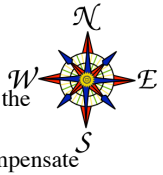
A Brief History of the Compass

Han Dynasty "Heaven Plate" Compass

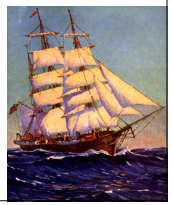
Early Chinese Compasses

- 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

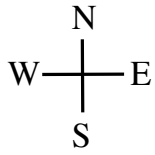


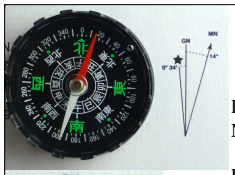
Compass Uses

- 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

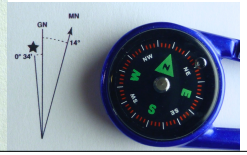




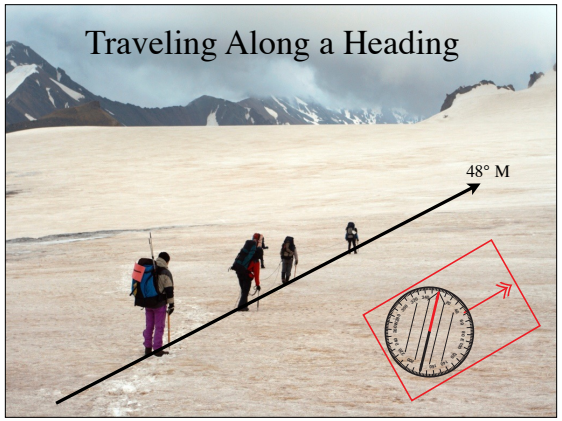
Orienting your Map to North

Put the compass on the map near the North Arrow.

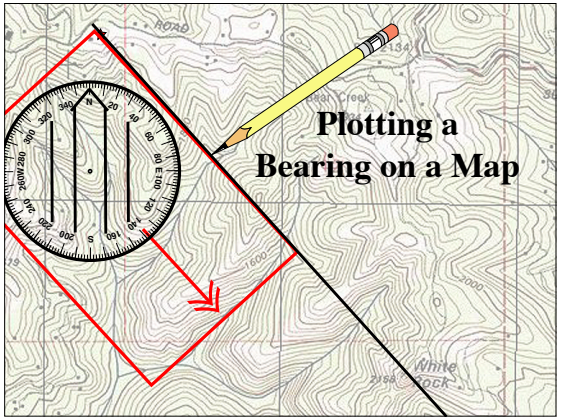
Rotate the entire map, along with the compass, until the compass is aligned with the magnetic north direction shown on the map.



Traveling Along a Heading

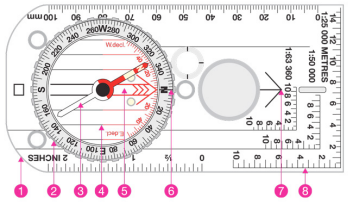


Sighting a Bearing to a Distant Object



Plotting a Bearing on a Map

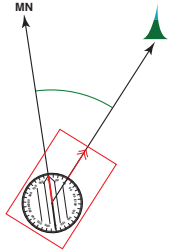
Basic Compass Components



1 - Baseplate
2 - Rotating Dial
3 - Magnetic Needle
4 - Orienting Lines
5 - Orienting Arrow
6 - Index Line
7 - Direction of Travel Arrow
8 - Scales

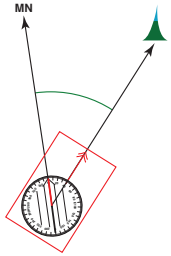
Using a compass to sight a bearing to a distant target.

Measures an angle between Magnetic North, your location, and the distant target.

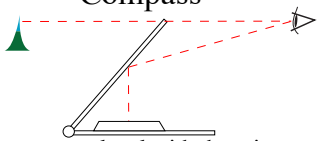


Using a compass to get a bearing to a distant target.

- 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.

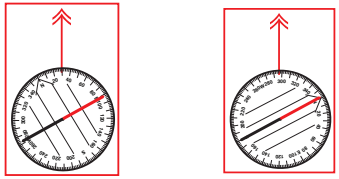


Sighting with a Mirrored Compass

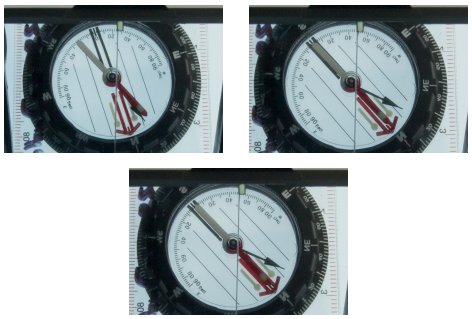


- Hold the compass level with the mirror at about a 45° angle.
- Use the sighting notch to align the compass with the target.
- Looking into the mirror, turn the dial to align the orienting arrow with the north needle.

Sighting with a Mirrored Compass

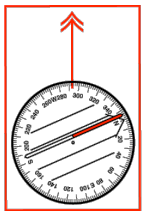


- Turn the dial to align the orienting arrow with the north arrow.

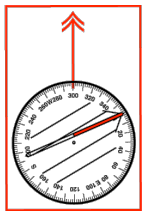


Needle Parallax

Good

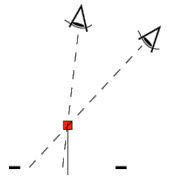


Bad



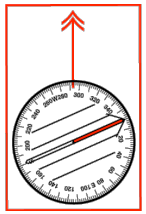
Keep the needle parallel to the orienting arrow.

