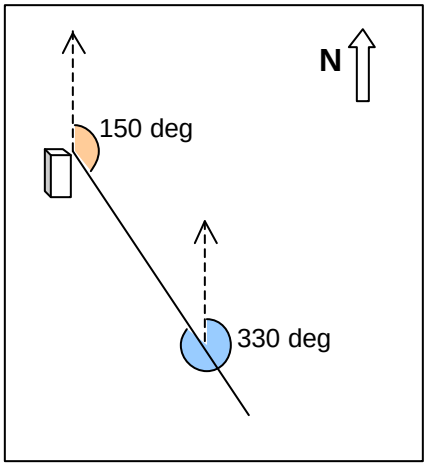


Fred reads a bearing of 345 degrees to the building. He draws a line on the map through the building at an angle of 345 degrees.

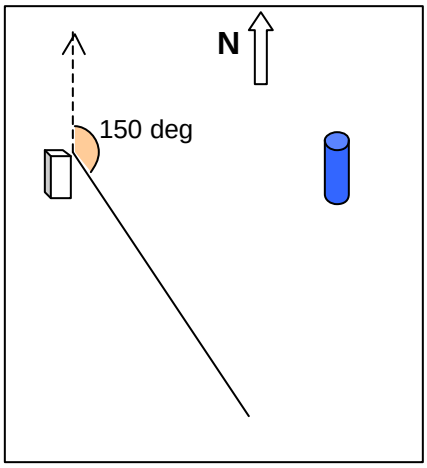


Fred is located at the intersection of the two bearing lines.

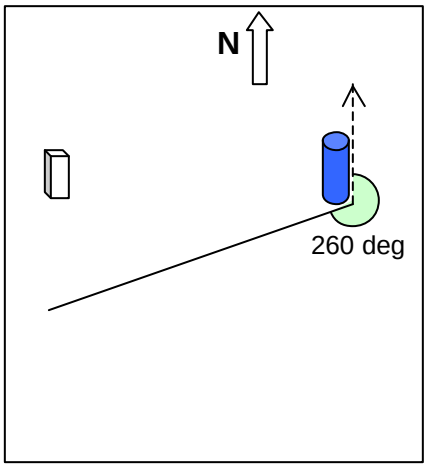
You can use the same approach to find the location of an unknown object by measuring the bearing to it from two known landmarks. For example, we have observers located at the building and the tower. Each measures the bearing to a car at an unknown location. In this example, the bearing to the car measured from the building is 150 degrees, and the bearing to the car measured from the tower is 260 degrees. To find the location of the car, we mark the building and tower locations on the map. Then, through each location we draw a line along the measured bearing as shown below. The car must be located at the intersection of the two bearing lines.



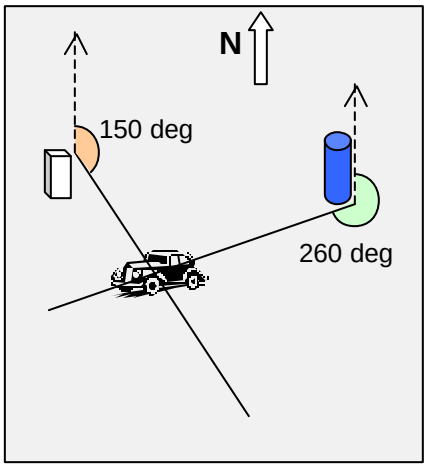
You will notice that the bearing measurements can be made at the landmark or at the unknown location. The difference between a bearing from the unknown location to the landmark, and from the landmark to the unknown location is always 180 degrees. That is why you can use the bearing measured at either location to draw the same line.



Bearing line at 150 degrees from building to unknown car location.



Bearing line at 260 degrees from tower to unknown car location.



The car location lies at the intersection of the two bearing lines.

Triangulation on a Topo Map

If you are navigating outdoors with the aid of a topo map and a compass, you can apply the triangulation technique to find your location on the map. Using the compass, you would take a bearing measurement to two visible landmarks such as hilltops, radio towers or other noticeable sites. A good strategy for triangulation is described below.

First, set the compass up for the bearing to one of the landmarks. To do this, you rotate the circle showing the directions until the correct bearing is shown along the arrow. Now, set the compass down on the map so that the long, straight edge lies on the landmark. Then, rotate the whole compass until the north mark is pointed up on the map (along the vertical lines), keeping the straight edge on the landmark. The arrow points along the correct bearing. Draw a line along the straight edge. Your position lies on this line. Repeat the same procedure for the second landmark. The point at which the lines intersect should be your location.

Source USGS website: http://mac.usgs.gov/mac/isb/pubs/factsheets/fs03501.html

Correcting for Magnetic Declination

In reality, there is one more step you have to take to triangulate on a topo map. When we use a compass to find a bearing with respect to north, we rely on the fact that the **geomagnetic** North Pole and the **geographic** North Pole are pretty close to each other. It turns out that the geomagnetic North Pole moves around pretty slowly relative to the geographic North Pole. In

2004 it is located approximately at 82.3° North and 113.4° West, (Refer to http://www.geolab.nrcan.gc.ca/geomag/northpole_e.shtml for more information.)

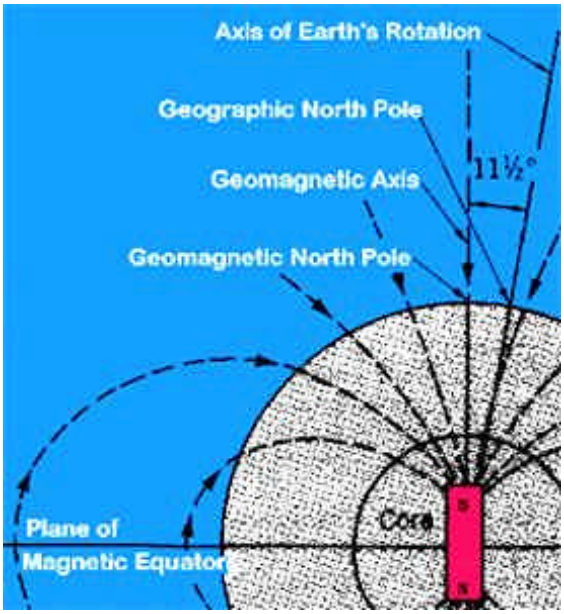


Image source: http://rst.gsfc.nasa.gov/Intro/Part2_1a.html

This means that a magnetic compass needle does not point exactly towards geographic north. The angle between geographic and magnetic north at a specific location is known as the magnetic declination.

