NAVIGATION AND FLIGHT PLANNING

Okay so let's talk about VFR Flight Planning. So, in order to complete our flight plan there are several steps we must do. I've created a list of those items as you see on the board and I will give you a handout at the end for future reference. This may seem like a lot of steps, but that's why we're going to do this together and make sure we get this Navigation Log filled out right and that we understand what the information means and how we get it.

As you advance through your flying, you be able to utilize flight planning apps and technologies, but we first need to build a good foundation and understand how we calculate these items manually.

1. **Weight and Balance**

   So, at this point we've talked about weight and balance, so I won't go into much detail here, but I want to consider a few items:

   - How much Weight am I bringing along?
   - Can I start with full fuel/will I need to make a fuel stop?

   So, we'll assume we've completed a W&B and you and I can take off within our aircraft and center of gravity limits.

2. **Weather Pre-Brief**

   In the days prior to our cross country trip, we could be checking out the local news, various weather apps for the big picture of the weather and forecast. Once it gets closer than I want to take a look at some official weather sources such as:
   Aviationweather.gov
   1800WXBRIEF
   Contact Flight Service

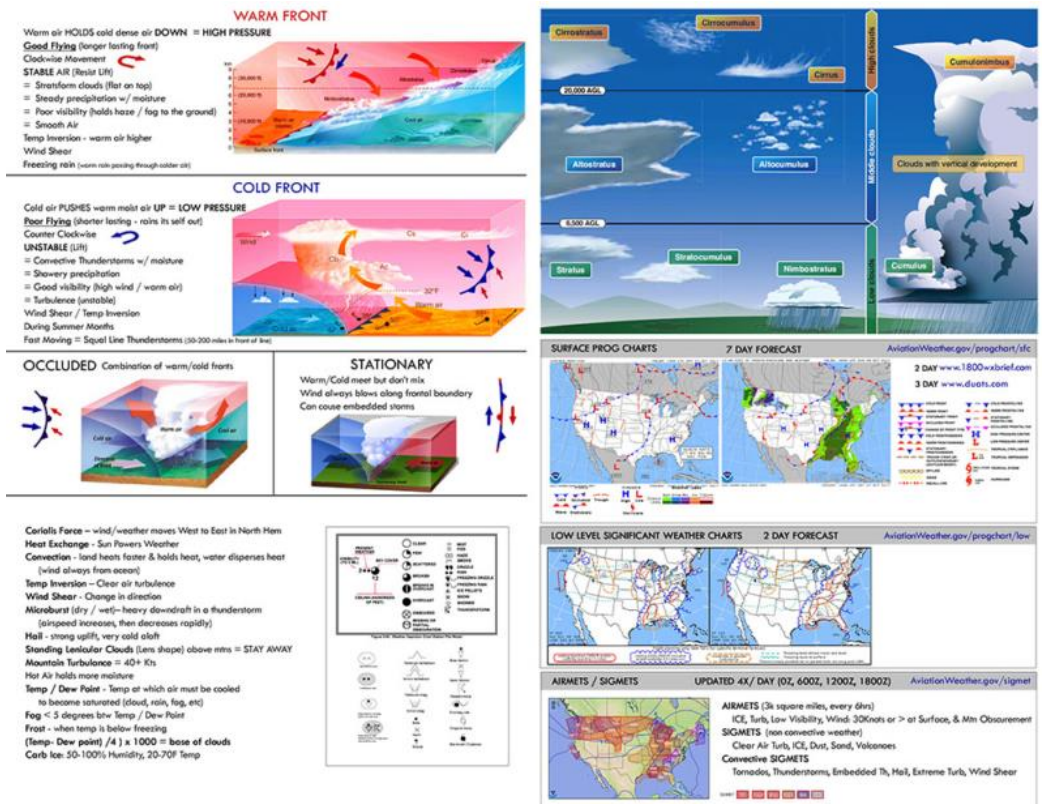
   A standard briefing is requested for flights that are due to depart within six hours, and requires the following information:

   - Type of flight (VFR or IFR).
   - Aircraft identification.
   - Aircraft type
   - Cruising true airspeed.
   - Departure airport.
   - Proposed departure time.
   - Proposed cruising altitude.
   - Route of flight.
   - Destination.
   - Estimated time enroute.
   - Remarks
   - Fuel on board
   - Alternate airport.

   An Outlook briefing is requested if your proposed departure time is six hours or more in the future.

And an abbreviated briefing is requested to update an earlier briefing.
Each of these briefings will give you current weather information for airports along your route, forecasts, and winds aloft.