Parallax Side View

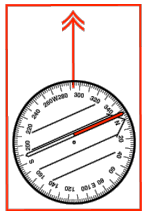


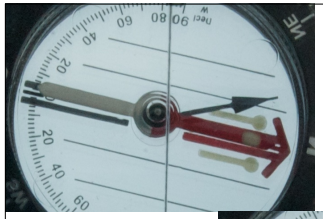
Needle Parallax

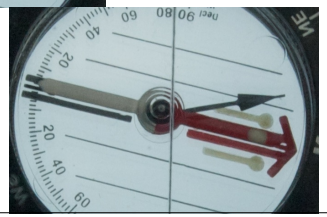
View from Above



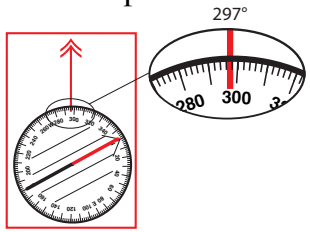
View from Behind





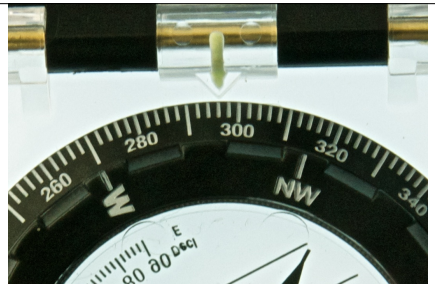


Sighting with a Mirrored Compass



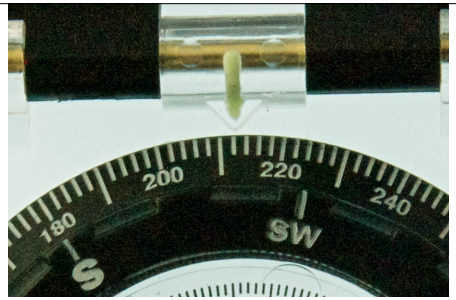
- Read the bearing from the index line

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

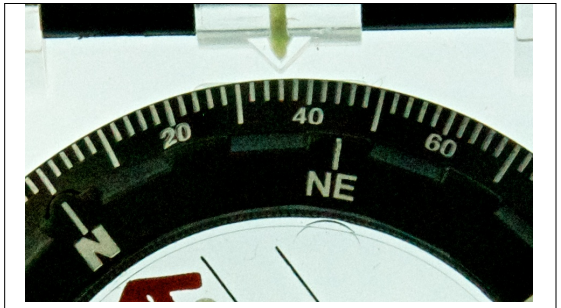


Labeled every 20°
Longer tics every 10°
Each increment is 2°

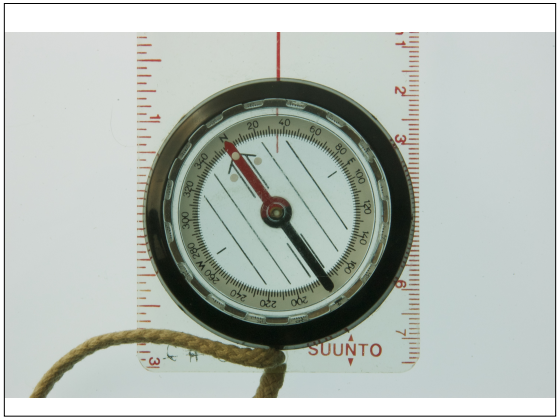
296°

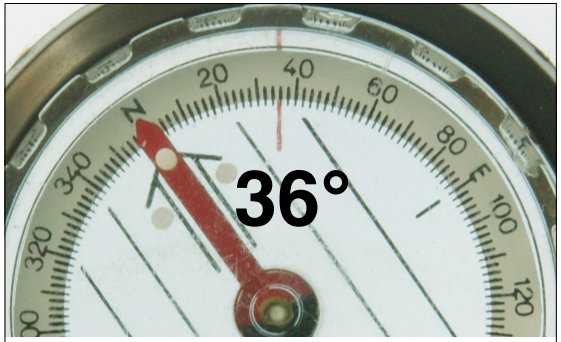


212°

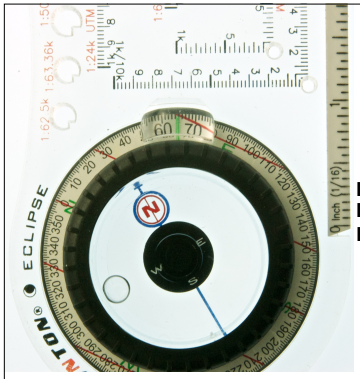


36°



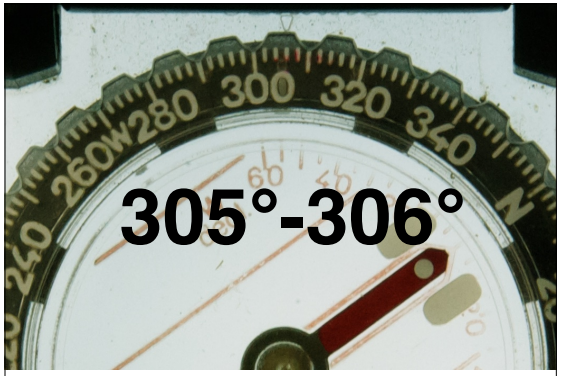


?



Circle in a Circle
to
"Box the Needle"

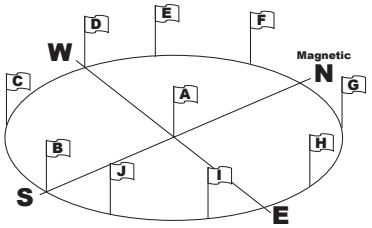
Labeled every 10°
Longer tics every 5°
Each increment is 1°



357°

357.5°

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.

A to B = _____
B to D = _____
C to A = _____
D to G = _____
E to H = _____

F to I = _____
G to J = _____
H to C= _____
I to D = _____
J to F = _____

A to E = _____
A to F = _____
A to B = _____
A to H = _____
D to A = _____

Field Exercise

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

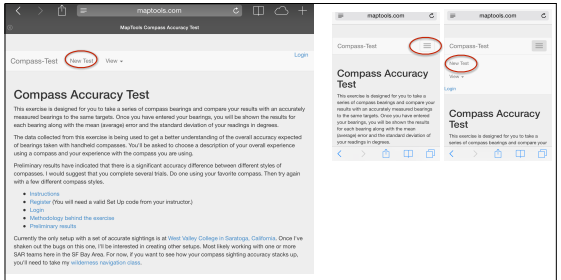
Practice sighting bearings

Align your sighting with the right edge of all targets, except **C**.

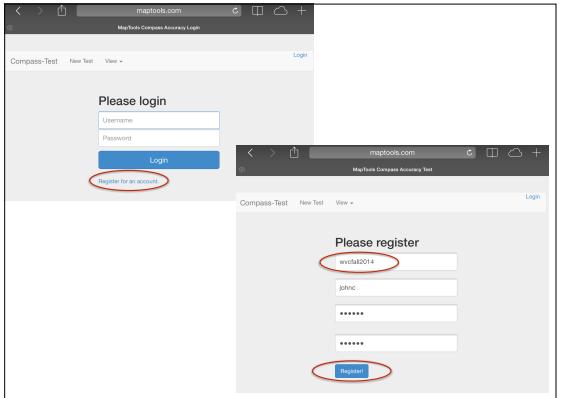
A - Top of tree **B** - Lamp post **C** - Top of distant tree **D** - Column **E** - Column **F** - Column

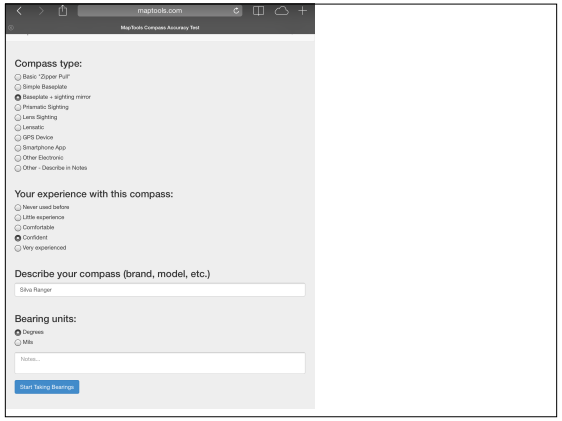
G - Column **H** - Column **J** - Column

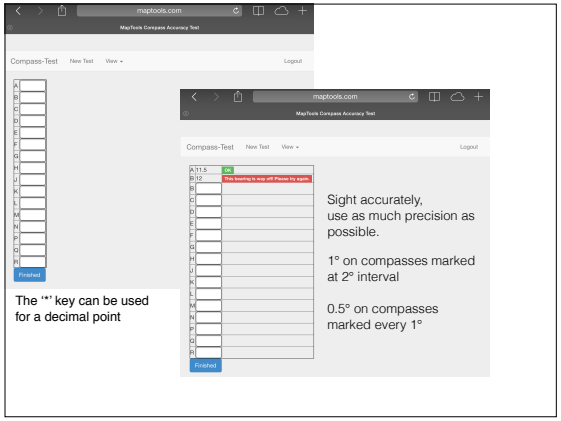
There are 18 targets to sight.