Topo maps help us make adjustments for this. On a topographical map, near the legend, you will see a symbol like one of these:

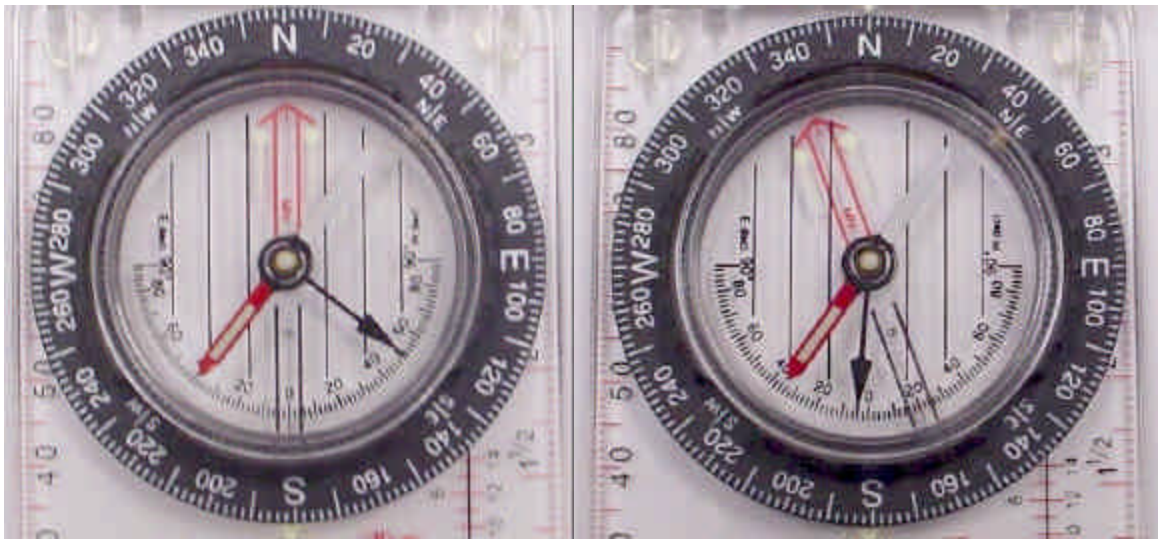
Image Source: http://mac.usgs.gov/mac/isb/pubs/factsheets/fs03501.html

This picture shows the magnetic declination for a map. The sense of the declination describes whether magnetic north is to the east or west of true north. For easterly declinations, a negative sign is shown. For western declinations a plus sign is shown. These signs indicate how to convert from the true bearing shown on the map to the compass bearing that you would need to follow. For example, in Boulder, Colorado in 2004, the declination is 10.4 deg East. This means that the direction of magnetic north is 10.4 deg east of true north. If a landmark on the topo map is at a (true) bearing of 10.4 deg, its magnetic bearing is 0 deg (10.4 – 10.4 deg). So to get there following a magnetic compass you would head off towards 0 deg as shown on your compass. For locations with westerly declination you would add the declination to the true bearing shown on the map to find the magnetic bearing to follow.

When you are using a compass and topo map to find location by triangulation you have to do the reverse. If you measure the bearing to an object with your compass, you have to add an easterly declination or subtract a westerly declination before drawing the bearing line on your map.

If you are working with a compass and map there are two types of adjustments you can make to correct for magnetic declination: temporary and permanent.

- *Temporary* – Work with true bearing on the map, and correct the compass measurements each time. For example, if you want to find your location on the map and you measure bearing using your compass to two landmarks, first adjust the bearing you measured before drawing the lines on the map. If the declination is easterly, add the declination to your reading before drawing the line. A compass bearing of 92 degrees in Colorado would be drawn as a line at 102 degrees on the topo map (92 plus 10). If the declination is westerly, subtract the declination from your measured compass bearing before drawing the line.
- *Permanent* – On some compasses, there is a permanent adjustment eliminating the need to add or subtract the declination. There will be a small screw adjustment on the backside of the compass. Turning the screw will change where the red outline arrow is pointing. To permanently adjust the compass, turn the screw until the "red-to-north-red" arrow points to the degree of declination. For example, if our declination is 15 west, turn the screw until the arrow is pointing 15 degrees to the west of north, or 345 degrees (360 minus 15). The pictures below show the compass before and after the declination has been corrected.

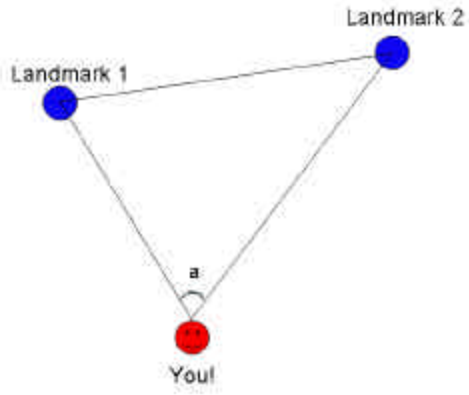


Source: Image created by Matt Lippis, University of Colorado, Boulder, 2003.

The left compass shows no declination correction. The red arrow is pointing directly north. The right compass shows a declination correction of 20 degrees west. The red arrow is pointing toward 340 degrees, which is 20 degrees west of north.

Using an Orienteering Compass with a Topographical Map

An orienteering compass is made specifically for use with topographical maps. By measuring the bearing to two or more landmarks with the compass, you can use the basic triangulation and magnetic declination techniques to find your position on the topo map.



Source: Image created by Matt Lippis, University of Colorado, Boulder, 2003.

1) Determine your declination. Either correct this permanently or just find it to be used later.
2) Find two landmarks on the map that are easily identifiable. Antenna towers or big mountains usually work best.
3) Find those landmarks outside, and take their bearings with your compass. Write these down on the map, possibly next to the landmark on the map. Make sure and correct for declination. If you permanently adjusted your compass, then this is already corrected for you, but if you only did the temporary adjustment, add or subtract that to your bearings.
4) On the map, find your first landmark. Draw a line from the landmark in the direction of the bearing for the first landmark. For example, if your first landmark was at a bearing of 30 degrees, draw a line angled 30 degrees from that landmark.
5) Do the same for the second landmark.
6) These two lines should intersect. You are (more or less) at the point where they intersect. Now you know where you are!

7) To get a more accurate location, you can measure a bearing to a third landmark. With three landmarks, the bearing lines do not all intersect at a single point, but their intersections should form a small triangle. Your location is within this triangle.

Lesson Vocabulary List —

- **Scale** – The ratio of a distance on a map versus the actual distance it represents.
- **Legend** – The feature of the map that gives important information about the map. Includes the scale, location and landmarks symbols used by the map.
- **Orientation**– Shows which direction is north on the map.
- **Elevation** – The height of a location. At sea level this would be 0 feet.
- **Topographical Map** – A map that includes elevation information. Usually used for outdoor travel.
- **Contour Lines** – Lines on a topographical map that show the elevation along that line.
- **Compass** – An instrument that uses a magnetized metal bar to indicate the direction of the earth's magnetic poles.
- **Bearing** – The direction in degrees that an object is at, such as a mountain or tree.

Activity Attachments —

Activity 1: Classroom Triangles – Students will make compass measurements in the classroom to find their location on a map of the room.

Activity 2: Topo Triangulation – Students will learn how to triangulate with just a map. True triangulation requires both a map and compass, but to simplify the activity and make it possible indoors, the compass information is given.

Activity 3: Topos, Compasses, and Triangles, Oh My! – Students will learn how to do actual triangulation using a compass, map and view of outside landmarks.

Lesson Closure and Follow-up —

Ask your students this question: "If you wanted to go somewhere you have never been to, how could you find your way there?" (Possible answer: Use a map.) Are all maps the same size? (Answer: No.) What tells us the size of a map and how much area it shows? (Answer: The scale.) Where on the map do we find the scale and other important information about the map? (Answer: In the legend.) Ask the students that if they were planning a trip outside, how could a topographical map help them? (Possible answer: It shows the elevation and other interesting features like mountains, rivers and vegetation.) If you were lost, could you find your location? (Possible answer: Yes, if you had a map and compass.) What is the method that you could use to find your location? (Possible answer: Triangulation.)