So, as I get ready to plan my XC trip I like to go online to Aviationweather.gov to get a snapshot of the weather at my departure, destination, and enroute to make sure the weather will be VFR and I can complete my flight safely. *Once we finish our Navigation Log and prepare for our Cross Country I will then go online to 1800WXBRIEF and file my flight plan and also get a Standard weather briefing. Or alternatively we can call the FSS to obtain this briefing.*
Check general conditions: Ceiling & Visibility, Clouds, Precipitation, TS, Winds, Turb, Ice



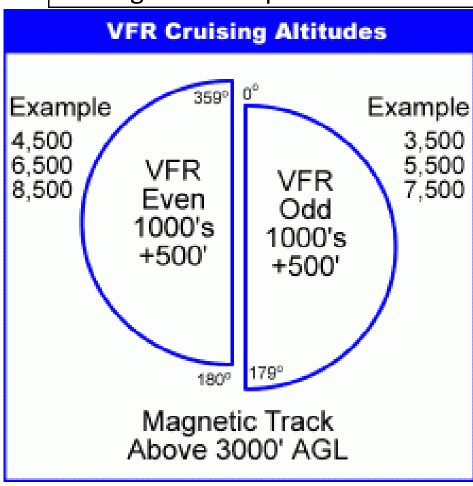
3 types of Navigation
Pilotage: Navigation by reference to landmarks, looking out the window. Select checkpoints that are easily identified select them frequently. 1 inch on section =6.86 Nautical Miles.
Dead Reckoning: Navigation by means of time and direction calculations. A position is estimated using ground speed, time, and heading. So, if I know I am flying 100 knots it will take me 90 minutes to fly 100NM.
Radio Navigation: Our primary example will be VOR's (Very High-Frequency (VHF), Omnidirectional Range. VORs have AM voice broadcast ability. VOR emits a signal in all 360°, called radials, we can tune in this VOR frequency and find out location in regard to the VOR station.

Terminal Aerodrome Chart: 1:250,000, 1 inch = approximately 3.4 NM)
Sectional Chart: 1:500,000 Scale, 1 inch = approximately 6.9 NM)
World Aeronautical Chart: 1:1,000,000, (1 inch = approximately 13.9 NM)

3. Draw Course & Determine Altitude

We need to have a current sectional. Changes are made every 6 months. But it's important that during our weather briefing we check for Aeronautical Chart Bulletin in the Notices section of the Chart Supplement (published every 56 days) and consult NOTAMS prior to each flight. FAA regulations state that a pilot must be familiar with all available information concerning a flight. This includes having up-to-date charts and keeping them current. Updating your charts is as important as any other flight planning responsibility. The quickest or most efficient way to get from point A to B is a straight line. Consider terrain, airports, emergency landings, civilization etc. along the route.

DO'S	DONT'S
Have Airports along Route	Fly over water for extended time periods
Consider Emergencies enroute	Hard to see landmarks (could get lost)
Have good checkpoints enroute	Fly over very mountainous terrain



Part 91.159 VFR Altitude Rules. (Chart is Oriented to True North but we can make a good estimate of whether we are flying generally east or generally west and we can change this later once we verify our MH, alternatively we can quickly subtract mag variation from our course to determine what altitude we would need to fly.

POH says that at 8000' we can glide 12NM, so our glide is about 667' lost per NM. At 4500 we can glide about 6.75NM.

4. Mark Checkpoints

Next we want to mark out some visual checkpoints that we can identify along our route while we are in the air. Now we are going to have two checkpoints that I will mentions now, and we'll talk about more later. Top of Climb and Top of Descent. My first checkpoint will be this Top of Climb point where we have reached our cruise altitude. We will calculate that here shortly. I know that point will be somewhere in the ballpark of 0-10NM (Look at Time, Fuel and Distance Chart POH), so I will make my second checkpoint around 15 nautical miles away. (Typically want our checkpoints 10-15NM apart. This helps us keep track of our location.)

Go through and write down each checkpoint and a description.

- Pilotage, looking out the window
- Dead reckoning, our time between legs and our course
- Radio Navigation, have VOR's to use along route and use radials as checkpoints (we will plan to use the 077° radial from KPAE, a 257° bearing to the station.

Before continuing, a review of terms and abbreviations is important.

Abbreviation	Term	Significance
TC	True Course	The angle between your course and true north.
MC	Magnetic Course	True course corrected for magnetic variation.
Var	Magnetic Variation	The number of degrees left or right used to correct a true course to a magnetic course.
WCA	Wind Correction Angle	The correction applied to a course to correct for wind drift. Use E6B to calculate.
Dev	Magnetic Deviation	Each magnetic compass has built-in errors due to magnetic fields in the airplane affecting the compass's accuracy. The compass deviation correction card, which is calculated for each compass installation, provides corrections in 30° increments.
CH	Compass Heading	This is the compass heading you will fly for a specific leg of your flight in your specific airplane.
ETE	Estimated Time Enroute	You will calculate the amount of time you expect to fly each leg using deduced reckoning.
ATE	Actual Time Enroute	You will record the actual amount of time each leg took to fly. You'll use a timer in the airplane to measure this.

5. **True Course (Using Plotter)**
   Next we want to find the course route for our flight. Remember that our sectional chart is in reference to true north and so we start with a True Course and our goal will be to convert that into Magnetic Heading.

6. **Winds Aloft Forecast (MSL Alt, printed in true) Record wind Direction & Velocity**
   Wind Comes from and Blows Toward. Wind 270 is coming from the W and blowing E
   Next we will go online to AviationWeather.gov and look at the winds aloft forecast for our area, which would be Seattle. Note winds and temperatures. Get Alt Setting for Departure and Destination.

If the winds are light and variable, or less than 5 knots, the code will read 9900.

If the winds are between 100 and 199 knots, the code will start with a 7, i.e. 7545. In order to read this, subtract 50 from the direction (75-50=25) and add 100 to the speed (45+100=145). Therefore, 7545 would read as 250° at 145 knots.

