Basic Compass Use

Troop 2 High-Adventure Week

Revised 7 July 2005

This note will attempt to explain the basic use of a compass for navigation and mapping applications related to scouting and camping. Although some advanced compass and map principles are confusing or even complicated the basic skills are easy to understand and should be learned. With just a little effort every scout should certainly be able to master the simple compass skills described below. Most scouts should be able to master all these skills.

The Compass

First, let's look at the basic compass.

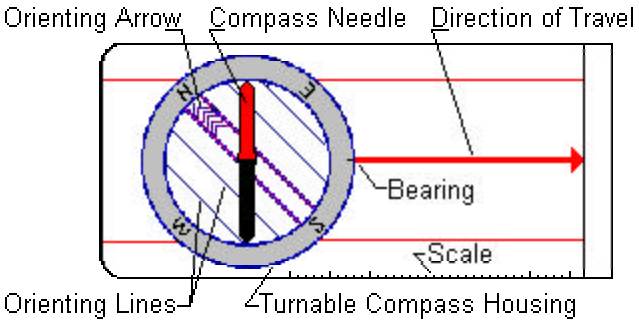


Figure 1. Basic Compass

The parts of the compass are:

- Baseplate – plastic plate that everything is attached to.
- Compass Housing – is the ring with 360º inscribed onto it.
- Orienting Arrow – the arrow on the Compass Housing used to align the compass with the map or Magnetic North.
- Orienting Lines – lines used to align the Compass Housing with the map or Magnetic North. These are parallel to the Orienting Arrow.
- Bearing Mark – the mark showing the direction of travel measured in degrees.
- Direction of Travel (arrow) – The line pointing to your destination if you travel at the bearing shown on the Bearing Mark. This line points to your destination.
- Compass Needle – the floating needle pointing toward Magnetic North.
- Scale(s) – are calibrated markings used to measure distances on maps.

Magnetic North

It is very important to remember that a compass does not really point to true north, except by coincidence in some areas. The compass needle is attracted by the Earth's magnetic force, which varies in different parts of the world (and is constantly changing). When you read north on a compass, you're really reading the direction of the magnetic north pole. All bearings given by a compass are with respect to magnetic north.

NOTE: When we talk about compass bearings, we will always use magnetic bearings and degrees from magnetic north. Later when we use a map we will learn to correct a bearing for *true north*. But meanwhile, compass bearings are always given in magnetic degrees.

Simple Compass Skills

The first thing you'll probably want to do is figure out what direction you are walking and what direction to walk to return to the starting point. To do this we must know how to "take a bearing" and figure out how to calculate the return bearing

Taking a Bearing

1. Start by holding the compass flat and level with the ground against your stomach at belt level.
2. Point your body (including the compass) toward a well-defined object in the direction you wish to travel.
3. Rotate the *compass housing* (the ring with number inscribed onto it) until the *orienting arrow* is closely aligned with the *compass needle*. Make sure the **red** (colored) end of the *compass housing* is aligned with the **red** (colored) end of the *compass needle*.
4. Read the bearing from the bearing mark. This bearing is the direction you will be traveling.

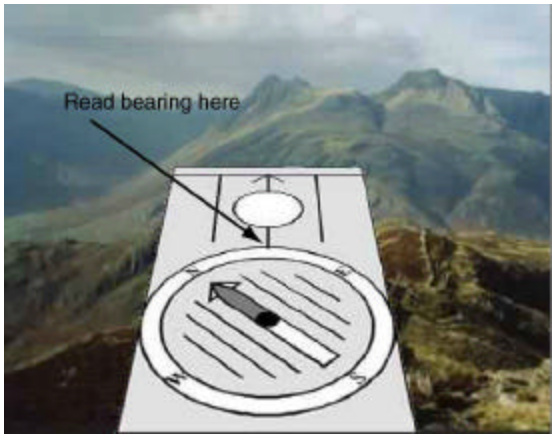


Figure 2. Taking a compass bearing.