Lesson Assessment and Evaluation —

Pre-Lesson Assessment

- Discussion Question: Ask the students how they could figure out their location if they were hiking along a trail in the middle of Rocky Mountain National Park. (Possible Answers: Look at a map, use a GPS receiver or a compass.)

Post-Lesson Assessment

- Question/Answer: See "Lesson Closure and Follow-up" section above for questions.

Homework

- Internet Search: Have students find topographical maps on the Internet. Ask them to bring one in and share with the class during the next class period.

Lesson References —

For additional information on topo maps, please refer to the U.S. Geological Survey's website at: http://mac.usgs.gov/mac/isb/pubs/factsheets/fs03501.html.

For additional information on the magnetic field and magnetic declination : http://www.ngdc.noaa.gov/seg/geomag/
For information on the location of the magnetic pole: http://www.geolab.nrcan.gc.ca/geomag/northpole_e.shtml

Lesson 6: Activity 1 - Classroom Triangles

This activity is planned for 28 students.

Activity Materials List —

- 28 copies of Worksheet 1 – Classroom Triangles

Activity Equipment and Tools List —

- Pencils
- Compass
- Graph paper
- Ruler
- Tape measure

Activity Cost Estimate —

Less than $5 total

Activity Attachments —

None

Activity Time Estimate —

50 minutes

Activity Procedure —

Background

In Lesson 5, we learned how to take bearing measurements in the classroom and outdoors. Now we will use those measurements for triangulation. Students will work in teams of 2 or 3 to take bearing measurements to landmarks in the classroom (or other rooms in the school).

Before the Activity

Please note: you need to have made some bearing measurements to objects in the classroom from one location BEFORE your students can complete this activity. Take three bearing measurements of an object from one "mystery" location that the students will try to figure out.

Depending on the time available, you can create the classroom map ahead of time, or have the students do it. On a piece of graph paper create a scale that maps one square of the paper to a reasonable length in the classroom. You can use a tape measure, or if there are square tiles on the floor, you can count tiles and fractions of a tile.

Determine the direction to magnetic north in your classroom. Pick the wall that is most directly to the north as "classroom north." You should orient your classroom map so that the walls closest to north-south are on the left and right sides, and the closest to east-west walls are on the top and bottom. Draw a pseudo magnetic declination indication on your class map that shows which way magnetic north points with respect to your classroom north.

Draw the outline of the room on the paper, and mark several fixed landmarks that are easy to sight. Selecting objects that are roughly at waist to chest level for the students will make it easier to get accurate bearing measurements. You can use things like the edge of a desk, the doorknob, or the edge of the chalkboard. Alternatively you could hang up markers on the walls as your landmarks. Make sure that the landmarks are correctly placed on the "map," and make two or more copies for each team.

Practice taking a bearing measurement from one location in the classroom to each of the landmarks, making the "declination" adjustment and figuring out where you are.

With the Students

Hand out a copy of the classroom graph you created.

1. Illustrate how to draw a bearing line on the map through the landmark and how to find the intersection of two bearing lines. Identify the x, y (horizontal and vertical) coordinates of the intersection, and show them from where in the classroom the measurements were made.
2. Give the class bearing measurements that you made from an interesting point in the classroom to three landmarks. Have the students work in teams of two or three to figure out the location using triangulation.
3. Now have the students use a compass to take their own bearing measurements to classroom landmarks, and mark their location on the map. They can check their answers using a tape measure or by counting floor tiles.
4. Discuss the results of the activities. Ask the students how they decided which landmarks to use. How did this affect their results? (Answer: If the landmarks are almost along the same line, you do not get very reliable results. If the landmarks are at close to 90 degrees apart, you get the best results.) If you sited to three landmarks, how big was the triangle that bounded your position?

Math Skills Reinforced —

6^{th}, 7^{th} and 8^{th}: Identifying the intersection of two points, taking a bearing measurement, calculating simple triangulation and determining a landmark on a map

Activity Troubleshooting Tips —

When you draw the classroom map, make sure to leave space between the walls and the edge of the paper. If the classroom is very skewed relative to north, it might be very confusing to take accurate bearing measurements.

In part two, you can compute the bearing relative to classroom north using the measured locations of the landmarks in the classroom. This will be easier and more accurate since the students will not use a magnetic compass for this part anyway. On the other hand, you should probably check that the results are consistent.

For part three, you should check to see if your classroom has any unusual magnetic disturbances that might make the compass readings difficult.

Activity Assessment & Evaluation —

Pre-Activity Assessment

- Lesson Review: With students, review how to take a bearing. Pass out compasses to each student (or pair of students) and go over the steps of how to take a bearing, using the front of the classroom or the teacher's desk. Next, have students volunteer to explain how to take a bearing in their own words.

Activity Embedded Assessment

- Worksheet: Have students follow along with activity using attached worksheet.

Post-Activity Assessment

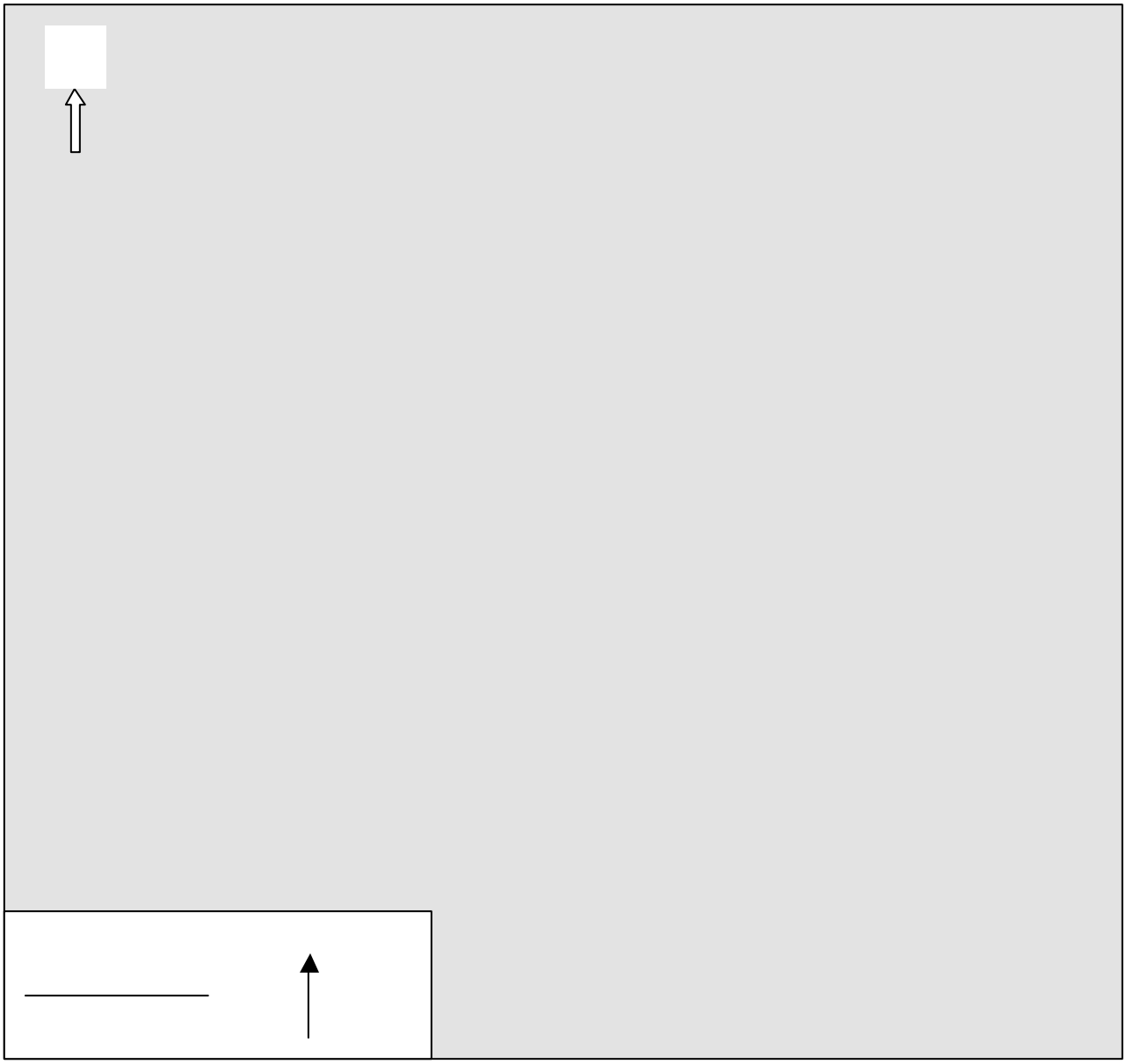
- Pairs Check: Trade worksheets with another student or student group. Have them check for location accuracy using their compass and the bearings listed in part 3.
- Discussion/Question: With the students, discuss the activity. Did they have trouble finding their location using two or three bearings?