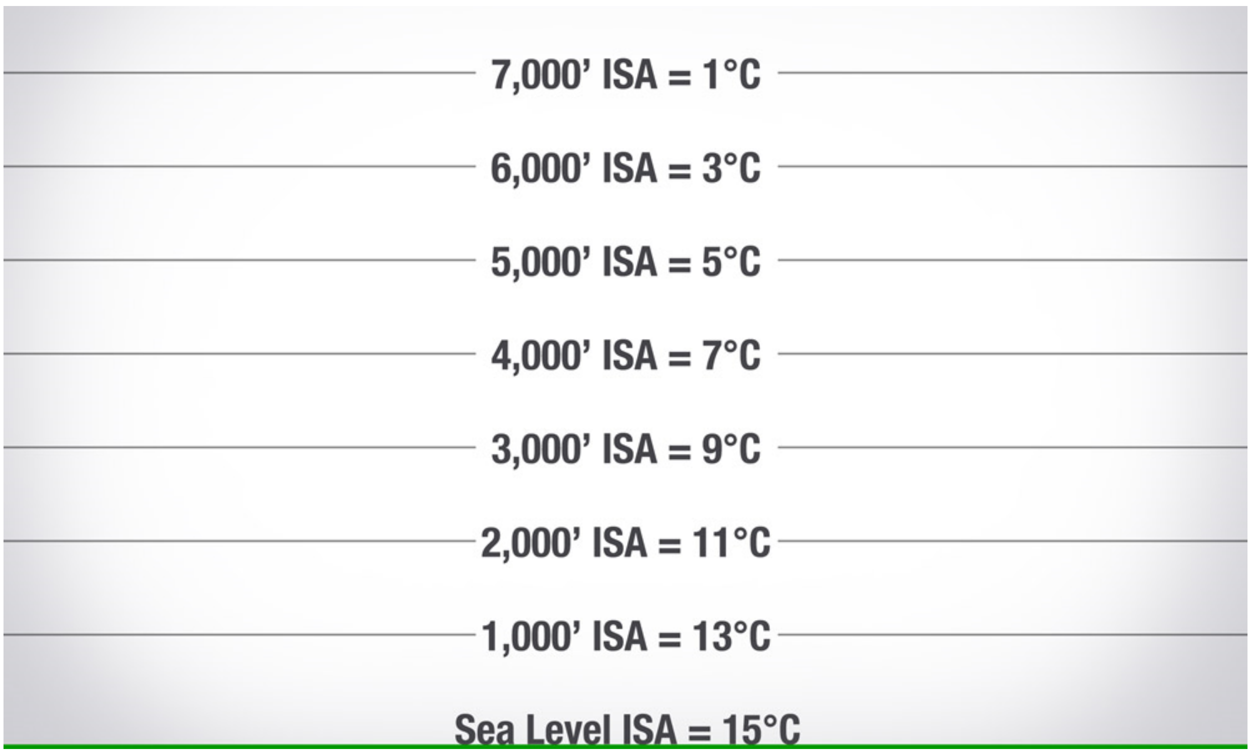
If the winds are 200 knots or more, the wind will be recorded as 199 knots. For example, 7599 means the winds are from 250° at 199(+) knots.

Winds are not recorded for altitudes within 1500 feet of the ground elevation. Returning to the table, BIH at 3,000 feet is left blank. That is because BIH has an elevation of 4,124 feet, which is above the forecast altitude level.

Temperatures are not recorded for altitudes within 2500 feet of the ground elevation. BIH at 6,000 feet reads 9900. Notice that there is no temperature information. Again, BIH is at 4,124 feet, which is within 2,500 feet of 6,000.

Wind Departure:
Wind Aloft
Wind Destination
Input wind direction and velocity as well as temperature for each checkpoint.

-Standard temperature lapse rate of -2°c per 1000' gain in altitude.



7. **Calculate Pressure Alt & True Air Speed (for Cruise and Climb)**
   29.92-Alt Setting=____x1000. Example: Altimeter setting is 30.10. (29.92-30.10= -0.18), (0.18x1000=-180') Subtract this value from field elevation and from cruise alt. For our example if we were at Tacoma and filed elevations is 295' our pressure altitude would be (295'-180' to give a pressure altitude of approximately of 115).

- Alt setting above 29.92: (pressure altitude will be lower than normal) (pressure becomes greater, which increases the density of air in a given volume, better performance)
- Alt setting below 29.92: (pressure altitude will be higher than normal) (pressure becomes lesser, which decreases the density of air in a given volume, worse performance)

***We can go through and calculate pressure alt at departure and destination and enroute, but it is much simpler to use the next higher set of numbers in the POH.**

8. Calculate TAS

Cruise Performance Chart. Use Pressure Alt and RPM closest to our selected flight. Standard Temperature Lapse Rate is -2c per 1000ft. If we are flying at 3000' that means we should be at 9°. (3x-2=-6), (15-6=9). If temps below standard performance will be better, if above standard performance will be worse. Select the TAS corresponding to the correct Temperature, Altitude and RPM. Note TAS and GPH.