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





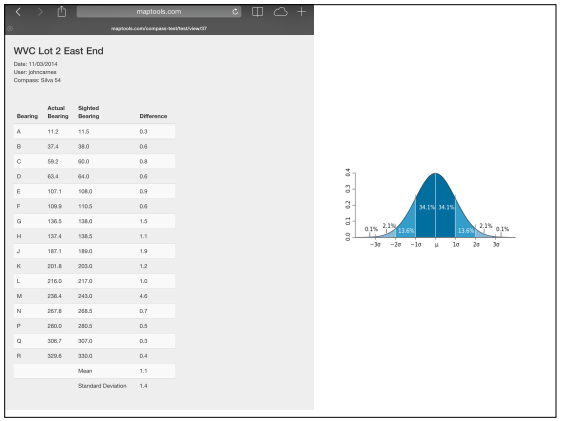


The '*' key can be used for a decimal point

Sight accurately, use as much precision as possible.

1° on compasses marked at 2° interval

0.5° on compasses marked every 1°



Layout ID	Test ID	User	Compass	Mean	Standard Deviation
1	1	johncarnes	Brunton 54LU	0.1	0.5
4	15	johncarnes	54LU	0.0	0.8
4	12	johncarnes	Brunton Eclipse Mirrored	-1.0	1.3
1	4	johncarnes	Brunton Sightmaster	-0.1	1.7
1	9	johncarnes	Cammenga 3H	-0.5	1.8
1	3	johncarnes	Silva Ranger	-0.1	1.9
4	11	johncarnes	Francis Barker M-73	1.8	2.0
1	7	johncarnes	China Black Sighting	-0.6	2.3
4	14	johncarnes	Brunton Eclipse GPS	-0.5	2.6
1	8	johncarnes	Francis Barker M-73	1.8	2.9
4	13	johncarnes	Celestron w/ Glasses	-3.3	3.5
4	10	johncarnes	iPhone 4S Theodolite Pro app	1.1	5.2

How I measured accurate bearings

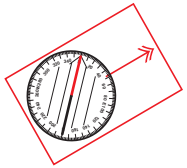
- Used differential GPS to find a 90°T base line (~210m)
- Used surveyors total station to transfer bearings from the baseline to two points outside of the classroom.
- Used total station to sight bearings to targets.
- Overall accuracy +/- 0.2° based on the baseline accuracy.
- Targets measured relative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



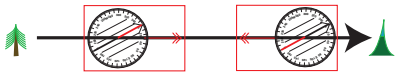
Traveling Along a Heading

- Sight to a distant object, and then travel towards that object.
- In poor visibility, darkness, or featureless landscapes, send a partner ahead to the limit of visibility and align them with the heading.
- Take back bearings on your starting point.

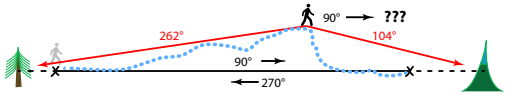
Using a back bearing

- 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.

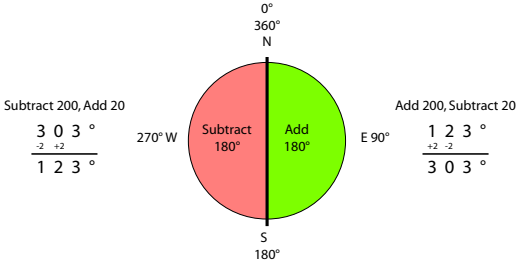
Check that you are on course using a back bearing



- 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

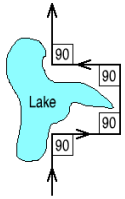
100m = 53 paces
10m = 5.3 paces

230 m =
53 + 53 + 5 + 5 + 5

or if you have your calculator handy...

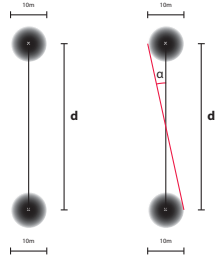
230 / 100 * 53 = 121.9

Pacing around an obstacle



Bearing & Distance with a GPSr

Angular Error in GPS Bearing to Waypoint



Angular Error in GPS Bearing to Waypoint

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

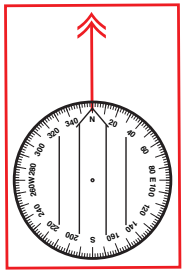
$$\alpha = \tan^{-1}\left(\frac{10}{d}\right)$$

d	α
100m	6°
200m	3°
300m	2°
400m	1.4°
500m	1.1°
600m	1.0°
700m	0.8°
800m	0.7°
900m	0.6°
1000m	0.57°

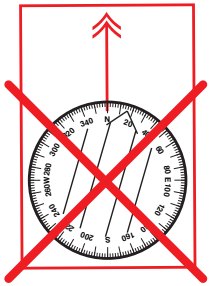
Field Exercise

- Pace/Time 100m distance
  - –Use you 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.

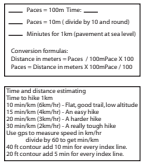
Compass
Not Adjusted for Declination



Compass
Adjusted for 16° E Declination



100m Pace Card



Paces = 100m Time: ____
Paces = 10m (divide by 10 and round)
Minutes for 1km (pavement at sea level)

Conversion formulas:
Distance in meters = Paces / 100mPace X 100
Paces = Distance in meters X 100mPace / 100

Time and distance estimating
Time to hike 1km
10 min/km (6km/hr) - Flat, good trail, low altitude
15 min/km (4km/hr) - An easy hike
20 min/km (3km/hr) - A harder hike
30 min/km (2km/hr) - A really tough hike
Use gps to measure speed in km/hr
divide by 60 to get min/km
40 ft contour add 10 min for every index line.
20 ft contour add 5 min for every index line.

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.

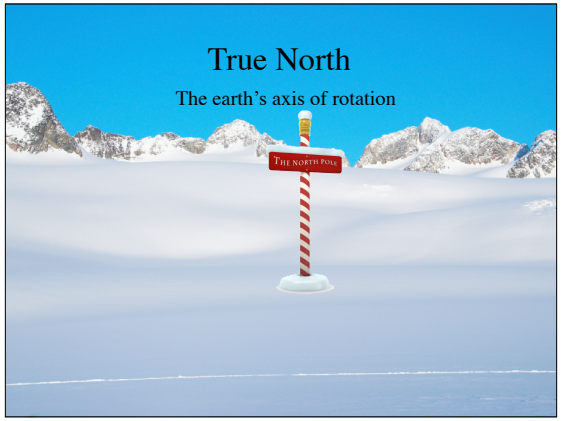
Let's do it!

Return to the classroom by....

At which North Pole does Santa Claus live?