The easiest way to figure your return bearing is to look at the number inscribed on the compass housing that is exactly opposite the direction of travel bearing. For example, if your direction of travel is 20º then the return bearing will be 200º. Try this a few times to practice.

Note: The return bearing is basically the direction of travel bearing PLUS 180º (1/2 the number of degree in a circle) when the addition is performed using modulo 360 arithmetic. Modulo 360 arithmetic means that you add or count up to 360 then start again at 1. So you would count 358, 359, 360, 1, 2, etc. If your bearing is 150º then the return bearing would be 150 + 180 = 330º. But, if your bearing is 310º then the return bearing is 310 + 180 = 130 (310 + 180 = 490 – 360 ==> 130)

Go outside and try taking bearings of different objects in your yard or neighborhood. You should know that iron, electrical appliances, and power lines may cause your reading to be inaccurate so try to make sure you are in the open when you practice. A flashlight held close to your compass will cause inaccurate measurements and bad bearings.

Finding Direction of Travel

The second basic compass use is to travel in a particular "direction of travel" for a given distance. This is why most compasses have a *direction of travel* line. Suppose you are told to walk at a bearing of 80º for 1 hour. You will need to know how to determine if you are walking in the correct direction. Here is how you do that:

1. Rotate the *compass housing* until the 80º mark (80 on the dial) is aligned with the *bearing mark* and *direction of travel* line. Now don't move the *compass housing* anymore.
2. Hold the compass flat and level with the ground against your stomach at belt level.
3. Rotate your body (including the compass) until the *orienting arrow* becomes closely aligned with the *compass needle*.
4. Without moving your body, or the compass, look up at whatever the *direction of travel* arrow is pointing toward and find a distinguishing landmark well in front of you. This landmark will be your target to walk toward.

If you walk toward this target you will be walking along a bearing of 80º as requested.

Summary of Bearing Work

Notice that when you were finding the bearing of a mountain, for example, you aimed the compass at a target and rotated the *compass housing* until the *orienting arrow* lined up with the *compass needle*. Then you read the bearing of the mountain from the compass at the *bearing mark*. In this case you were trying to discover what was the bearing of the target (mountain). Keep your body still and rotate the *compass housing* until the *needle* is aligned!

In the second case, you were given the bearing and you had to discover a target to head toward. For this example, you set the bearing of the compass at the *bearing mark* and rotated your body and compass until the *orienting arrow* lined up with the *compass needle*. If you had moved the *compass housing* you would have been heading in the wrong direction. Set your bearing and move your body until the arrows align!