7000	1
6000	3
5000	5
4000	7
3000	9
2000	11
1000	13
0	15

To calculate Pressure ALT. Standard rate-altimeter setting. Example setting of 30.10. 29.92-30.10= -0.18*1000= -180'.
(1"=1000')

Use E6B to determine TAS, Set Pressure Alt next to temp, read TAS on outer and IAS on inner.

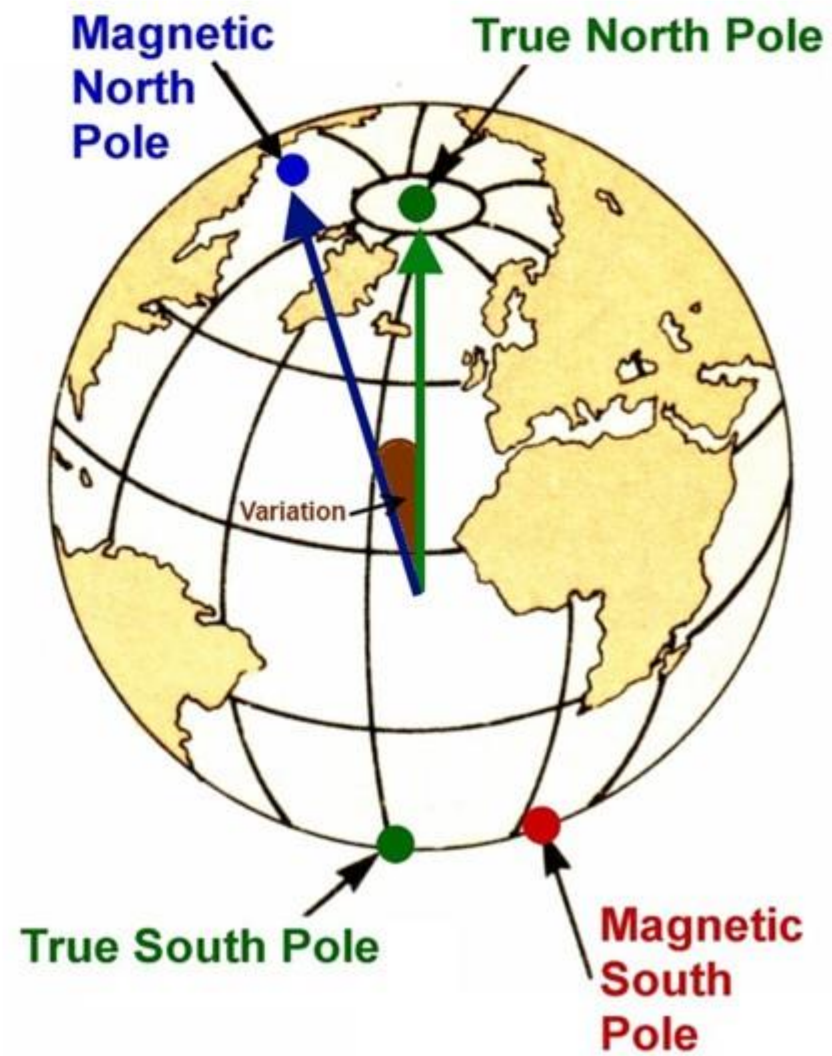
9. Calculate TH

-L/ +R WCA. Our wind correction angle is how we must compensate for wind drift to remain on our desired course. We start with out True Course and subtract left WCA and add right WCA. Using E6B set the wind direction under the True Index and grommet on 100. Mark wind velocity up from center. Now rotate True Course underneath True Index and slide the wind mark to our TAS. Read the WCA. Add if right, subtract if left. (This will also tell us what our GROUNDSPEED will be as well).

10. Calculate MH (East is Least, West is Best)

Now we must correct our True Heading for Magnetic Variation. Our nearest Isogonic Line (the Magenta Dashed line Is 16 degrees East. We subtract East. "East is Least, West is Best".

II: Technical Subject Areas
Task G: Navigation and Flight Planning



11. Calculate and determine final CH by accounting for Magnetic Deviation.

For	N	30	60	E	120	150
Steer	0	27	56	85	116	148
For	S	210	240	W	300	330
Steer	181	214	244	274	303	332

Using compass card correction.

12. Calculate Top of Climb

POH Time, Fuel and Distance to Climb Chart. OR
Groundspeed using E6B

Cruise Altitude – Airport Elevation, ex: 5500-32=5468' to climb, to climb at 500' per minute would give 5468/500=11 minutes.
(Minutes to climb/60 min per hour) * GS = Distance to climb. (Using VY). Mark Checkpoint On Flight Plan.

13. **Calculate Top of Descent**
    Cruise Alt -Field Elevation/500fpm. Ex 4500-1300=3200. 3200/500=6.4Minutes. Use E6B. Set speed on outer scale. Read the time on inner and the distance out the outer. OR 3:1 rule. For every 1000' feet to descend expect 3NM. Mark Checkpoint on Flight Plan.