Suggestions to Scale Activity for Grades 6 to 8 —

- 6^{th} Grade: Have students work in groups to do Worksheet 1.
- 7^{th} and 8^{th} Grade: Have students work alone to complete Worksheet 1.

Lesson 6: Activity 1, Worksheet 1 - Classroom Triangles

Your Name: _____ **Date:**_____



Landmark 1_____Bearing_____Corrected bearing_____

Landmark 2_____Bearing_____Corrected bearing_____

Landmark 3_____Bearing_____Corrected bearing_____

Unknown location coordinates x =_____y =_____

Unknown location name _____

Lesson 6: Activity 2 - Topo Triangulation

This activity is planned for 28 students.

Activity Materials List —

- 28 copies of 6th Grade Worksheet 1.
- 28 copies of 7th & 8th Grade Worksheet 2.
- Compass to Protractor.

Activity Equipment and Tools List —

- Pencils
- Protractors
- Graph paper
- Rulers

Activity Cost Estimate —

Less than $5 total

Activity Attachments —

None

Activity Time Estimate —

50 minutes

Activity Procedure —

A. Background

Topographical Maps

An important navigational map is the topographical (or more typically called the topo) map. The important feature of a topo map is that it shows elevation (or height). Contour lines show the elevation. Each contour line represents an elevation. For example, the innermost circle on the left is marked 40. That means that every point on the contour line is at an elevation of 40 feet (notice that inside the contour line the ground is *over* 40 feet in elevation). By taking a cross-section of the area (the line from A to B) the elevation can be plotted as it has been done below the topo map. Note that this only shows the elevation plot for that particular cross-section (line).

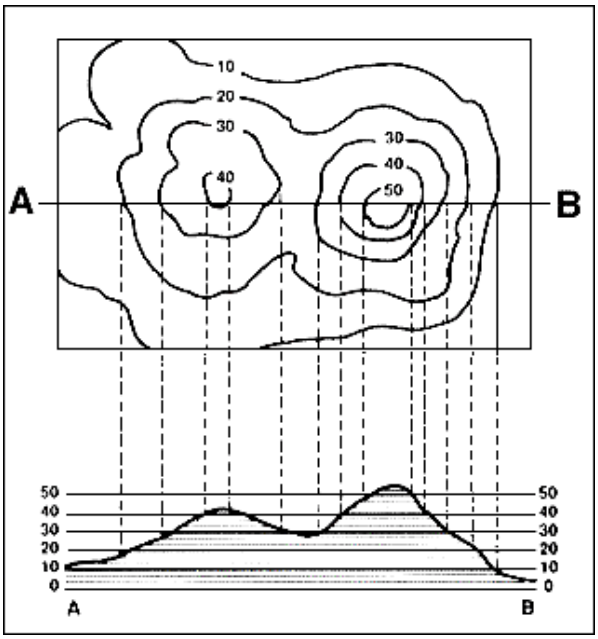


Image source: http://interactive2.usgs.gov/learningweb/teachers/mapsshow_act4.htm

Topo maps are tricky to read at first, but with a little practice and some helpful tips, reading them becomes much easier.

The first thing to notice is the distance between the contour lines. If they are far apart, the slope, or elevation change, is small and vice-versa. If the contour lines are close together, the slope is steeper. The Grand Canyon, known for its high canyon walls, would have contour lines that are very closely packed together. A state like Nebraska, known for its flat plains, would barely even have any contour lines. An example of how contour lines work is illustrated in the picture above. On the left side, the 10 ft. contour line is far away from the 20 ft. contour line. Looking at the same point on the elevation plot, the slope is moderately level. It would be easy to walk up this slope. But looking at the right hill the distance between the 40 ft. contour line and the 50 ft. contour line is small. The corresponding elevation plot shows a steep slope. Walking that part of the line would be much more difficult.

Another type of feature that is easy to see on a topo map is a hill or mountain peak. These are represented by rough circular shapes nested within each other that get higher as you go to the middle of the circle. If the circles are getting closer and closer together, the slope up to the peak is getting steeper. If the circles are getting farther apart the slope is leveling out. In the picture above, there are two hills, one on the left and one on the right. The one on the right has tight circles that are not very far apart so the slope on that hill is steep. The peak or summit of that hill would be somewhere within the 50 ft. contour circle. The left hill's circles are not as tight, showing a more moderate slope, and the peak or summit of that hill would be somewhere within the 40 ft. contour circle.

Scale, Orientation and Grids for Topo Maps

Topo maps have a set of standard scales that they use. This number is a ratio of the distance on the map related to the actual distance. For example, if the ratio were 1:4, an inch on the map

would represent 4 in. of actual distance. Of course, this scale is far too large to be useful, so real scales are much smaller. Below are the 3 most common scales for topo maps.

- 1:250,000 – These maps cover a large area and are not as detailed as their counterparts below. Using this scale, an inch on the map is approximately an actual distance of 4 miles. These maps are useful for long-range exploration.
- 1:62,500 – These maps cover a moderately sized area. An inch on the map equates to roughly a mile of actual distance.
- 1:24,000 – These maps cover a small sized area. An inch on this map equates to 2,000 ft. This unit of measurement is useful for surveying, so these maps are generally made for this purpose. They certainly can be used for other purposes.

The orientation of topographical maps is always north. In other words, north is always pointing up. Topo maps are designed specifically to be used with compasses.

Topo maps also have a grid. This grid separates the map into many small square sections. This makes it easier to read the map, use a compass, and talk with other people about your location. It is a lot easier to say "I am in grid A5" than it is to say "I am at N40'0.1" by W103'45.6"." This grid is made by drawing lines some distance apart that run north-south and then drawing lines that run east-west that same distance apart. This results in a square pattern on the map. These lines are also useful when using a compass.