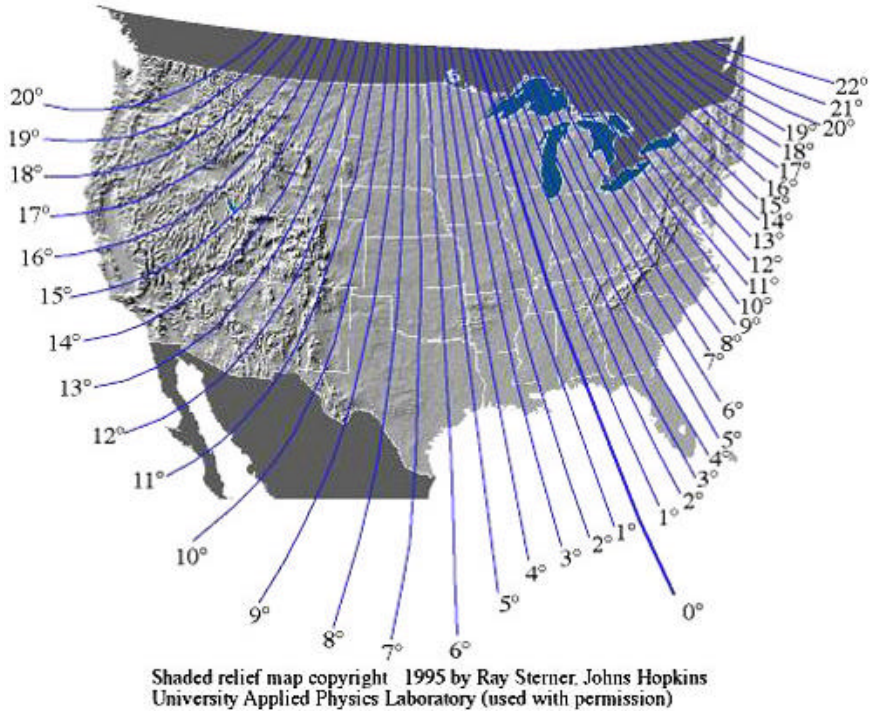
Map Usage – Getting Oriented

The next step is to begin using a map in order to find your location, destination and calculate the bearing to your destination. To do this you must know how to *orient a map* or align the map with magnetic north then correct for true north. You align the map with magnetic north because that is the direction in which compass needles point. Almost all maps will have a legend or scale you can use to determine true north from magnetic north.

Now is the time to point out that the correction between magnetic north and true north is not constant around the world or across North America in this case. The following diagram illustrates how the magnetic field lines are distributed in the US.

Declination

The difference between magnetic north and true north is called the declination or declination correction. Just as all compasses read in magnetic degrees most maps are drawn with true north as up.



Shaded relief map copyright 1995 by Ray Sterner, Johns Hopkins University Applied Physics Laboratory (used with permission)

In Los Angeles the correction is about 15º east but in northern Washington it is about 20º East. Last year when we were in Minnesota it was about 1º west so we could ignore the correction for the most part.

This is where things get a bit tricky because you have to remember to correct for magnetic north and there are two ways to do that. First though, let's get the basic principle down as follows:

Figure 3. Orienting a map

1. Set the *compass housing* so that N (north) or 360º on the dial is aligned with the *direction of travel line*.

2. Lay the compass so that its long edge is aligned with the map edge or one of the vertical map grid lines.
3. Rotate the map and compass together until the *needle* is centered in the *orienting arrow* as shown above. Remember red on red.

When this is done the map is oriented spatially (in space) with magnetic north, which generally is not good enough to use for navigation. Now we have to correct between magnetic north and true north.

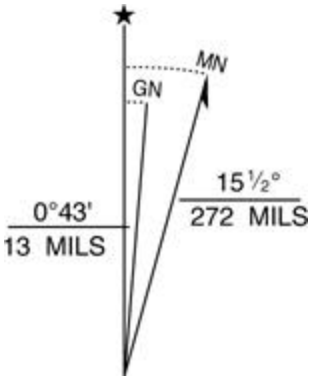
Correcting for Declination

If you look closely at the compass in the figure above you will see that the compass housing is <u>not</u> set at 360º (or 0º) but rather 360 – 15 = 345º. In other words the *compass housing* is rotated to the east (clockwise) by 15º to account for the declination angle in Los Angeles.

Once this is done, you repeat steps 2 and 3 above and the map will be oriented to true north as it should be. All navigational maps are drawn with true north up as indicated by the arrow with TN or the * at the end. When repeating steps 2 and 3 above you still align the compass edge with the map edge or vertical grid line. Then you center the *compass needle* in the *orienting arrow* as before. It is just that the housing has been rotated to account for the declination angle.

Some people like to orient the map differently as follows:

1. This time set the compass housing so that N (north) or 360º on the dial ***is*** aligned with the *direction of travel line*.
2. Lay the compass so that its long edge is aligned with the legend arrow marked with MN (magnetic north) symbol.
3. Rotate the map and compass together until the *needle* is centered in the *orienting arrow* as shown above.



Now the map is also oriented properly to true north. Either method works well but often you will have to use a ruler and pen to extend the MN line to help align the compass baseplate with the MN arrow. This is no problem and can be easily done well before you start your trek.

Finding Your Position on a Map

If you are in the wilderness and you don't know where you are so you want to use a map and compass to find your location, you are probably in trouble. The only way to do this is to orient the map as described above then look for prominent features around you and try to find them on the map.