14. **Record Distances between each checkpoint**
    Use Plotter to get distance between each checkpoint.
15. **Calculate Est GS at each checkpoint**
    Use wind side of E6B.
16. **Calculate Est time Enroute**
    We must know our Groundspeeds and Distances for each leg of our flight plan. Directions on the front of E6B. Black triangle goes to our Groundspeed. Leg distance on the outer ring of E6B, time on inner scale.
17. **Calculate Fuel Burn**
    Gal per hour under black triangle, time on inner, gallons used on outer. (Don't forget fuel burned in taxi and runup and VFR day/night reserves).
18. **Fill in Airport Frequencies Box.**

19. **Fill in any remaining notes/ plan traffic pattern**

20. **Google Earth/Foreflight Preview of the route**

DIVERSIONS:

Note the time
Verify the airplane's present position
Determine the location of the new destination
Turn in the appropriate direction to an estimated heading, taking into consideration: airspace, obstructions, and/or adverse weather
Determine the distance and compass heading to the new destination
Distance:

- **Plotter**
- **Mileage scale on chart**
- **1 min of latitude = 1 NM**

Compass Heading

- **Use compass rose on VOR on map**
- **Turn to the compass heading**

Select prominent landmarks to aid in flying the new course
Compute ETE, ETA, and the fuel required to reach the new destination
Contact FSS to amend your flight plan

To compute groundspeed, note time over one landmark, and fly to the next. Using distance and time solve for speed. Align time on inner scale with distance on the outer scale and read GS under black triangle. Then use distance remaining. Black scale for groundspeed, read distance on outer scale and time on inner scale.

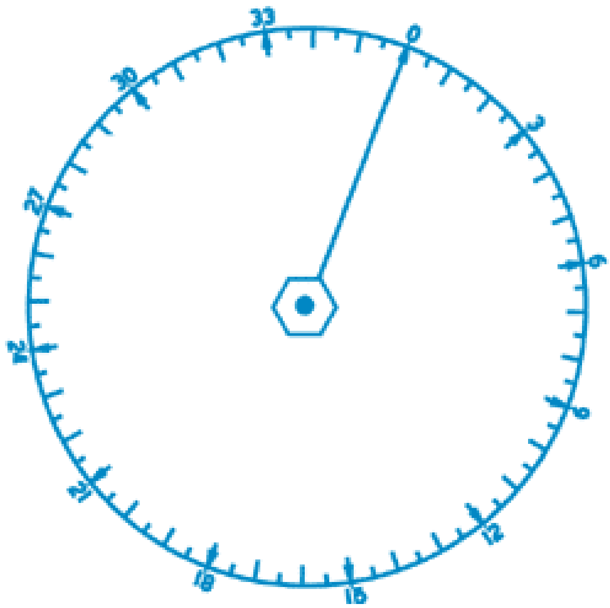
NOTE:
When diverting to a nearby airport (25 NM or less) and fuel is not critical, make reasonably accurate estimates rather than performing actual computations

VOR NAVIGATION

- A VOR is a older method of navigating but is still very much used today and still very relevant even though we have GPS. If the GPS stops working, the battery dies, the satellites fail (example a solar flare), we need some sort of ground based navigation to back it up. Each VOR that we see on the sectional chart is its own independent station, with its own power and transmitter, so one might break but there will still be many other VOR's working.
- A VOR system is made up of a ground component and an aircraft receiver component. Ground stations are located both on and off airports to provide guidance information to pilots both enroute and during arrival and departure. Aircraft equipment includes a VOR antenna, a VOR frequency selector, and a cockpit instrument.

- In the aircraft we have this instrument that looks sort of like our heading indicator and with a little knob labeled OBS next to it. This stands for Omni-Bearing Selector. At the top of the instrument is a little heading bug that points to our OBS selection. As we move this card around we see that the CDI (Course Deviation Indicator), will move left and right and a little triangle on the right side of the instrument will flip TO/FROM.

- The ground station is aligned with magnetic north and emits two signals—a 360-degree sweeping variable signal and an Omni-directional reference signal. The signals are compared by the aircraft's receiver, and a phase difference between them is measured, giving a precise radial position of the aircraft and displaying it on the OBI, HSI, or RMI.
- VORs come with high, low, and terminal service volumes and dimensions. High-altitude VORs can be used up to 60,000 feet and 130 nautical miles wide. Low-altitude VORs service aircraft up to 18,000 feet and up to 40 nautical miles wide. Terminal VORs go up to 12,000 feet and 25 nautical miles. The network of VORs typically provides thorough coverage along published visual flight rules (VFR) and instrument flight rules (IFR) route



We could be on any one of these radials being emitted from the station. We can use our instrument in the cockpit to tune to a VOR and track TO the station or FROM the station on a selected radial.

To find what radial you are on FROM the station spin the OBS until you get the needle centered with the FROM Flag. VOR indication does not matter what heading you are on, it simply tells you your location relative to the station.

If I want to fly TO the Station, rotate the OBS until the needle centers with a TO indication, this is your bearing to the Station.

IN THE AIRPLANE

Input the VOR frequency into NAV one and make sure it is in the active. Next we want to identify the station by listening to the Morse Code Identifier to ensure the VOR is function properly. Let’s say we don’t know where we are in relation to the VOR. Simply rotate the OBS to center the CDI with a TO Flag. Fly this heading (bearing to the station).

Positive sensing: Flying TO the station with a TO Flag, Flying FROM the station with a FROM Flag.

Reverse Sensing: Flying TO the station with a FROM Flag, Flying FROM the station with a TO Flag.

Intercepting a course means to get on the course and start tracking it.

Tracking a course means to stay on the desired track while correcting any deviation, mainly caused by crosswind.