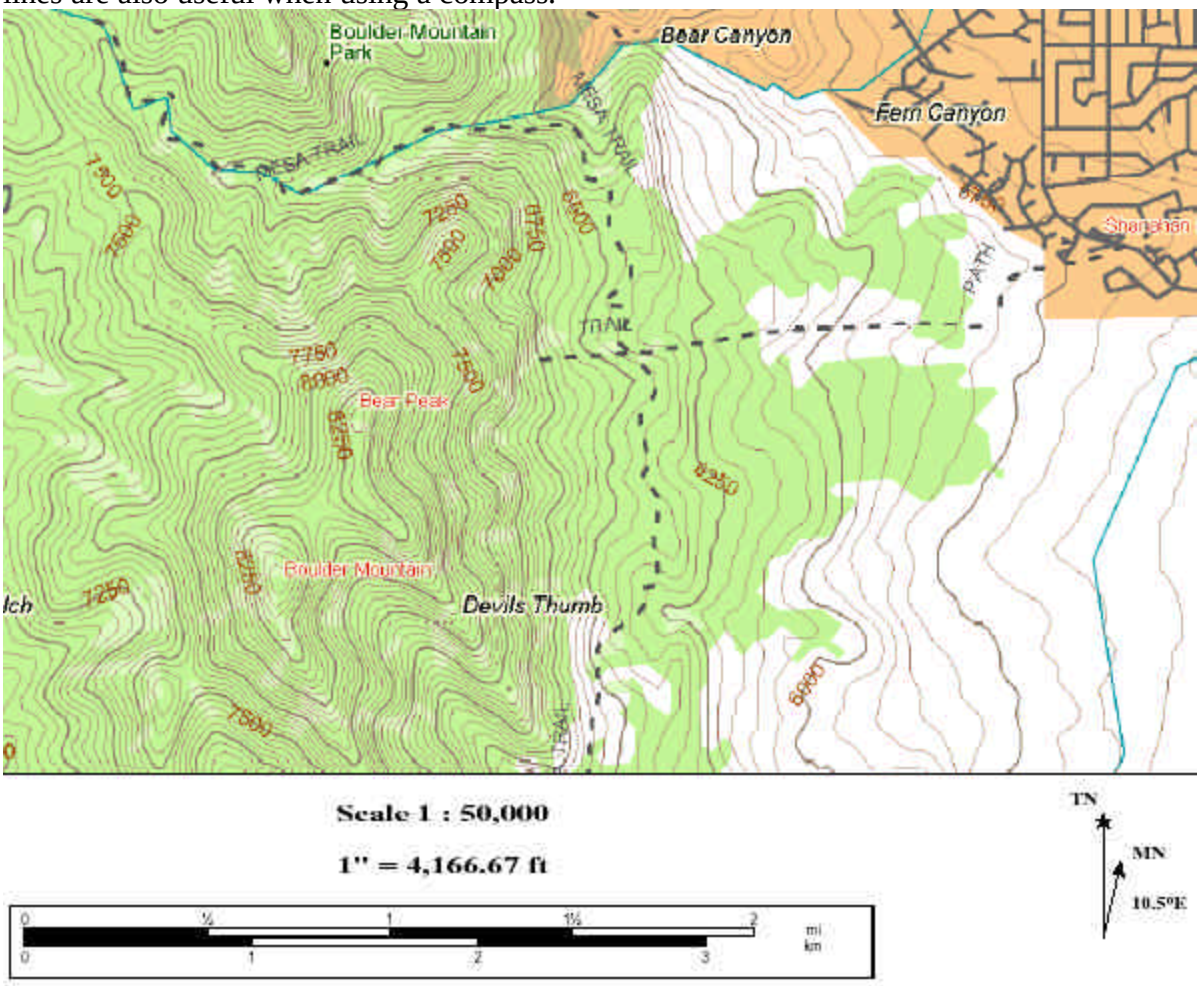


Photo courtesy of DeLorme: © 2002 DeLorme (www.delorme.com) Topo USA ®

Using an Orienteering Compass with a Topographical Map

The great thing about an orienteering compass is that it is made specifically for use with topographical maps. The most important thing a compass and map can tell you is your location. This is done by *triangulation*. By finding two landmarks and taking a bearing to each of them, you can find your location. Just follow the steps below:

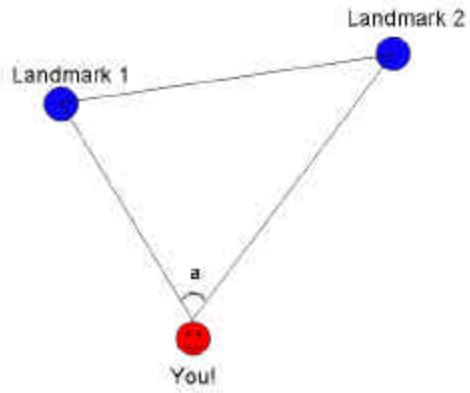


Image created by: M. Lippis, University of Colorado, Boulder, 2003.

1. Determine your declination and correct for it on your compass.
2. Find two landmarks on the map that are easily identifiable. Antenna towers or big mountains usually work best.
3. Find those landmarks outside and take their bearings with your compass. Write these down on the map, possibly next to the landmark on the map. Make sure and correct for declination. If you permanently adjusted your compass, then this is already taken care of for you but if you only did the temporary adjustment add or subtract that to your bearings.
4. On the map, find your first landmark. Draw a line from the landmark in the direction of the bearing for the first landmark. For example, if your first landmark was at a bearing of 30 degrees, draw a line angled 30 degrees from that landmark.
5. Do the same for the second landmark.
6. These two lines should intersect. You are at the point where they intersect. Now you know where you are!
7. To get a more accurate location, do this for 3 landmarks. With 3 landmarks, your intersecting lines will form a triangle. Your location is within this triangle.

Before the Activity

Complete the activity yourself before hand in order to become familiar with the process.

With the Students

Compass to Protractor Worksheet

This worksheet will give students practice in converting a compass measurement to a protractor measurement in addition to reversing a bearing direction (i.e., if a tree is at a bearing of 100 degrees from you, what bearing are *you* from the tree?)

1. Discuss how the bearing of an object such as a mountain or other landmark depends on where the bearing is being taken. For example, if you are standing in front of the classroom facing the class, the door may be to your *left*, but the students' *right*. If students are sitting beside a partner, one of them will have to look left, and the other will have to look right to see each other.
2. Explain that triangulation is like finding a bearing, only it is backwards. You may be lost, but you know where the mountain is. In the next worksheet you will be take a

bearing of certain landmarks and then start at those landmarks to work backwards to figure out where you are.

3. If you have a compass it is easy to switch the bearing directions: just look on the other side of the needle. However, how would you do it without a compass?
4. Give each student a piece of graph paper, a ruler, and a copy of the compass–protractor worksheet.
5. Have each student set up a coordinate grid.
6. Label the top part of the graph as 360 and 0 degrees. (This is north.)
7. Label the end of the right axis 90 degrees. (This is east.)
8. Label the bottom part of the graph as 180 degrees. (This is south.)
9. Label the end of the left axis 270 degrees. (This is west.)
10. The origin will represent the student.
11. Have the students complete the worksheet.
12. Have students share ideas for an easy way to switch from one bearing to another.

