A Brief History of the Compass

Han Dynasty “Heaven Plate” Compass

Early Chinese Compasses

- 2500 BCE the Chinese knew that a loadstone on a piece of floating wood, would always orient itself in the same direction.
- Later with the move from bone to iron needles, it was noticed that an iron needle placed near a loadstone would also take on these directional properties.

The Italian Contribution

- Greek “Rose of the Winds” added to the compass card as cardinal directions
- Adjustable metal spheres used to compensate the ships compass for cannons and other metal onboard the ship

Compass Uses

- In wilderness navigation a compass is used to do the following:
  - General orientation to the 4 cardinal directions
  - Traveling along a heading
  - Measuring an angle or bearing between north, yourself, and a distant object
  - Plotting or measuring a bearing on a map
- This is using the compass as an expensive protractor.

Orientation to the Cardinal Directions

- The cardinal directions North, South, East and West

Orienting your Map to North

Put the compass on the map near the North Arrow.

Rotate the entire map, along with the compass, until the compass is aligned with the magnetic north direction shown on the map.

Traveling Along a Heading

48° M

Sighting a Bearing to a Distant Object
Using a compass to get a bearing to a distant target.

- Sight to the target with the compass.
- Turn the ring to align the orienting arrow with the red end of the magnetic needle.
- Read the bearing from the ring at the index line.

Sighting with a Mirrored Compass

- Hold the compass level with the mirror at about a 45° angle.
- Use the sighting notch to align the compass with the target.
- Looking into the mirror, turn the dial to align the orienting arrow with the north needle.

Sighting with a Mirrored Compass

- Turn the dial to align the orienting arrow with the north arrow.
Needle Parallax

Keep the needle parallel to the orienting arrow.

Parallax Side View

Needle Parallax

View from Above

View from Behind

Sighting with a Mirrored Compass

• Read the bearing from the index line

You don’t have to read the bearing by looking in the mirror!

Labeled every 20°

Longer tics every 10°

Each increment is 2°

296°

212°
Compass Bearing Practice Course

Using your compass, take magnetic bearings for the following sets of flags:

- Stand back away from the flags far enough that you can see both flags at once to line up the bearing.
- Your bearing must be within ±2° of the actual to be considered correct.

Field Exercise

- Practice sighting bearings
- Return to classroom in 45 minutes.
Practice sighting bearings

There are 18 targets to sight.

Online data collection & analysis
Point your browser to maptools.com/compass-test or use the QRCode on the handout.

How I measured accurate bearings
- Used differential GPS to find a 90°T baseline (~210m)
- Used surveyors total station to transfer bearings from the baseline to two points outside of the classroom.
- Used total station to sight bearings to targets.
- Overall accuracy +/- 0.2° based on the baseline accuracy.
- Targets measured relative to the baseline +/- 0.01°.
Field Exercise

- Practice sighting bearings
- Return to classroom in 45 minutes.

Traveling Along a Heading

- Set the desired heading on the dial at the index line.
- Box the magnetic needle in the orienting arrow.
- Travel in the direction pointed to by the direction of travel line.

Using a back bearing

- A back bearing is taken looking back to where you took the original bearing.
- A back bearing is 180° different from a forward bearing.
- An easy technique is to align the south end of the needle rather than the north end.

Check that you are on course using a back bearing

- Don’t touch the dial
- Just align with the south end of the needle

Calculating a back bearing

Measuring distance by pacing

- Counting pace
  - Picture
- Get to know your flat ground 100 meter pace count. (Memorize this number!)

Pacing – Counting Aids

- Pacing Beads
- “Tally” Counter
Example Pace Conversion

100m = 53 paces
10m = 5.3 paces

230 m =
53 + 5 + 5 + 5

or if you have your calculator handy...