Intercept the course

Tune and identify

Before using a VOR for navigation, you must tune its frequency and make sure you are receiving the correct station.

Equipment varies, but this is the general procedure for identifying the VOR:

1. Dial-in the VOR frequency
2. Listen to and confirm you have the correct Morse code identifier.
3. Check that no warning flags are present on the VOR display.

Newer equipment can automatically tune the VOR after you enter the identifier letters. Some units can automatically decode the station's id and display its letters on a screen.

1. Find your current position relative to the station

Rotate the Omni-Bearing Selector (OBS) until the needle centers. It is best to select the bearing to or from the staion that corresponds to the direction inbound or outbound of the desired track.

The bearing displayed on the top of the dial is your current bearing to or from the station.

2. Choose an intercept angle

To calculate an intercept angle, double the difference between the bearing to intercept and the current bearing to the station. If tracking inbound, use 'TO' bearings, otherwise, use 'FROM' bearings ("radials"). Cap the result at a minimum of 20º and a maximum of 90º.

```
Intercept Angle = |current bearing - desired bearing| x 2

20° ≥ Intercept Angle ≥ 90°
```

The FAA's Instrument Flying Handbook uses the above method. However, with experience, you may choose other methods, as long as the intercept angle is not larger than 90º. Several factors will affect this choice, including distance to the station, radial difference, and groundspeed.

So for example, you are on the 300º bearing TO the VOR and want to intercept the 350º inbound track:

```
Intercept angle = |300-350| x 2 = 50° x 2 = 100°
```

Since the result is larger than 90º, cap the intercept angle at 90º:

```
100° > 90°


Intercept angle = 90°
```

3. Select the desired course to track

Rotate the OBS to the desired course. In our example, the desired course is 350º bearing to the station (the 170º *radial* inbound), so set the OBS to 350º.

4. Fly the intercept heading

Note to which side the needle deflected (left or right.) To intercept the course, fly towards the needle with the intercept angle you chose in step 2.

For this example, you are on the 300º degrees bearing to the station, the desired track is 350º inbound and you determined the intercept angle is 90º. You can now find the intercept heading: `350 - 90 = 260°`

Note about reverse sensing

**This assumes you are flying in the general cardinal direction to match the desired track. Otherwise, you would get reverse sensing: CDI deflected in the opposite direction of the desired course. Avoid this by matching the OBS direction to the general direction you are trying to track. With an HSI, this problem is eliminated when tracking a VOR course.*

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5. Complete the intercept

As the CDI centers, begin turning towards the heading corresponding to the desired course. Choosing how fast or far to lead the turn may take some practice. Factors to consider for this turn include the distance from the VOR, the intercept angle, and the ground speed.

Track the course

The goal here is to keep the CDI needle centered.

In perfect, no-wind, conditions, the needle should remain centered while the heading matches the OBS.

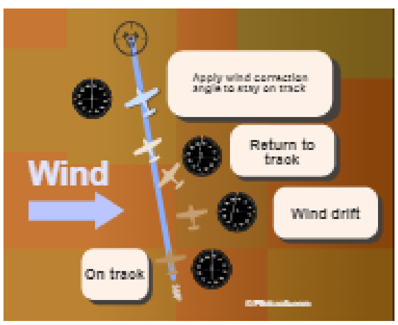
However, perfect conditions are rare in the real world, and the CDI may start deviation to the left or right.

The direction to which the CDI deflects is the direction from which the crosswind is blowing. A way to remember this is to imagine the needle direction as the wind side: "The wind is the needle."

Reverse sensing, again

**Using a traditional, non-HSI VOR, you should be wary of reverse sensing while tracking the course. With reverse sensing, instead of "the wind is the needle," it becomes "you are the needle." Meaning, if the CDI goes right, you'll have to turn away from it to the left. To prevent this, use an OBS bearing that matches the direction you are going to, not its opposite.*