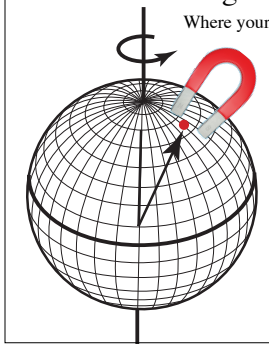
True North

The earth's axis of rotation



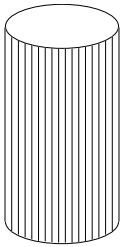
Magnetic North

Where your compass points

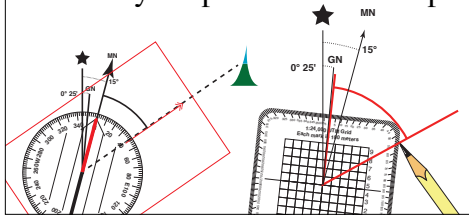


Grid North

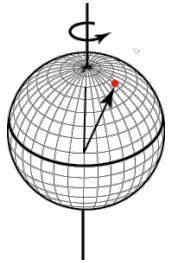
Where the UTM grid lines "point" to



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

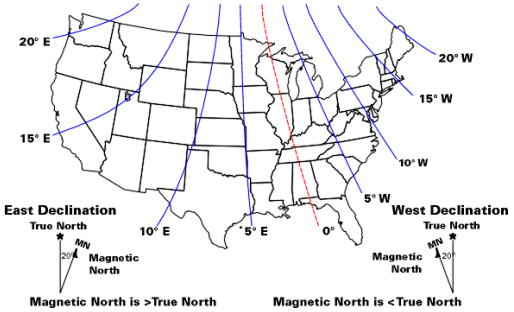


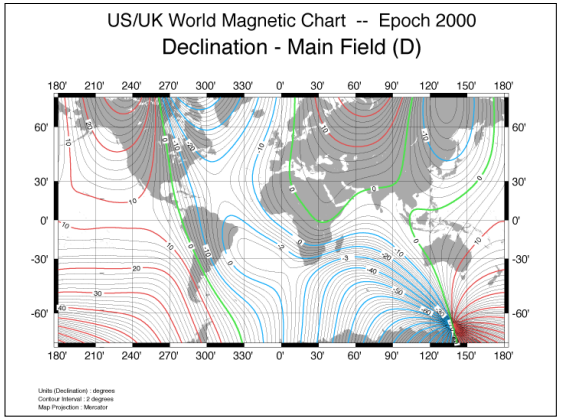
True v.s. Magnetic North



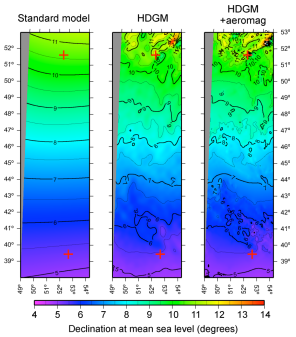
What is the difference here?

- 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…

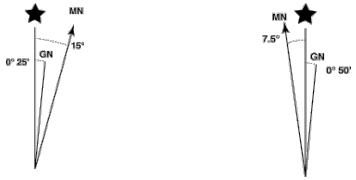




High Definition Geomagnetic Model



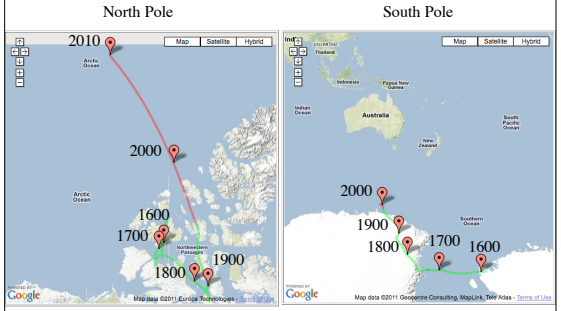
Declination Diagrams



Declination changes over time

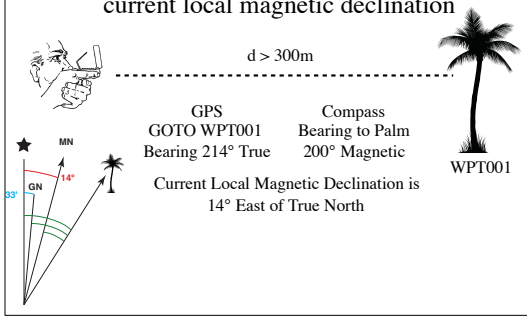
- Here in Northern California it changes by about 1° every 20 years.
- The declination shown on your topo map may be out of date.
- What about declination displayed by my GPS?
  - It probably correct as of the date of manufacture.

Magnetic Poles

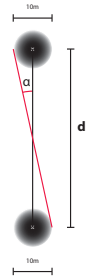


Declination Calculator at www.ngdc.noaa.gov

Using your GPS & compass to measure current local magnetic declination



Angular Error in GPS Bearing to Waypoint



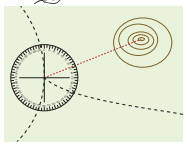
$$\tan(\alpha) = \frac{5}{\frac{d}{2}} = \frac{10}{d}$$

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

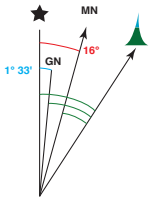
d	α
100m	6°
200m	3°
300m	2°
400m	1.4°
500m	1.1°
600m	1.0°
700m	0.8°
800m	0.7°
900m	0.6°
1000m	0.57°

Using your map & compass to measure current local magnetic declination

Compass
Trail Jct -> Peak
52° Mag.



From the map
Trail Jct -> Peak
68° True



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

Check you compass & sighting technique using these methods and the declination for the area

- Find some place near your home to establish your personal compass testing location.
- Identify several features, at least 1km away, that you can sight on.
- Use a map to determine True bearings to these features. Convert these bearings to Magnetic using the calculated declination for the area.
- Check your compass and technique. Experiment with the your gear to see if it influences your compass.
- Keep notes, so you can repeat this in the future.

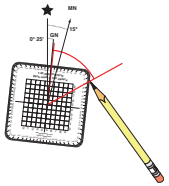
Choosing a North Reference

- 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.



North Reference on your 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

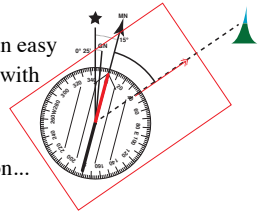
- Lines of Longitude are True North lines.
  - Often the two vertical edges of the map are lines of longitude and can be used as True North reference lines.
  - They may be the only two True North lines on you map. Unless you map has a lat/lon grid printed on it.

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 Compass

- 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

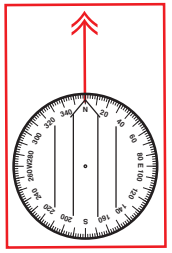
Rack & Pinon Gear

Friction Fit

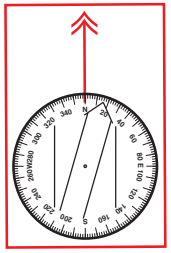
Note position of the orientation lines

North Reference on your Compass

Compass
Not Adjusted for Declination



Compass
Adjusted for 16° E Declination



North Reference on your Compass

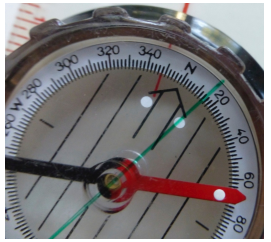
- Card style compasses and sighting compasses generally can not be adjusted, and will always provide bearings relative to Magnetic North.
- This is because the card and magnet are fixed to each other and sealed inside of the capsule.

North Reference on your Compass

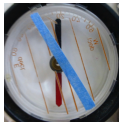
- When the orientation arrow can not be adjusted independently from the angular dial, you can use some other mark to align the compass needle.
- Some compasses have a printed scale for this purpose.
- You can also make you own mark on the capsule. (remember you need to be able to change the mark, as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

Alternate North Reference Adjustments

Alcohol Pen on capsule

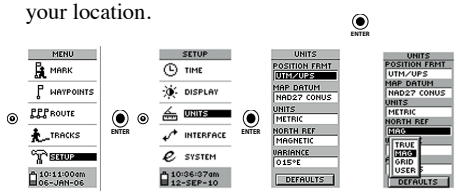


Tape on bottom of capsule



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

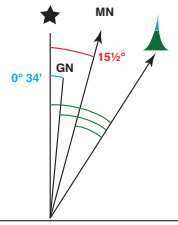
- Set your compass and forget it
  - Adjust for the declination in your compass.
  - All bearings will be grid or true.
  - No conversion required to use it on a map.
  - Don't forget to check the setting occasionally.
  - Don't forget to change it when you go somewhere else.
- Set your compass to 0°, 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!