230 / 100 * 53 = 121.9

Pacing around an obstacle

Angular Error in GPS Bearing to Waypoint

Angular Error in GPS Bearing to Waypoint

\[
\tan(\alpha) = \frac{\frac{5}{d}}{\frac{10}{d}} = \frac{5}{2}
\]

\[
\alpha = \tan^{-1}\left(\frac{10}{d}\right)
\]

<table>
<thead>
<tr>
<th>(d)</th>
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<td>6°</td>
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<td>200m</td>
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<td>0.6°</td>
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<td>1000m</td>
<td>0.5°</td>
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</tbody>
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Field Exercise

- Pace/Time 100m distance
  - Use your GPS to “measure” the 100m course. Accuracy?
- More practice sighting bearings
  - Use a different compass or try to improve your accuracy.
- Locate flags using bearing and distance.

Compass

- Not Adjusted for Declination
- Adjusted for 16° E Declination

100m Pace Card
Locate 3 flags using bearing and distance.
• Bearings and distance are posted at the starting point.
• Try using both your compass and pacing as well as you GPS.

At which North Pole does Santa Claus live?

True North
The earth’s axis of rotation

Magnetic North
Where your compass points

Grid North
Where the UTM grid lines “point” to

The North Reference you choose determines where 0° is when you measure an angle with your protractor or compass.

True v.s. Magnetic North
What is the difference here?

- Fruitvale Ave. is aligned with True North.
- So are the edges of parking lots 4 & 5.
- Let’s go take a bearing along the edge of lot 4 and see what we get…

High Definition Geomagnetic Model

Declination Diagrams

Declination changes over time

- Here in Northern California it changes by about 1° every 20 years.
- The declination shown on your topo map may be out of date.
- What about declination displayed by my GPS?
  - It probably correct as of the date of manufacture.

Declination Calculator at [www.ngdc.noaa.gov](http://www.ngdc.noaa.gov)

Using your GPS & compass to measure current local magnetic declination

- GPS: GOTO WPT001 Bearing 214° True
- Compass: Bearing to Palm 200° Magnetic
- Current Local Magnetic Declination is 14° East of True North
Angular Error in GPS Bearing to Waypoint

\[
\tan(\alpha) = \frac{5}{2} = \frac{10}{d}
\]

\[\alpha = \tan^{-1} \left( \frac{10}{d} \right)\]

Using your map & compass to measure current local magnetic declination

From the map
Trail Jct -> Peak
68° True

Current local magnetic declination is (68 - 52) 16° E. of True North

Choosing a North Reference

- On your Map
- For your Compass
- For your GPS

- When the north references are different, you will need to do conversions as you move bearings between your map, compass, and GPS.

North Reference on your Map

- North Reference is important when you are plotting or reading bearings on the map.

- Grid North is easy to use on maps with printed UTM / MGRS / USNG grid lines.
  - Lots of north reference lines already printed on the map.
  - Likely to be very close to True North.
  - When the level of accuracy required is low, Grid North lines are often used as True North lines.

North Reference on your Map

- Lines of Longitude are True North lines.
  - Often the two vertical edges of the map are lines of longitude and can be used as True North reference lines.
  - They may be the only two True North lines on your map. Unless you map has a lat/lon grid printed on it.

North Reference on your Map

- You can draw parallel lines aligned with Magnetic North onto your map for use as north reference lines.
  - Many aviation and marine charts have preprinted Magnetic North lines. Most other maps do not.

North Reference on your Map

- The needle or card of your compass will always align itself with Magnetic North.

- Thus Magnetic North is an easy and natural choice to use with your compass.

- But it’s not the only option...
North Reference on your Compass

• Some compasses allow the orientation needle to be moved independently from the angular measurement dial.
• This makes it possible to set you compass to read bearings in any of the three north references.

Declination Adjustment

- Rack & Pinion Gear
- Friction Fit

Note position of the orientation lines

North Reference on your Compass

- Card style compasses and sighting compasses generally can not be adjusted, and will always provide bearings relative to Magnetic North.
- This is because the card and magnet are fixed to each other and sealed inside of the capsule.

North Reference on your Compass

- When the orientation arrow can not be adjusted independently from the angular dial, you can use some other mark to align the compass needle.
- Some compasses have a printed scale for this purpose.
- You can also make you own mark on the capsule. (remember you need to be able to change the mark, as you change your locale.)