Wind Correction



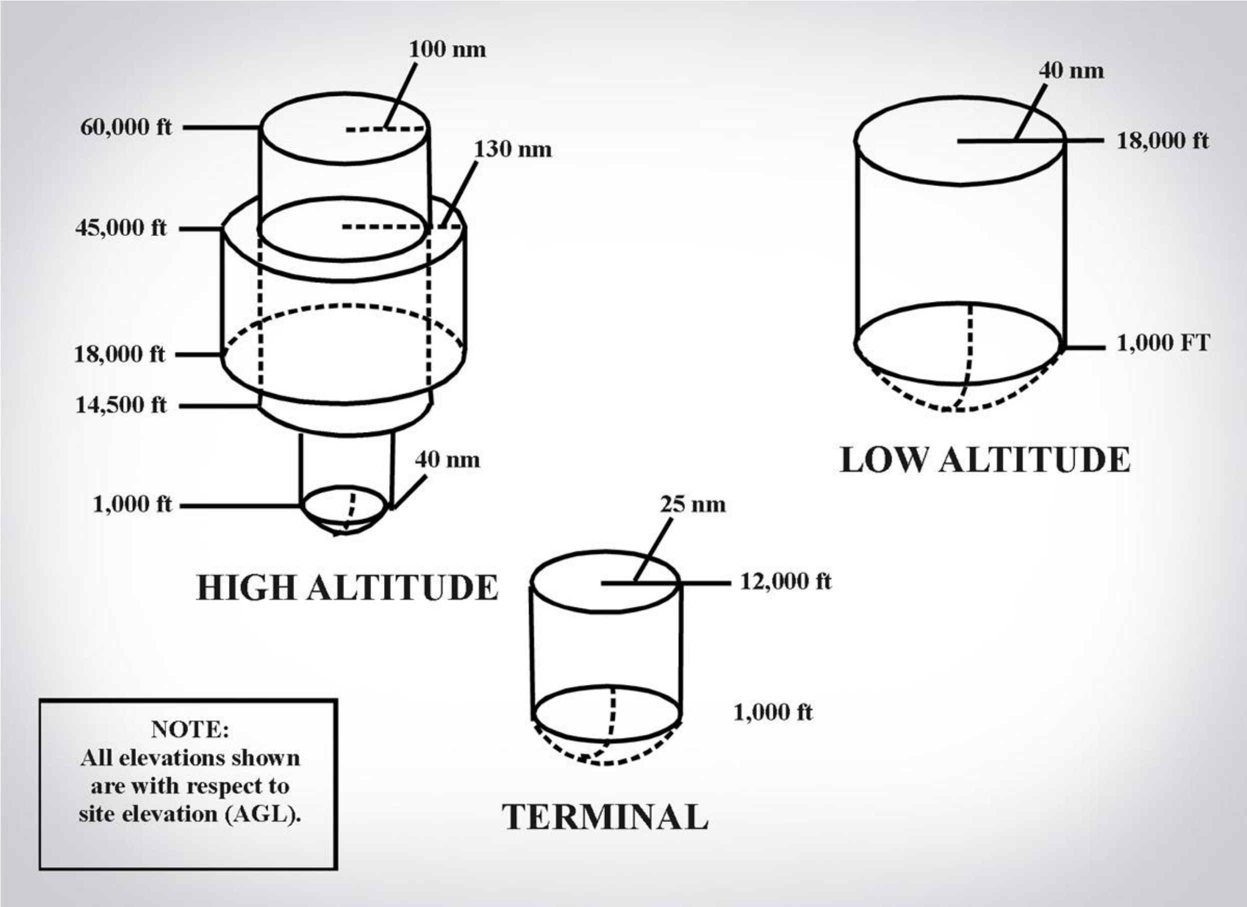
If you don't know the wind direction, you'll have to find the best correction by trial and error. Otherwise, an E6B, FMS or a electronic flight computer can calculate it for you.

Fly a heading that is slightly into the wind to get back on track. Then decrease the correction angle to stay on it.

Tracking towards the VOR

As you get closer to the station, the CDI needle will become more sensitive. Once you pass over it, you may momentarily see a full deflection of the needle.

To keep on track, do not chase the needle. Keep the same heading that worked before. As you get further away, tracking outbound now, the needle should start moving back to the center.



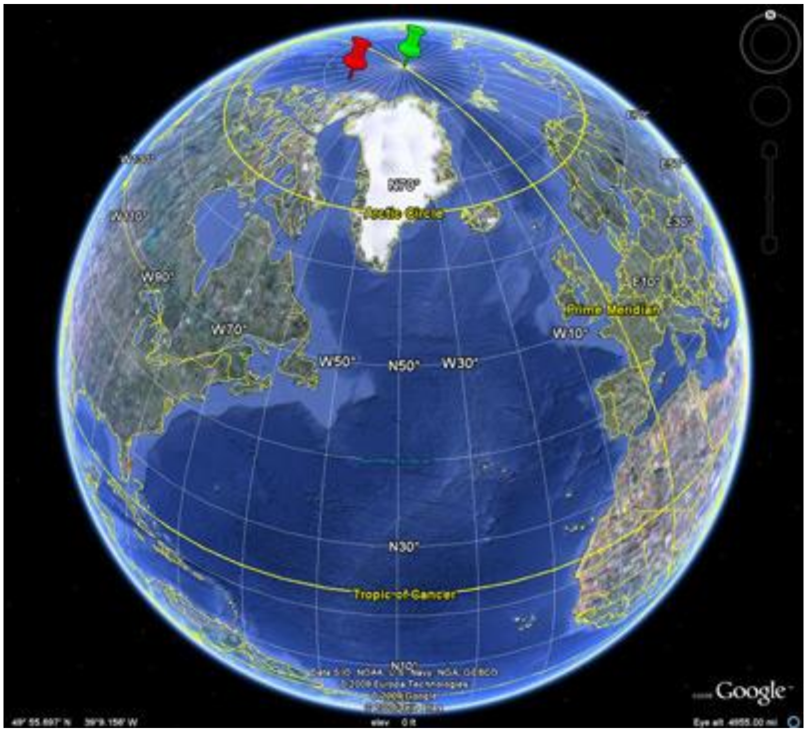
Additional Resources and topics for consideration

True North Vs Magnetic North

The true north pole, aka the celestial north pole, is the point on the Earth's surface intersecting Earth's rotational axis on the northern hemisphere (and thus the axis around which all stars appear to rotate). Prior to the introduction of the Global Positioning System, there were no perfect indicators of true north.