Generally, this is difficult to do and you must be very familiar with how to read a topographical (topo) map. You can learn how to read a map from the Orienteering merit badge pamphlet or from my favorite booklet called Basic Essentials – Map and Compass by Cliff Jacobson. There are probably other good books available from BSA or a sporting goods store that you could use.

You can always find your exact position accurately using a global position system (GPS) receiver as described in "Using a GPS" from last years high adventure week.

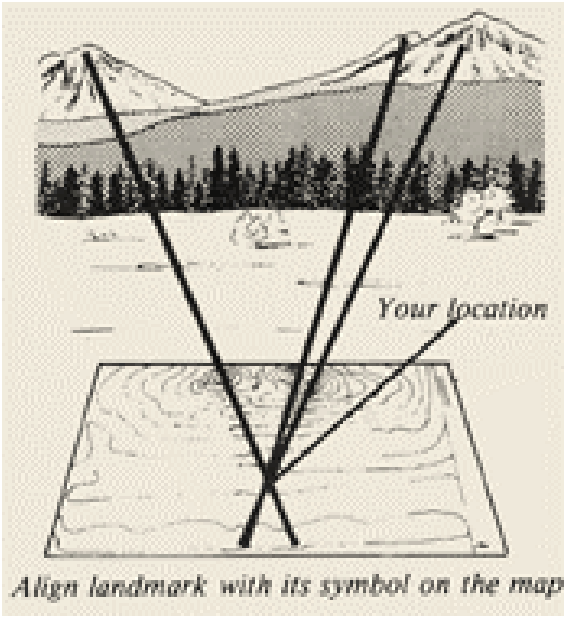


Figure 4. Finding landmarks

Finding Bearings from a Map

If you want to be well prepared for a hiking trek or canoe expedition you should work out your route before you start the adventure. To do this you will want to plan your route, mark the route on a topographic map, and determine the bearing of each route segment. This means you will need to know how to find a bearing between two points on a map. The map does not need to be oriented to do this.

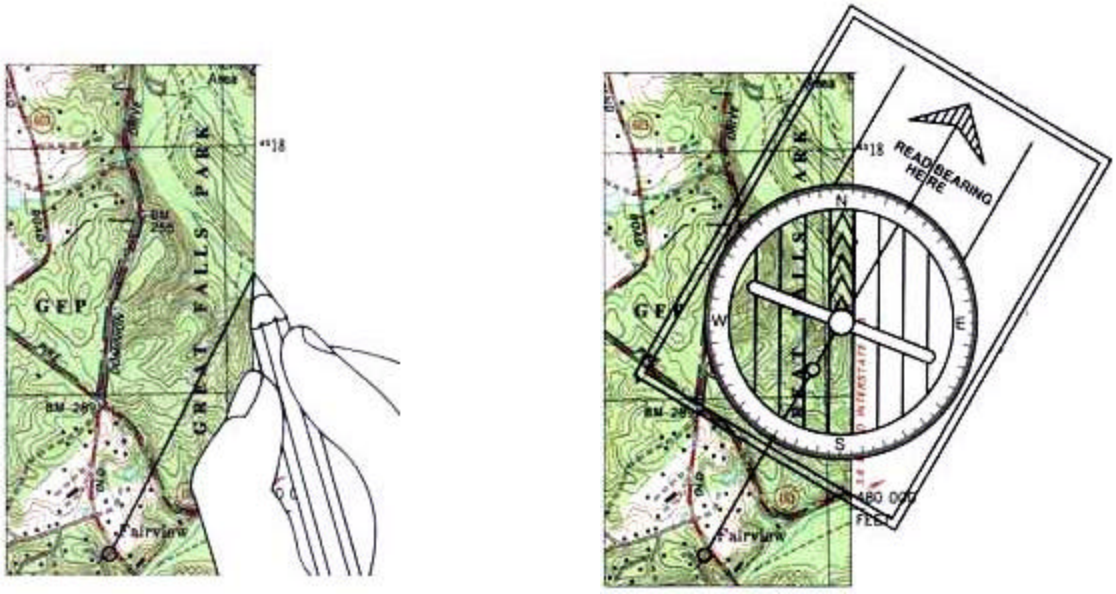


Figure 5. Finding bearings using a map

To find the bearing of a trail segment on a topo map you'll do the following:

1. Draw a line between the staring point of the segment and the final point of the segment as shown on the left figure panel. The map does not need to be oriented.