For 6th Graders using Worksheet 1

1. Talk about topographical maps.
2. Talk about how triangulation is used to find your location.
3. Give each student a worksheet.
4. Tell them to find East Portal. Ask them if they heard a train north of them, where can they be? (Possible answer: south, or below, the train tracks.)
5. If the dam is at a bearing of 100 degrees, what is the bearing to you from the dam? On a compass, this would be the opposite direction, so 280 degrees. This is 10 or 170 degrees on a protractor depending on where you start your angle measurement. Ten degrees comes from the fact that 270 degrees is west, and 90 degrees is east. This would be a horizontal line through Mammoth Creek Dam. Placing the protractor on this imaginary horizontal line and measuring "up" 10 degrees (in the west direction), will give you 280 degrees. Likewise, measuring 170 degrees starting from the east direction will produce the same direction.
6. Now have them draw a line from the Mammoth Creek Dam at 10 degrees on the protractor, which is the same as a bearing of 280 degrees.
7. Ask them why this line is important. (Possible answer: their location is along that line.)
8. If Haystack Mountain is at a bearing of 241 degrees, what is the bearing to you from the mountain? On a compass, this would be the opposite direction, so 61 degrees. This is 29 or 151 degrees on a protractor (again, 29 degrees measuring "up" from the east and 151 measuring from the west).
9. Now have them draw a line from Haystack Mountain at 29/151 degrees on the protractor, which is the same as a bearing of 61 degrees.
10. Ask them if the two lines intersect. (Possible answer: Yes.)
11. What is important about the intersection of these two lines. (Possible Answer: That it is the students' location.)
12. Now that they know their location, ask them to figure out which lake is Clue #5. (Answer: Crater Lake.)

For 7th & 8th Graders using Worksheet 2

1. Talk about topographical maps.
2. Talk about how triangulation is used to find your location.
3. Give each student a worksheet.
4. Tell them to find East Portal. Ask them if they heard a train north of them, where could they be? (Possible answer: South, or below, the train tracks.)
5. Ask them to find a big body of water that has a dam. (Answer: Mammoth Creek Dam.)
6. If the dam is at a bearing of 100 degrees, what is the bearing to you from the dam? On a compass, this would be the opposite direction, or 280 degrees. This is 10 or 170 degrees on a protractor depending on where you start your angle measure. Ten degrees comes from the fact that 270 degrees is west, and 90 degrees is east. This would be a horizontal line through Mammoth Creek Dam. Placing the protractor on this imaginary horizontal line and measuring "up" 10 degrees (in the west direction) will give you 280 degrees. Likewise, measuring 170 degrees starting from the east direction will produce the same direction.
7. Now have them draw a line from the Mammoth Creek Dam at 10 degrees on the protractor, which is the same as a bearing of 280 degrees.
8. Ask them why this line is important. (Possible answer: Their location is along that line.)
9. Ask them which mountain/hill they think they are located on? (Possible answers: Nebraska Hill or Haystack Mountain.)
10. Remind them that the top of the hill/mountain they are on is just south of them. Ask them what hill they think they are on now. (Answer: Nebraska Hill.)
11. Now the students know which hill they are on, they just do not know where on the hill.
12. If Haystack Mountain is at a bearing of 241 degrees, what is the bearing to you from the mountain? On a compass this would be the opposite direction, or 61 degrees. This is 29 or 151 degrees on a protractor (again, 29 degrees measuring "up" from the east and 151 measuring from the west).
13. Now have them draw a line from Haystack Mountain at 29/151 degrees on the protractor, which is the same as a bearing of 61 degrees.
14. Ask them if the two lines intersect. (Possible answer: Yes.)
15. What is important about the intersection of these two lines? (Possible answer: That it is the students' location.)
16. Now that they know their location, ask them to figure out which Lake is Clue #6. (Answer: Crater Lake.)

Math Skills Reinforced —

6^{th}, 7^{th} and 8^{th}: Reading elevation lines and understand that there are 360 degrees in a circle, representing a compass measure as an angle from a given location, measuring corresponding angles with protractors, creating a coordinate graph

Activity Troubleshooting Tips —

The students might get confused using protractors in place of compasses. A compass starts at North (0 degrees), while a protractor starts at west or east (0 or 180 degrees). Make sure that they know that 0 degrees on a compass is 90 degrees on a protractor.

Many students might not hike very often. Give the students an idea of how long it might take to wander cross-country through trees and rocks for 4 hours (about 2-3 miles).

Activity Desired Student Outcomes —

After this activity, students should know how to identify major features in topographical map, and triangulate their position using a map.

Activity Assessment & Evaluation —

Pre-Activity Assessment

- Background Worksheet: Have students use compass – protractor worksheet to practice converting compass measurement to protractor measurement.

Activity Embedded Assessment

- Worksheet: Have students follow along with activity using attached, grade appropriate worksheet.

Post-Activity Assessment

- Discussion Question: Ask the class what they have learned from this activity. Facilitate a discussion, and put the answers on the board.

Suggestions to Scale Activity for Grades 6 to 8 —

- 6^{th} Grade: Have students do worksheet 1.
- 7^{th} and 8^{th} Grade: Have students do worksheet 2.

Lesson 6: Activity 2, Worksheet 1 - Reading your Topo Map (6th)

Your Name:_____ Date:_____

Instructions

You and a friend left to go on a hike earlier today. You have been walking for a while, and now you do not know where you are. You have looked around and taken a few bearings of landmarks you see. Following is what you know:

Clues

A) Your hike started at "East Portal" 4 hours ago.
B) You can hear a railroad somewhere to the north.
C) You took a bearing of Mammoth Creek Dam at 100 degrees.
D) You took a bearing of Haystack Mountain at 241 degrees.
E) You see another small lake at 305 degrees.