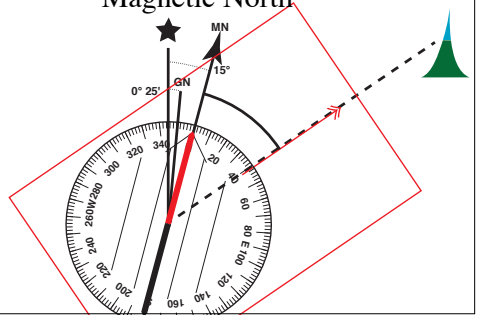
Converting Between North References

- Use the north reference or declination diagram
- Add another line representing the bearing to the target



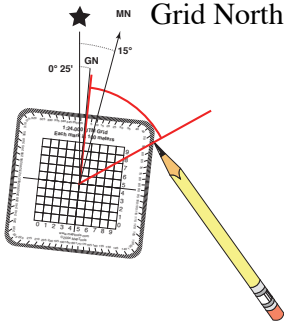
0° is aligned with Magnetic North

The angle is measured relative to Magnetic North

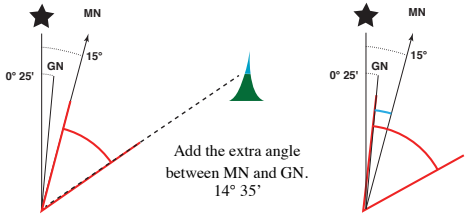


0° is aligned with Grid North

The angle is measured relative to Grid North

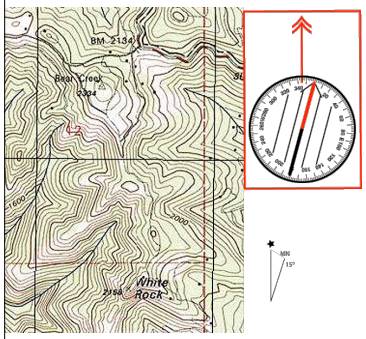


To convert from Magnetic to Grid



Orienting your map using your compass

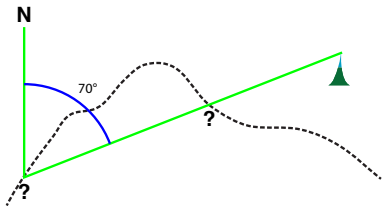
- Adjust the compass to look like the declination diagram.
- Set the compass down on the map with its edge parallel to a true north line.
- Rotate the map and compass until the magnetic needle is boxed.
- Don't do this on a metal surface.



Plotting a Bearing onto your map

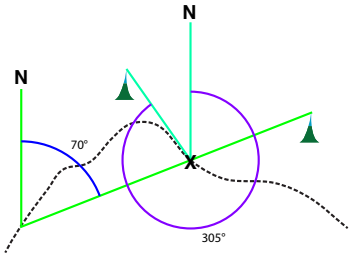
- Why we plot bearings
  - Where am I?
    - Location by resectioning
  - Where is the ____ I can see in the distance?
    - Location by intersection
  - Using straight line course legs

Location by Resectioning
a.k.a Triangulation



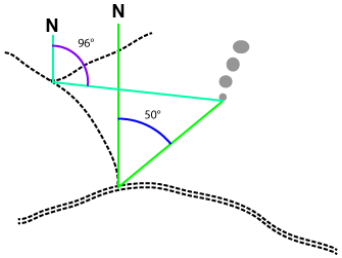
A single bearing, sighted to a peak,
resulting in two possible locations along a trail.

Location by Resectioning



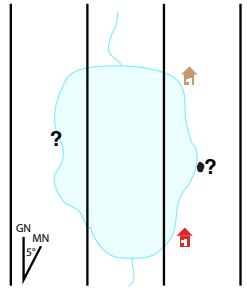
A bearing to a second peak
confirms the location on the trail.

Location by intersection

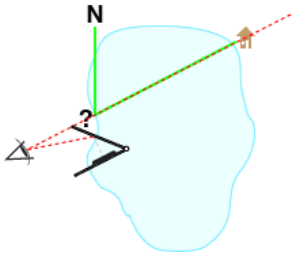


Using bearings sighted from two or more
known locations, to find an unknown location.

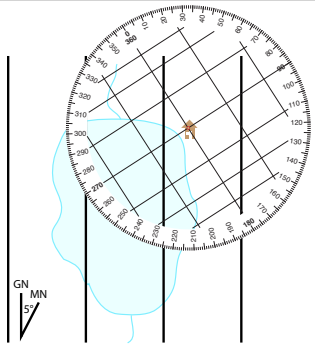
An example



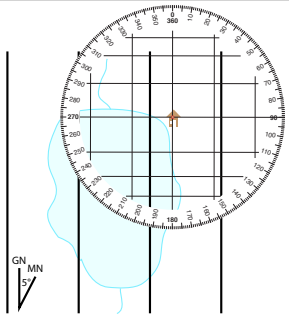
Where are we along the shoreline?
Where is the cave we can see across the lake?



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

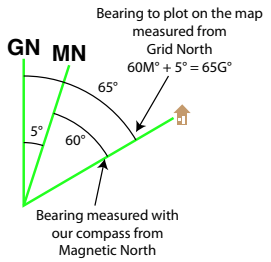


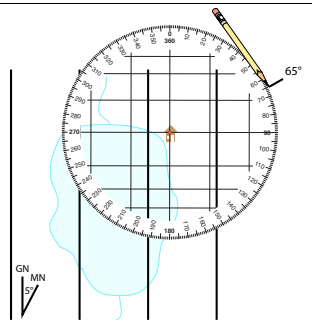
Center your protractor on the known location.



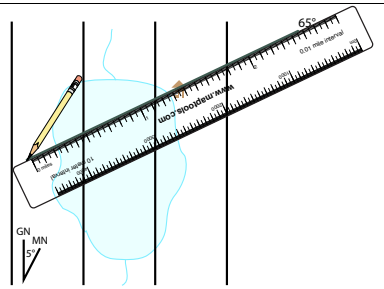
Align the protractor with Grid North.

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

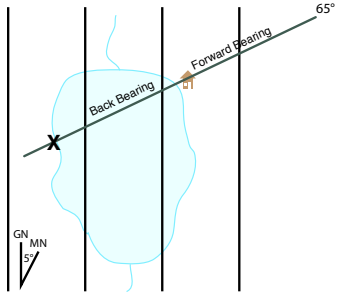




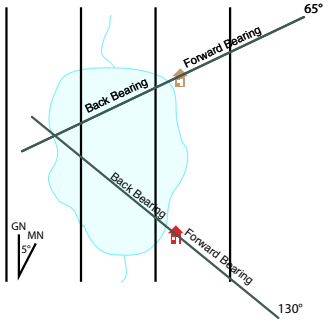
Mark the converted bearing at the edge of the protractor.



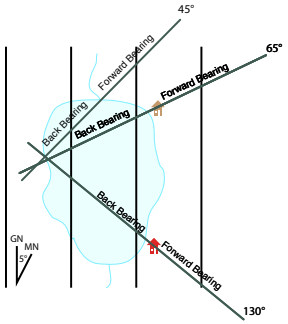
Use a straight edge to draw the bearing line.
Remember the cabin was NW of us,
so we want the line to the SW of the cabin.



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

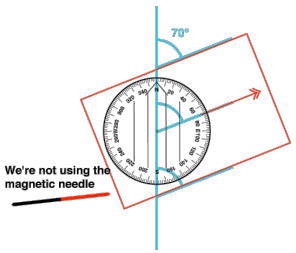


A bearing to a second cabin helps confirm our location.
But it also shows us standing in the lake!