2. Align the *compass baseplate* with the line you just drew. Disregard the *compass needle* as it will not be used in this procedure.
3. Move the *compass housing* until the *orienting arrow* or *orienting lines* are aligned with the map edge or one of the vertical grid lines as in the right figure panel.
4. Read the <u>true</u> bearing from the *bearing mark* of the compass.

Now you know the true bearing to travel but you really need to know the magnetic bearing because that is what the compass will supply. We want to do the arithmetic to transform these true bearings to magnetic bearings now while you have time to think about the process rather then when you are in the field.

Produce Magnetic Bearings

Here is a simple rhyme that may help you remember when to add or subtract the magnetic declination from the true bearing.

Declination east – compass least
(subtract east declination from your map direction).

Declination west – compass best
(add west declination to your map direction).

Figure 6. Subtract east, add west

For example, if your map and compass produce a bearing of 312º and the declination angle is 15º east the magnetic bearing is:

312 – 15 = 297 degrees

if the true (map) bearing is 7º then the magnetic bearing is:

7 – 15 = 352 degrees (-8 degrees equals 352 degrees because 360 minus 8 equals 352)

Summary

If you can learn and understand everything described above they you know more about map reading and navigation than most people around and you'll be much less likely to get yourself lost. You may even be able to help your group find its location if they do get lost. You will certainly be a much better prepared scout.

APPENDIX

Background Science

Let's review a bit of basic science. A compass needle is made of slightly magnetized iron so it will try to align itself with the Earth's magnetic field. A force is always produced between two magnet bodies that will try to align each body's magnetic field. This is part of the "electromagnetic force", one of the four know physical forces[1]. The Earth's magnetic field points to *magnetic north*.

The churning molten iron and nickel[2] metals at the planetary core produces a magnetic field that surrounds the earth and extends for thousands of miles into space. We call this field the *magnetosphere* but it looks nothing like a sphere and actually forms a very exotic shape driven by the hugely strong solar wind from our Sun. (You could look up magnetosphere on the web to see some illustrations of the Earth's magnetic field. They are quite interesting.)

The Earth's magnetic field is not exactly aligned with the north and south poles so more advanced compass work requires that you correct for the misalignment between the magnetic field (magnetic north) and the Earth's rotational axis (true north). This compass error is called *Declination* as we talked about above.

I feel obligated to mention here that there are a surprising number of people who actually believe that the Earth is hollow and is populated by a race of space alien reptile creatures. They also believe that these aliens move at will using holes in the earth located at each poll. I'm not sure if they realize that the North Pole is under water but maybe the aliens have a way of dealing with that. I'm personally pretty sure the earth is filled with molten metal and that is what produces the magnetic field but who really knows?

Advanced Principles

It is a good idea to take a new compass bearing every half-mile or so to help minimize your accumulated positional error. If you read some of the books cited later you'd also learn how to *aim off* to reduce you chance of missing a trail or landmark.

For example, if your bearing is off by 5^{o} and you travel 1 mile (5280 feet) you will miss your destination mark by 462 feet. Let's figure out how to calculate this error value using some basic trigonometric functions and identities and the illustration below.

1. You took a bearing and intended to head to the endpoint of the segment or vector labeled (r_1).
2. Instead, you ended up traveling along the path to the endpoint of segment labeled (r_2).
3. You will have traveled a mile or so but will call the distance r = 1 mile = 5280 feet.