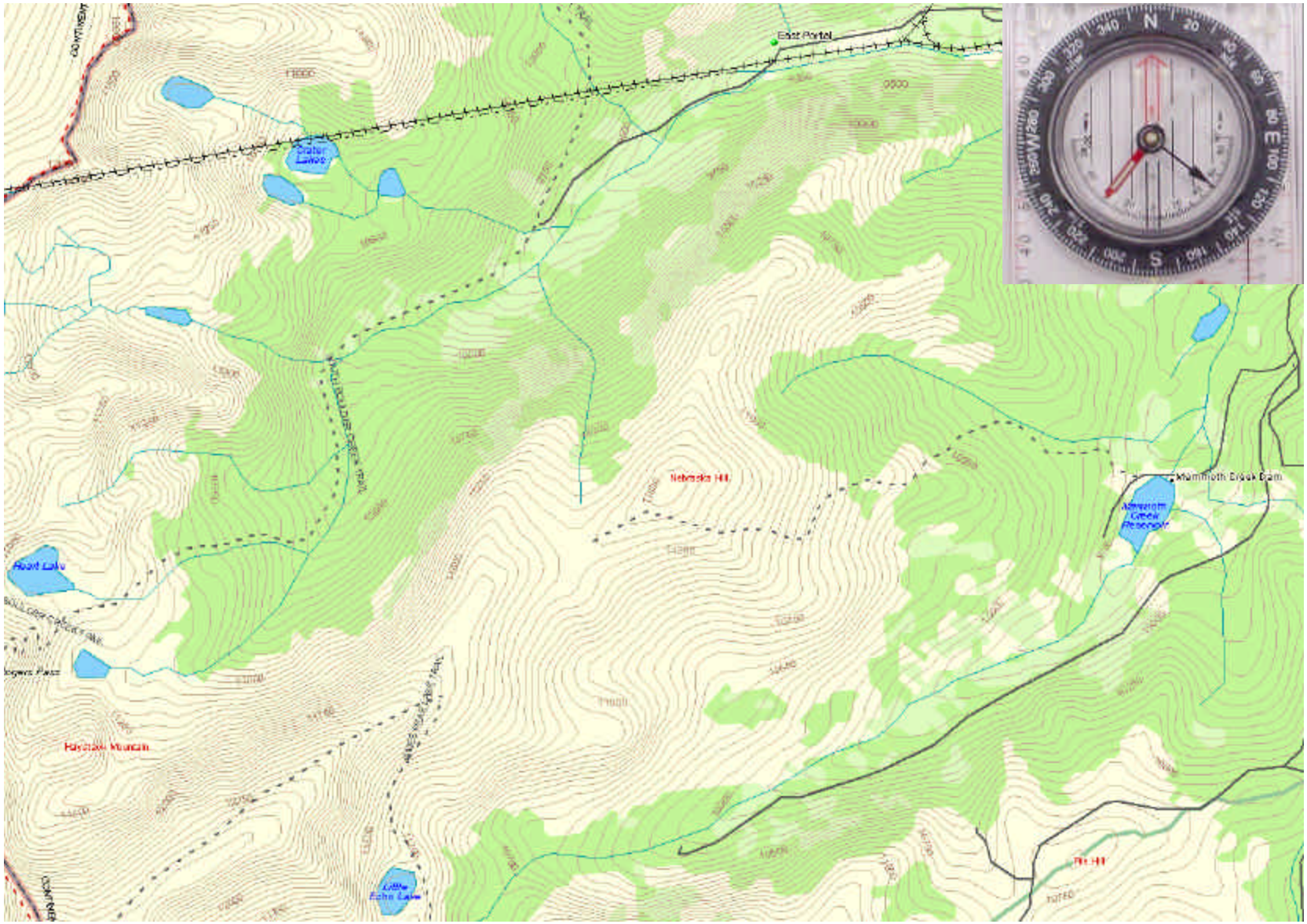
1) If someone were looking for you from Mammoth Creek Dam, what direction would they have to look?

2) Using your compass edge, draw a line from the Mammoth Creek Dam in the direction you wrote above. Your location is somewhere along that line.

3) If someone were looking for you from Haystack Mountain, what direction would they have to look?

4) Using your compass, draw a line from Haystack Mountain in the direction you wrote above. What is important about the place where the two lines meet?

5) Which lake is Clue E (above) talking about?



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Lesson 6: Activity 2, Worksheet 2 - Reading your Topo Map (7th & 8th)

Your Name:_____ Date:_____

Instructions

You and a friend left to go on a hike today. You have been walking for a while, and now you do not know where you are. You have looked around and taken a few bearings of landmarks you see. Following is what you know:

Clues

A) Your hike started at "East Portal" 4 hours ago.
B) Realizing that you were lost, you hiked up a nearby mountain/hill. You did not hike up to the top, but the top is directly south of you.
C) You can hear a railroad somewhere to the north.
D) You took a bearing of a big body of water (you think you saw a dam) at 100 degrees.
E) You see another mountain at 241 degrees.
F) You see another small lake at 305 degrees.

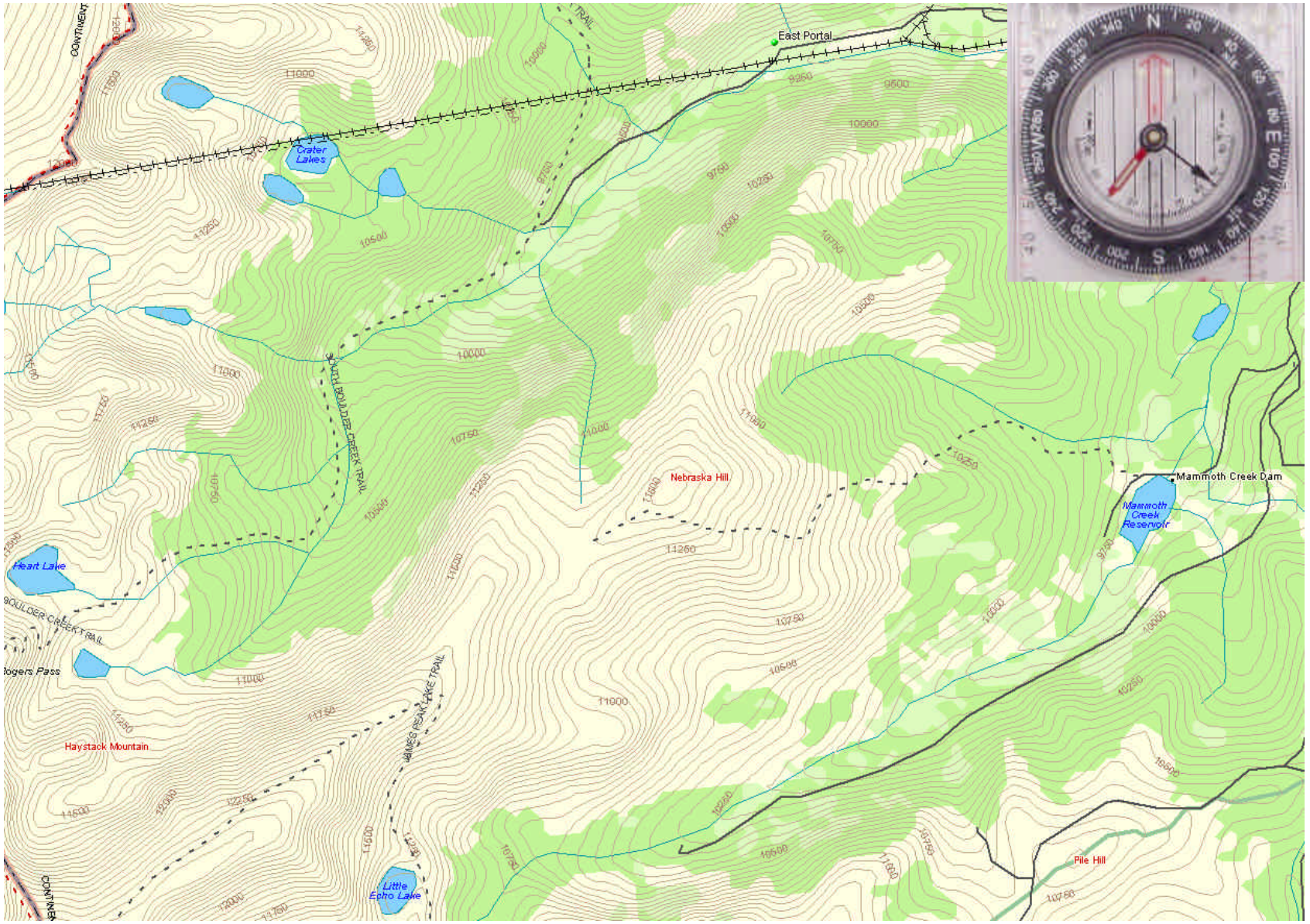
1) If someone was looking at you from the first body of water, Clue D, what direction would they have to be looking?