Alternate North Reference Adjustments

- Alcohol Pen on capsule
- Tape on bottom of capsule

North Reference on your GPS

- You GPS can be set to use any of the three north references.
  – Use the set up page for Heading or North Reference
- It will even figure out the angles to use based on your location.

Common Scenarios

Map=Grid, Compass=Mag, GPS=Mag

• Easy to use reference lines already on the map.
• No compass adjustment needed.
• Conversion between Grid and Magnetic is required to work with compass bearings on the map.

Common Scenarios

Map=Grid, Compass=Grid, GPS=Grid

• Easy to use reference lines already on the map.
• Compass adjusted to Grid North.
  – Adjustment should be checked for correctness
• No conversions required to work with compass bearings on the map.
Common Scenarios
Map=Mag, Compass=Mag, GPS=Mag
• You will need to draw reference lines on your maps.
• No compass adjustment needed.
• No conversions required to work with compass bearings on the map.
• You only need to worry about north reference at home when you draw the lines on your maps.

Two Schools of Thought
• Set your compass and forget it
  – Adjust for the declination in your compass.
  – All bearings will be grid or true.
  – No conversion required to use it on a map.
  – Don’t forget to check the setting occasionally.
  – Don’t forget to change it when you go somewhere else.
• Set your compass to 0°, and always think about it
  – All bearings will be magnetic.
  – Conversion to grid or true, or drawing magnetic north reference lines on your map, will be necessary for map work.
  – Works with all compasses.
  – You are more likely to remember how declination works.

No bearing or heading is complete without the word True, Magnetic, or Grid following it.
• Don’t make people guess, say it and write it!

Converting Between North References
• Use the north reference or declination diagram
• Add another line representing the bearing to the target

0° is aligned with Magnetic North
The angle is measured relative to Magnetic North

0° is aligned with Grid North
The angle is measured relative to Grid North

To convert from Magnetic to Grid
Add the extra angle between MN and GN.

Let’s take a break!
In about 10 minutes, we’ll return.

Orienting your map using your compass
• Adjust the compass to look like the declination diagram.
• Set the compass down on the map with its edge parallel to a true north line.
• Rotate the map and compass until the magnetic needle is boxed.
• Don’t do this on a metal surface.
Plotting a Bearing onto your map

• Why we plot bearings
  • Where am I?
  • Location by resectioning
  • Where is the _____ I can see in the distance?
  • Location by intersection
  • Using straight line course legs

Location by Resectioning a.k.a Triangulation

A single bearing, sighted to a peak, resulting in two possible locations along a trail.

Location by Resectioning

A bearing to a second peak confirms the location on the trail.

Location by intersection

Using bearings sighted from two or more known locations, to find an unknown location.

An example

Where are we along the shoreline?
Where is the cave we can see across the lake?

We sight a bearing to a known cabin on the map, with a result of 60° M
It's NE of our location.

Center your protractor on the known location.

Align the protractor with Grid North.
Our bearing was sighted relative to Magnetic North. We want to plot it relative to Grid North. We need to convert it.

Bearing measured with our compass from Magnetic North

Bearing to plot on the map measured from Grid North

60° + 5° = 65°

Mark the converted bearing at the edge of the protractor.

Use a straight edge to draw the bearing line. Remember the cabin was NW of us, so we want the line to the SW of the cabin.

The bearing plotted back towards our location defines our location where it crosses the lakeshore.

A bearing to a second cabin helps confirm our location. But it also shows us standing in the lake!

A third bearing reveals an "uncertainty triangle." Some of our bearing have small errors.

You can use your compass as a protractor

Plotting a bearing with a baseplate compass

Set the dial to the desired bearing (using the map's north reference) Align the compass with the north reference lines.

Keeping the compass aligned with the Grid North lines, move it until an edge touches the know point.
Locating a Column of Smoke with intersecting bearings

- From the Stanislaus River Campground, the smoke is visible at 210° M.
- From 755.88km E 4256.80km N, 142° M.
- From the Hells Kitchen Vista, 115° M.
- What are the UTM coordinates for the fire?
- How would you reach the fire traveling from the Hells Kitchen Vista? How long would it take you to get there?
You are hiking along a trail, north of Coyote Lake. You are not exactly sure of your location, and decide to sight some compass bearings to determine your location.