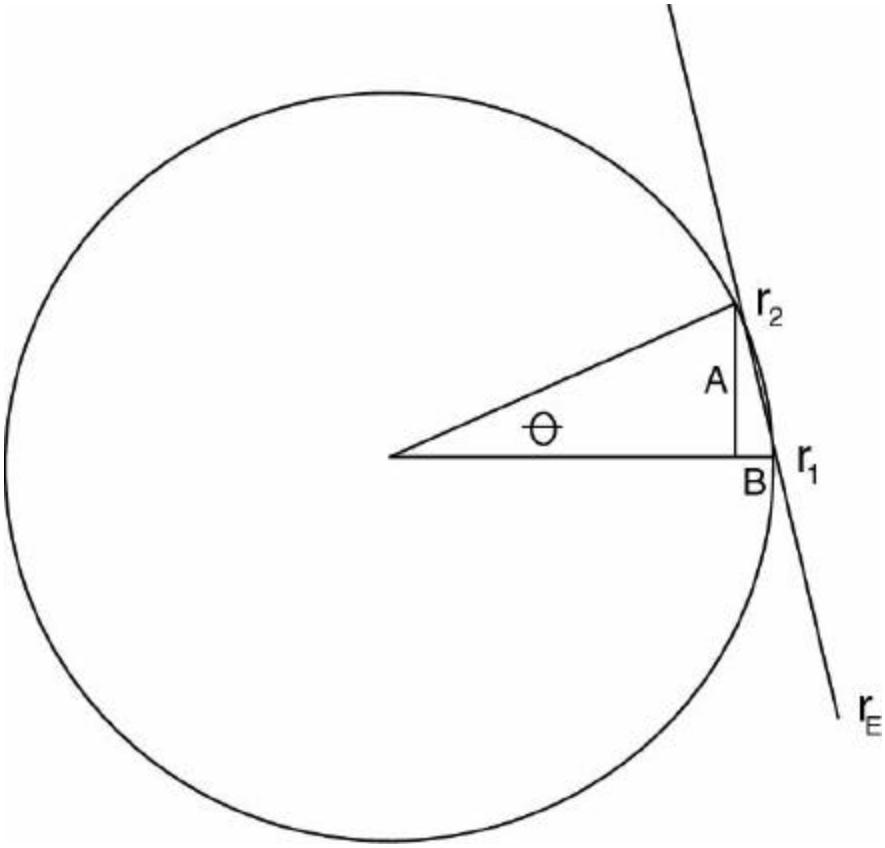
What is the magnitude (length) of the error len(r_E), or the length of the segment $| r_2 - r_1 |$?

Quick Answer:

For small angles you could approximate the error by the length of segment A which is:

$$R \sin(\text{theda}) = A$$

[1] The four forces are the Electromagnetic, Gravitational, Weak nuclear, Strong nuclear forces.
[2] Did you know that Nickel is magnetic?



A better approximation is R tan(theda) which is approximately equal to | $r_2 - r_1$| for small angles. The tangent is at right angle to r_2 and would intersect r_1 far outside the circle producing a very inaccurate result for large values of theda.

The correct answer is to notice that r_E is a chord and construct a triangle using A, B, and $|r_2 - r_1|$. Then solve for the length of the chord segment $r_2 - r_1$ exactly. The answer is:

Equ. (1) $|r_2 - r_1| = v\,(2-2\cos(\text{theda}))$ (v is square root)

Example:

theda = 5 degrees r = 1 mile or 5280 feet

r sin(theda) = 460 feet
r tan(theda) = 462 feet
$|r_2 - r_1|$ = 463.3 feet

Hint:

A = rsin(theda)
B = 1 – cos(theda)

Email me if you want the derivation of the answer Equ. 1. rtaylor@dspsystems.com

Bibliography

1. Basic Essentials – Map & Compass. Cliff Jacobson. The Globe Pequot Press. Guilford, Connecticut. (1999).
2. The Backpacker's Field Manual. Rick Curtis (ed.). Princeton University Outdoor Action Program. Three Rivers Press, New York. (1998).
3. Orienteering. Boy Scouts of America. Irving Texas. (1995 revision).