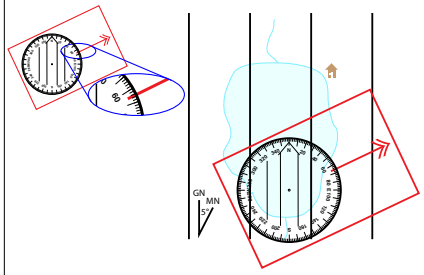


A third bearing reveals an “uncertainty triangle.”
Some of our bearing have small errors.

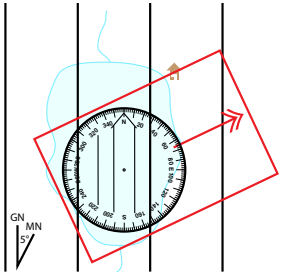
You can use your compass as a protractor



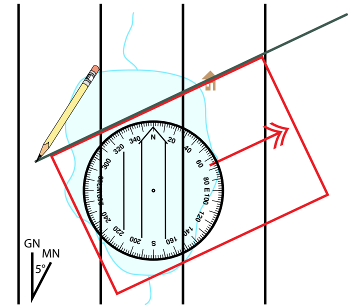
Plotting a bearing with a baseplate compass



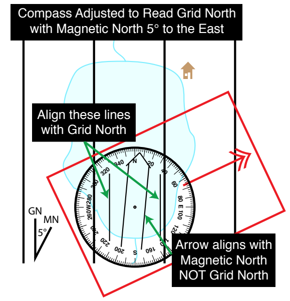
Set the dial to the desired bearing
(using the map’s north reference)
Align the compass with the north reference lines.



Keeping the compass aligned with the Grid North lines,
move it until an edge touches the know point.



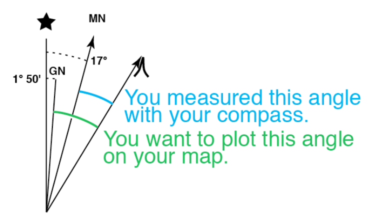
Draw the bearing line along the edge of the compass.

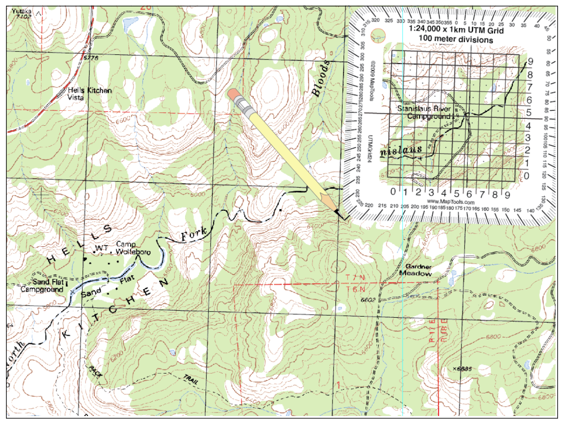


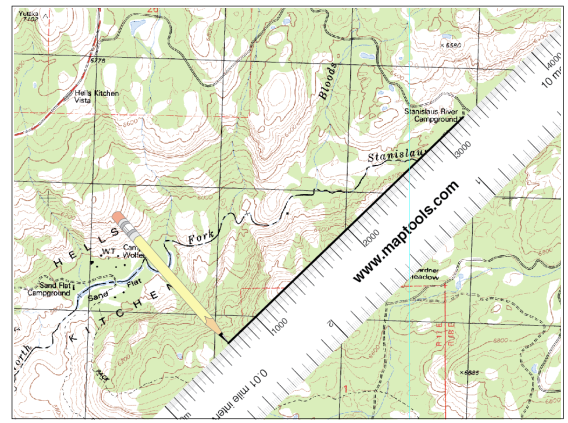
This compass, adjusted 5°E. declination, would provide bearings relative to Grid North. No conversion necessary.

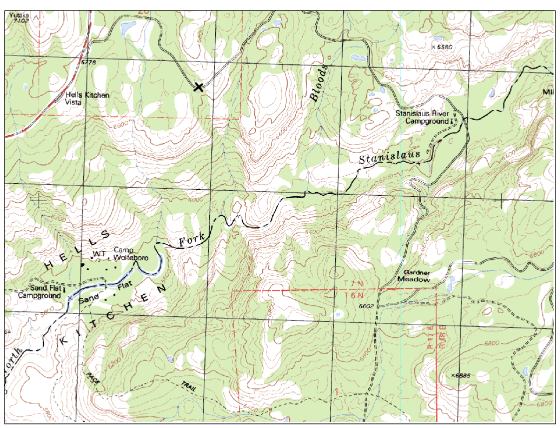
Locating a Column of Smoke with intersecting bearings

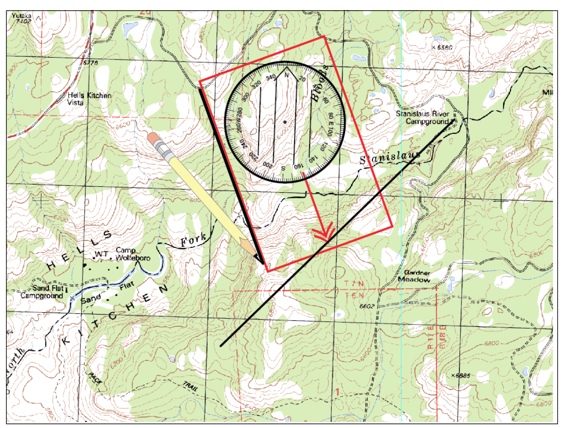
- From the Stanislaus River Campground, the smoke is visible at 210° M.
- From 755.88km E 4256.80km N, 142° M.
- From the Hells Kitchen Vista, 115° M.
- What are the UTM coordinates for the fire?
- How would you reach the fire traveling from the Hells Kitchen Vista? How long would it take you to get there?