Plotting Compass Bearings near Sharktooth Peak

You are hiking along a trail, north of Coyote Lake. You are not exactly sure of your location, and decide to sight some compass bearings to determine your location.

Sharktooth Peak: 59°M
Silver Peak: 87°M
Cockscomb: 136°M

First let’s get our north reference sorted out.

USGS provides us a declination diagram dated 1982. Probably too old to be accurate today.

Google “declination calculator”, and find the current magnetic declination for this map. Hint: Use the lat/lon from one of the map’s corners.

http://www.ngdc.noaa.gov/geomag-web/#declination

Now let’s look at the Grid North lines on the map.

Grid North varies with location.
But it doesn’t change over time.
So the Grid North information in the 1982 declination diagram should still be correct.

But the angle it makes with True North (the edge of the map) doesn’t look like a 1/4° to me!

I measured 1.4° between True and Grid North.
I measured triangle edges and used a trig function to get the angle.

I don’t think this kind of error is common. But it’s a good idea to check your maps when you first get them.

Our compass bearings are measured from Magnetic North.
We want to plot on the map, measuring from Grid North.

To convert from a Magnetic bearing to a True bearing...

Mag. + 13.2 + 1.4 = Grid
or
Mag. + 14.6 = Grid
round to
Mag + 15 = Grid

http://www.earthpoint.us/Convert.aspx
You are hiking along a trail, north of Coyote Lake. You are not exactly sure of your location, and decide to sight some compass bearings determine your location.

- Sharktooth Peak 59°M
- Silver Peak 87°M
- Cockscomb 136°M

Convert your bearings to work from Grid North. Plot them on the map.

You are somewhere east of Big Margaret Lake. Plot some bearings to find your exact location.

View North

View South

View West

Note that small errors change the location where the bearings intersect when the bearings are either very close to each other or when they are about 180° apart. Ideal targets are separated by 45° - 135°.

From your campsite at Frog Lake you can see what looks like an old mining cabin in the distance. Curious about its location, you take a bearing with your compass.

- 345°M

The next day you camp at Rock Creek Lake. Again you can see the cabin and take a compass bearing.

- 66°M

Where is the cabin? Should you take another bearing before you hike to the cabin?

Location by resectioning is often taught, but is seldom used in the field

It's rare to find 3 identifiable features all of which are on your map sheet.

It's more common to use just one bearing and combine it with other information, like being located on a trail or other identifiable feature.

Often you do not have enough information to detect errors in plotting.

Let's take a break!

In about 10 minutes, we'll return.
And then you get a map with no coordinate grid… use resectioning from GPS Waypoints!

Important Information...

- A map of the area with...
  - North Reference
  - Distance Scale
- Coordinates for a known location
  - It’s quick and easy to save the location of the trailhead where you parked, in your GPS.
  - Coordinates marked on the map can be entered into your GPS.

Use the GOTO feature on your GPS

- Your GPS will give you a bearing and distance to the stored location, from your current location.
- But it’s our current location that we want to know!

- Place your protractor on the stored location.
- Align 0° on the protractor with North on the map. Pay attention to the map’s north reference and to the GPS’s north reference set on the Tooling setup page.
- Mark the bearing at the edge of the protractor.

- GPS --> Stored Location
  40° True, 1.2 miles

- Use the 1 mile scale bar and the edge of a piece of paper, to mark a 1.2 mile distance.

- GPS --> Stored Location
  40° True, 1.2 miles

- Plot the bearing backwards from the stored location.

- Line the edge of the paper up with the stored location and the mark you made at the edge of the protractor.
- Measure backwards along the bearing line for 1.2 miles.

GPS --> Stored Location
40° True, 1.2 miles

You are here!
• Using a bearing and distance from a second known location will confirm your location and protect you from errors you may have made plotting the first one.

• Let’s try it out...

Use the protractor on your grid tool

Resection/Intersection Exercise

A bearing taken to Point A, is 53° M

Location by Resection Exercise

53° Mag. + 15°E Declination → 68° True