2) Using your compass edge, draw a line from the landmark in the direction you wrote above. Your location is somewhere along that line.

3) Which mountain do you think Clue E is talking about?

4) Using the same method you used for the first line, draw the second line from the mountain/hill in Clue E. Your location is where the lines intersect.

5) Which lake is Clue F talking about?



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Lesson 6: Activity 2, Compass-Protractor Worksheet
More Than One Way to Look at a Compass

Name:_____ Date:_____

1) Imagine that you are standing at the origin of your graph. Below are some bearings taken from the origin to where a landmark is.

2) Move in the direction of the bearing (for example, 0 degrees would mean move north). Now look back at the origin. What is the bearing from your new location to the origin?

3) Complete the chart below.

Bearing (in degrees) from:

You to Landmark	Landmark to You	You to Landmark	Landmark to You
0 (or 360)		**150**	
10		**200**	
50		**270**	
90		**290**	
100		**300**	

4) Can you discover a formula (or an easy way) to convert from one bearing to another?

Lesson 6: Activity 3 - Topos, Compasses, and Triangles, Oh My!

This activity is planned for 28 students.

Activity Materials List —

- 28 Topographical Worksheets 1.
- 28 Topographical Worksheets 2.

Activity Equipment and Tools List —

- Pencils
- Compass
- Topographical map of area

Activity Cost Estimate —

Less than $5 total

Activity Attachments —

None

Activity Time Estimate —

Field Trip

Activity Procedure —

Before the Activity

It is suggested that this activity follow Activity 1 of Lesson 6.

1) Find a location for a field trip. The location should have easily discernable landmarks (like mountains or radio towers) and changes in elevation (to illustrate the topographical features) to enhance the use of the activity. A national park would be an ideal location. A number of parks will be good, especially parks with hiking trails.
2) Obtain a topographical map for the area. Topographical maps can easily be obtained in any outdoor sports business. Call them first to see if they have topographical maps of the area that you have chosen. The sure way of getting maps is through the U.S. Geological Survey (USGS). They have offices all over the country, and possibly in your area. You can also check their webpage at http://www.usgs.gov/ (general information), or http://mac.usgs.gov/mac/isb/pubs/booklets/usgsmaps/usgsmaps.html#INFORMATION (maps).

They can also be reached at:

USGS Information Services
Box 25286
Denver CO 80225
1-888-ASK-USGS or 303-202-4700
Fax: 303-202-4693

3) Go to the website location, and do the activities.
4) Copy the topographical map for each of the students.
5) Copy the worksheets for the students.

With the Students

Part 1

1. Talk about topographical maps.
2. Give each student a copy of the topographical map, and a copy of Worksheet 1. Have them become familiar with the topo map using the worksheet.
3. Give them Worksheet 2. Tell them to look for **a distinguishing landmark on the topographical map** that they might be able to see from an open field. For example, a radio tower or a mountain.
4. Tell them to find that landmark outside.
5. Have them take a bearing of the landmark. Make sure to keep the bearing on the compass.
6. Correct the bearing for the declination. If you corrected the compass permanently, then this requires no more steps. If not, then subtract the declination from your bearing. For example, if your compass reads a bearing of 30 degrees, and the declination is +7 degrees, move the compass face to 23 degrees. If the declination is –5, move the compass face to read a bearing of 35 degrees.
7. On the map, place the long edge of the compass on the landmark.
8. Now rotate the compass, keeping the long edge on the landmark, until the meridian lines line up with north on the map.
9. Using your compass as a straightedge, draw a line on the map. The line should go through the landmark. You are located somewhere on this line.
10. Now a second line is needed to determine your location. Repeat steps 3 through 7 for another landmark.
11. The two lines should intersect. This is your location.
12. To get a more accurate idea of your location repeat steps 3 through 7 for a third landmark. The three lines will form a triangle, and you will be located in somewhere in this triangle.
13. When each student is done have them compare answers with other students.

Math Skills Reinforced —

6th, 7th and 8th: Reading elevation lines, using a compass to locate a landmark on a map

Activity Troubleshooting Tips —

The students might get confused while shooting their angles to the landmarks. One way to alleviate this confusion is to have the teacher select an initial spot to shoot angles from and mark it. Students could go to that spot in pairs and determine the angle to that landmark. The teacher can work with them and make sure that all answers are consistent from that one spot (i.e., 187 degrees to the radio tower from the big grey rock.

If there is adequate supervision, have the students wander to different spots, 20-50 yards apart. That gives them adequate room to work on their own, and their locations should be different than those of their classmates.

Make sure that they are not wearing metal belt buckles or have anything metallic or magnetic in their pockets, as such items can interfere with the compasses.

Activity Desired Student Outcomes —

After this activity, students should know how to identify major features in topographical maps.

Activity Assessment & Evaluation —

Pre-Activity Assessment

- Worksheet 1: Use the attached worksheet to help students learn how to read a topo map. Go over answers with them.

Activity Embedded Assessment

- Worksheet 2: Have students follow along with activity using the second worksheet.

Post-Activity Assessment

- Pairs Check: After activity, have students check each other's work for accuracy.

Suggestions to Scale Activity for Grades 6 to 8 —

- 6th Grade: Have students do first worksheet only.
- 7th and 8th Grade: Conduct activity as is.

Lesson 6: Activity 3, Worksheet 1 -
Reading a TOPO Map

Your Name: _____ Date: _____

1. What area does the topographical map cover? (Hint: look in the legend.)

2. What scale is the topographical map?

3. What is the magnetic declination for the map? Circle east or west below. Write the degrees on the line.

   East West Degrees: _____

4. What are some of the features you see on the map (landmarks, roads, etc.)? List at least 5 different features.

   _____

   _____

   _____

   _____

   _____

Lesson 6: Activity 3, Worksheet 2 -
Find your location

Your Name: _____ Date: _____

1. Look for 2 distinguishing landmarks on the topographical map that you can see outside. Write the names of your landmarks in the spaces below.

   _____ _____

2. Take the bearing of the first landmark. Make sure to keep the bearing on the compass. Write this down in the space below. (Ignore the second landmark for now.)

   _____

3. Correct the bearing for declination. If you corrected the compass permanently, then this requires no more steps. If not, then subtract the declination from your bearing. For example, if your compass reads a bearing of 30 degrees, and the declination is +7 degrees, move the compass face to 23 degrees. If the declination is –5, move the compass face to read a bearing of 35 degrees. Write this in the space below.

   _____

4. On the map, place the long edge of the compass on the landmark.

5. Now rotate the compass, keeping the long edge on the landmark, until the meridian lines line up with north on the map.

6. Using your compass as a straight-edge, draw a line on the map. The line should go through the landmark. You are located somewhere on this line.

7. Now a second line is needed to determine your location. Repeat steps 3 through 7 for another landmark.

8. The two lines should intersect. This is your location.

9. To get a more accurate idea of your location repeat steps 3 through 7 for a third landmark. The three lines will form a triangle, and you will be located in somewhere in this triangle.

10. Now compare your location to that determined by other students.