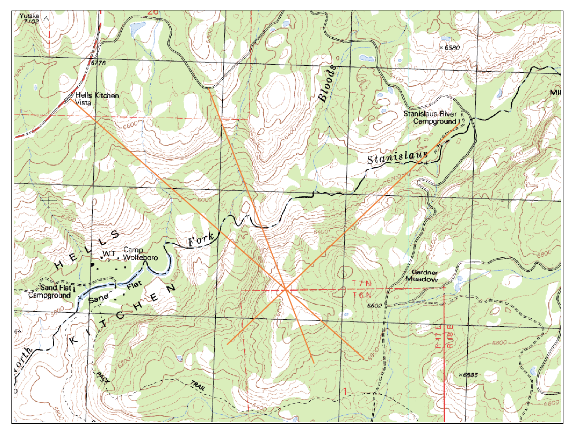


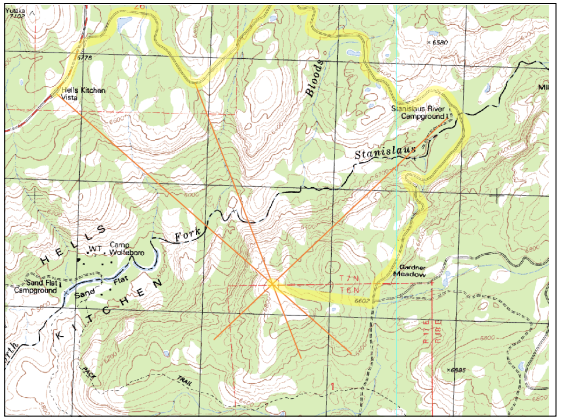


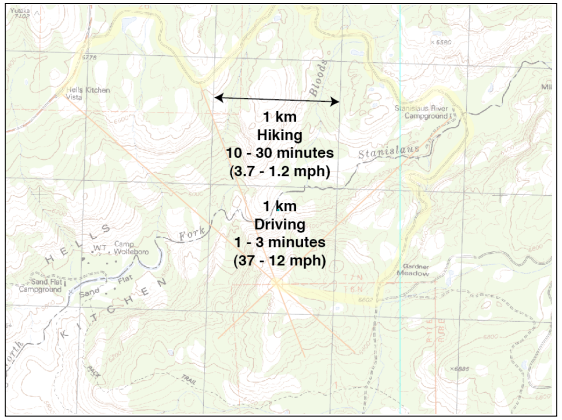


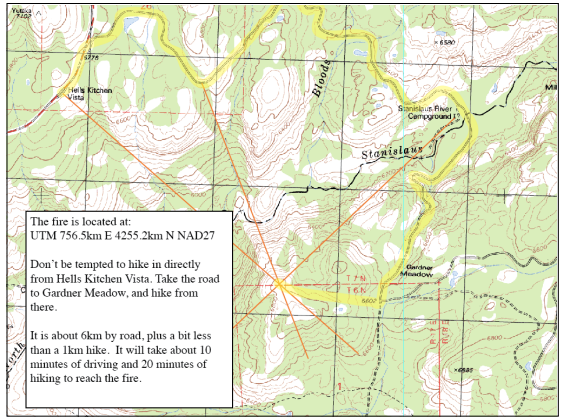












Plotting Compass Bearings near Sharktooth Peak

Sharktooth Peak Map

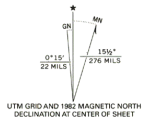
You are hiking along a trail, north of Coyote Lake.
You are not exactly sure of your location, and decide to sight some compass bearings determine your location.

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

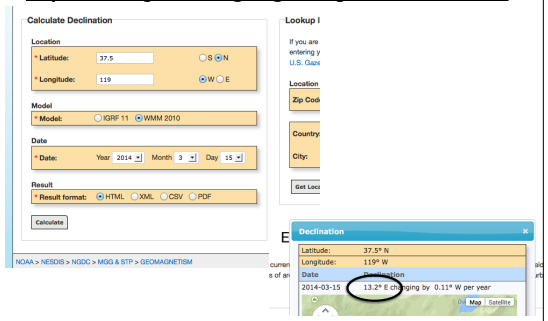
First let's get our north reference sorted out.

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

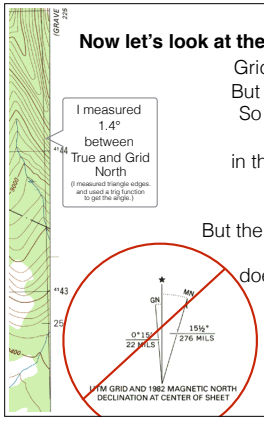
Google "declination calculator", and find the current magnetic declination for this map.
Hint:Use the lat/lon from one of the map's corners.



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

http://www.earthpoint.us/Convert.aspx

Lat Lon of Center of Map

Latitude: N37 26 15 Longitude: W119 03 45

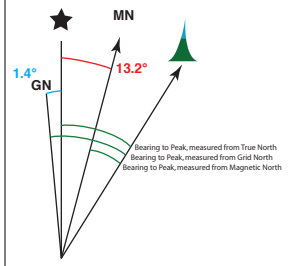
Calc View on Google Earth Free. User account is not needed.

Latitude	N37 26 15
Longitude	W119 03 45

Calculated Values - based on Degrees Lat Long to seven decimal places.

Position Type	Lat Lon
Degrees Lat Long	37.4375000°, -119.0625000°
Degrees Minutes	37°26.25000', -119°03.75000'
Degrees Minutes Seconds	37°26'15.0000", -119°03'45.0000"
UTM	11S 317533mE 4145404mN
MGRS	11SLA1753345404
Grid North	-1.3°
Maidenhead	DM07LK25MA00
GEOREF	EJAH56252625

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



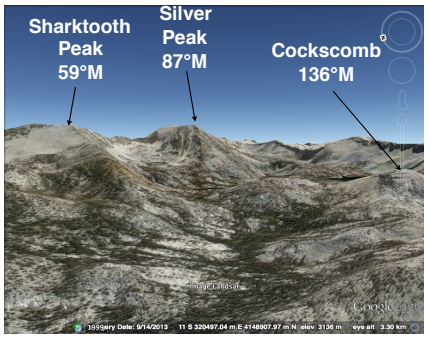
To convert
from a Magnetic bearing
to a True bearing…

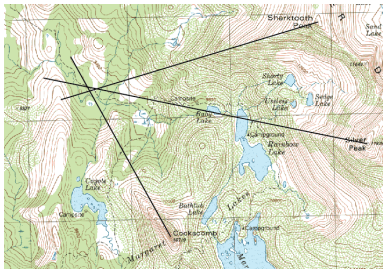
Mag. + 13.2 + 1.4 = Grid
or
Mag. + 14.6 = Grid
round to
Mag + 15 = Grid

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

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.

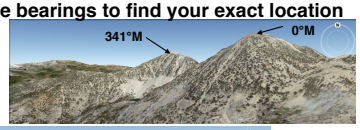
Sharktooth Peak	**59°M**
Silver Peak	**87°M**
Cockscomb	**136°M**





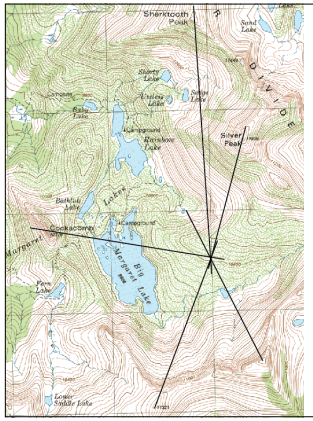
You are somewhere east of Big Margaret Lake.
Plot some bearings to find your exact location

View North



View West

View South



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.

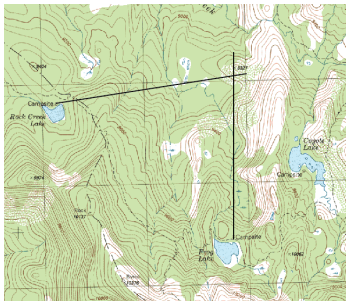
Curious about its location,
you take a bearing with your compass.

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.

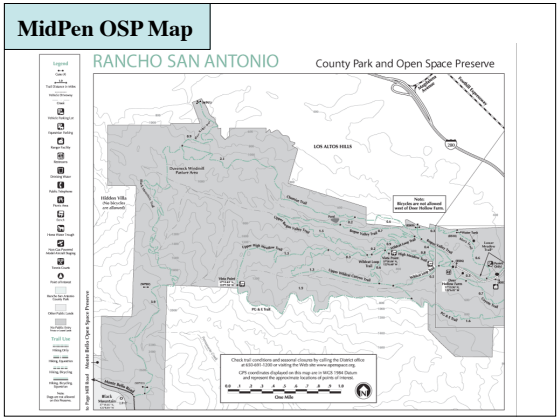
It's more common to use just one bearing
and combine it with other information,
like being located on a trail
or other identifiable feature.

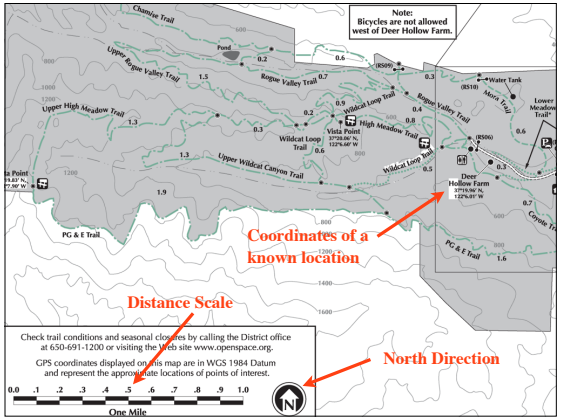
Often you do not have
enough information
to detect errors in plotting.