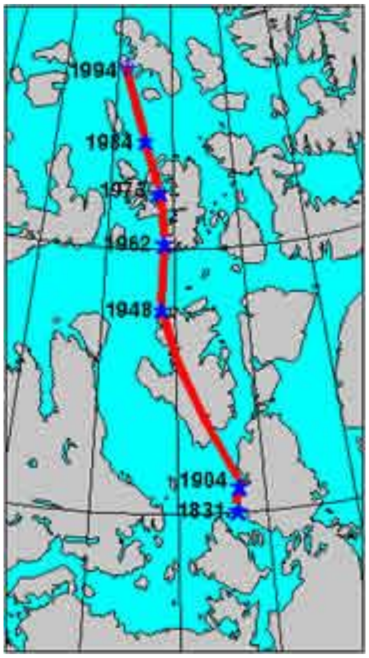
Two competing and often conflicting definitions of north have been used prior to the advent of GPS (and since). Magnetic north is the direction in line with the Earth's magnetic field, thought to be caused by the convective flows of liquid iron in the Earth's outer core, which causes a compass to point toward the magnetic north pole. An approximation of "celestial north" is in the direction of Polaris, which is a fairly bright star in the night sky and also the closest such star to Earth's rotational axis (and thus "true north") for about the last 1500 years.

First, the two poles do not coincide: here's a Google Earth image showing true north in green and magnetic north in red:



As you can see, they're close, especially from the perspective of those of us in the New World, but if you were sailing off the west coast of the British Isles, you might see up to a ten-degree difference between your compass and Polaris, and that's significant over a distance of even a few hundred miles. Navigators have known of this difference, known as the "magnetic declination", for centuries, and it was a secondary driving reason for the solution to the "problem of longitude" (how to determine, quickly and accurately, your current longitude; knowing this, in addition to being a key coordinate of your position at sea, also allows you to determine the necessary amount of "declination" from magnetic north to determine true north and thus the correct magnetic heading to your intended destination).

Second, Earth's magnetic pole changes over time; here's a map showing the changes in the surveyed position of the magnetic north pole through Nunavut, Canada over the past 130 years or so:



As you can see, the magnetic pole appears to be approaching true north, possibly due to gyroscopic stabilizations of the convective flows within earth's liquid inner layers. Again, for most of the U.S. the practical effects of observed shifts are minimal, but it has much more pronounced effect near the Prime Meridian which happens to be nearly perpendicular to the line between true and magnetic north.

II: Technical Subject Areas
Task G: Navigation and Flight Planning

Where is the North Pole?
The Geographic North Pole is the northernmost point on the planet, where Earth's axis intersects with its surface. Its latitude is 90 degrees north, and all longitudinal lines meet there. From there, every direction one turns is south. Because all longitudinal lines begin from it, the North Pole has no time zone.

The pole is surrounded by the Arctic Ocean, where the water is 13,400 feet (4,084 meters) deep and usually covered with drifting ice 6-to-10 feet (1.8 to 3 m) thick. About 434 light-years above the pole lies Polaris, the "North Star." During the course of the night, Polaris does not rise or set, but remains in very nearly the same spot above the northern axis year-round while the other stars circle around it. The star has been an important marker for navigation for centuries.

Over time, the location of the North Pole changes slightly. Earth's axis has a slight wobble, and since the pole intersects with the axis, it wobbles along with it. Scientists have calculated that the pole wobbles about 30 feet over seven years. The precise point of the pole at any given moment is known as the instantaneous pole.

In recent years, scientists have noticed that the axis is drifting rapidly eastward because of climate change. Since 2000, the pole has been moving steadily eastward by about 75 degrees, heading toward the Prime Meridian that runs through Greenwich, England, according to Surendra Adhikari, an Earth scientist at NASA's Jet Propulsion Laboratory in California. Adhikari said in a 2016 National Geographic article that the axis has shifted about 10 centimeters (4 inches) per year. Scientists suspect that rapidly melting ice sheets have caused a redistribution of mass. Melting ice moves mass around by adding water to the oceans and lightening the load on ice-covered crust, according to a 2005 Live Science article.

Magnetic North Pole
The Magnetic North Pole is not the same as "true north"; it is several hundreds of miles south of the Geographic North Pole. Earth's iron core and movement within its outer part generates a magnetic field, and the magnetic North and South poles are where the field is vertical. Compasses point to the magnetic North Pole.

The magnetic poles and the geographic poles don't line up, and the difference between them is called declination. Since its discovery in 1831, the Magnetic North Pole has been around Canada's Ellesmere Island, about 500 miles (800 kilometers) from the Geographic North Pole. But the magnetic field drifts, causing the angle of declination to change over time.

Currently, the Magnetic North Pole moves about 25 miles (40 km) each year in a northwest direction — at a faster rate than it has moved since tracking began in the 1830s. The change could cause problems for migrating birds and human navigation. Eventually, the magnetic North and South poles will move to the point that they "flip" and compasses would point south. This change will happen slowly and not in our lifetimes. The last "flip" occurred 730,000 years ago.
Line of Latitude and Longitude

A knot is 1 nautical mile per hour. Because there are 6,076.1 feet in a nautical mile and 5,280 feet in a statute mile, the conversion factor is 1.15. To convert knots to miles per hour, multiply knots by 1.15.