And then you get a map
with no coordinate grid…

use resectioning from
GPS Waypoints!

MidPen OSP Map



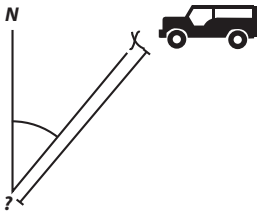


Important Information...

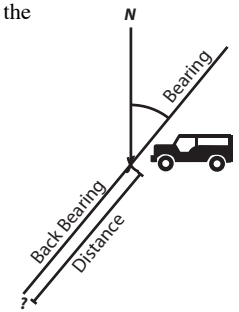
- A map of the area with...
  - North Reference
  - Distance Scale
- Coordinates for a known location
  - It's quick and easy to save the location of the trailhead where you parked, in your GPS.
  - Coordinates marked on the map can be entered into your GPS.

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!

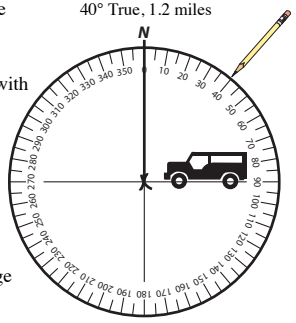


- Plot the bearing backwards from the stored location.



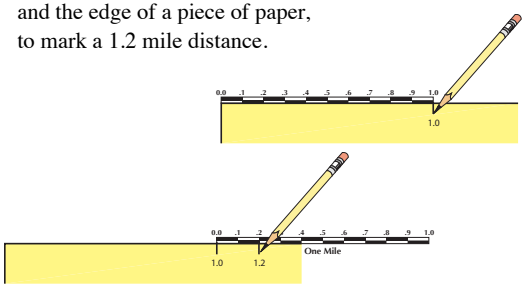
- Place your protractor on the stored location.
- Align 0° on the protractor with North on the map.
  Pay attention to the maps north reference, and to the GPS's north reference set in the Headings setup page.
- Mark the bearing at the edge of the protractor.

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



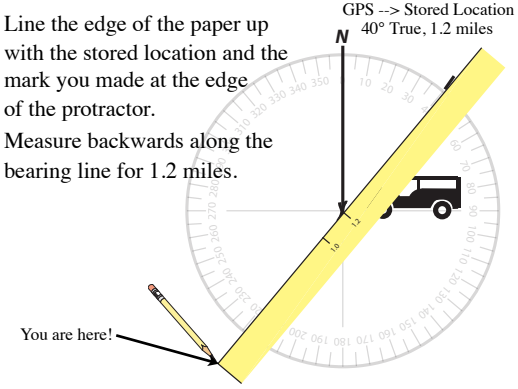
GPS --> Stored Location
40° True, 1.2 miles

- 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

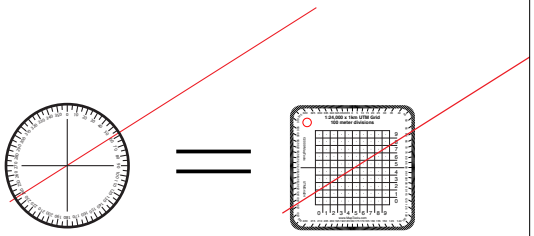
- Line the edge of the paper up with the stored location and the mark you made at the edge of the protractor.
- Measure backwards along the bearing line for 1.2 miles.

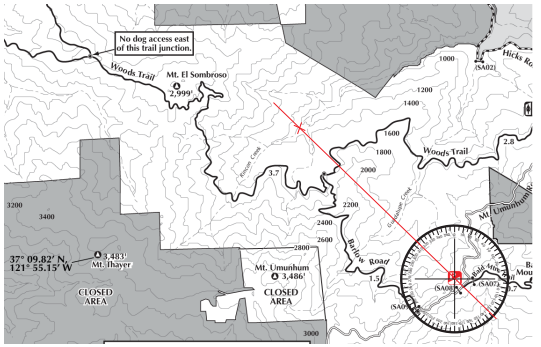


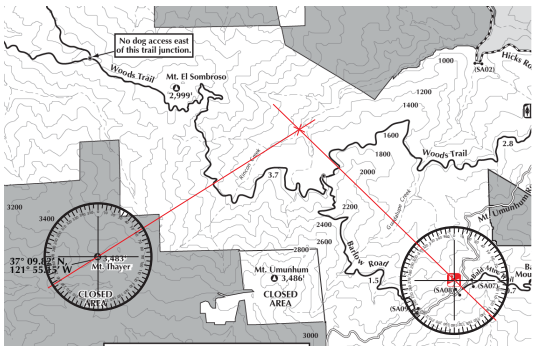
- Using a bearing and distance from a second known location will confirm your location and protect you from errors you may have made plotting the first one.

- Let's try it out...

Use the protractor on your grid tool

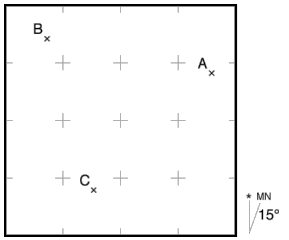




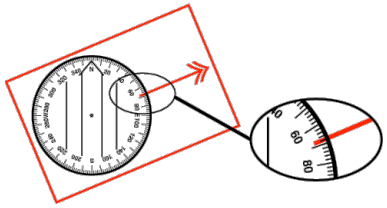


Resection/Intersection Exercise

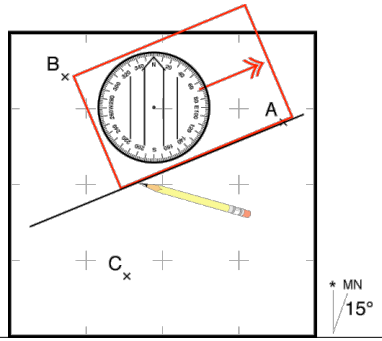
A bearing taken to Point A, is 53° M

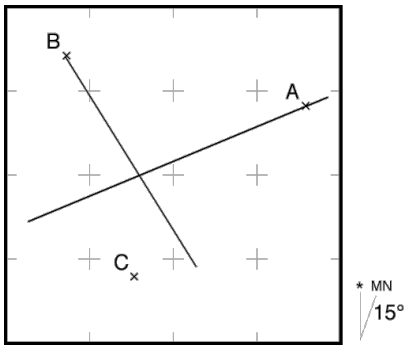


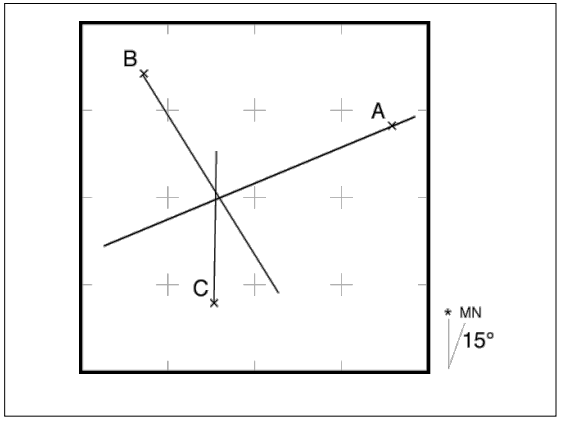
53° Mag. + 15°E Declination --> 68° True



Location by Resection Exercise






B
A
C
* MN
15°