Oceanography LAB #1:  
Marine Charts and Navigation

**Background Information**

*(See also the Lab #1 Hints File & Figures posted on the course site and Chapter 1 and Appendix 1 of Segar 4th edition)*

**Latitude and Longitude**

A *coordinate* is an address – a means of designating location. Most coordinate systems involve a network of intersecting lines, usually at right angles, called a *grid*. Since the Earth is round (nearly), we use a set of spherical coordinates (*Figure 1*) to designate locations on the globe. The lines of *latitude* are also called *parallels* of latitude, because they are parallel to the *equator* and to each other. Measured in *degrees*, latitude is equal to the angular distance north and south of the equator, from 0° at the equator to 90° at either pole. Each degree is divided into 60 minutes (1° = 60'). Latitude is given with its hemisphere notation (N or S, for north or south). For example, the latitude of Seattle in degrees and minutes is: 47°36'N.

Note that a number expressed in this way is not a decimal number; that is, it is not the same thing as 47.36 degrees N. In some applications, however, it is necessary to use degrees expressed as a decimal number (Question #5 of this lab, for example). The conversion from degrees and minutes to decimal degrees can be easily accomplished by simply dividing the number of minutes by 60. The resulting value is then written to the right of the decimal point. From the example above, 47°36'N = 47°+(36/60)°N = 47.6°N.

Lines of *longitude*, also known as *meridians*, are also expressed in degrees, and refer to the angular distance on Earth measured from the *prime meridian* (0°), which passes through Greenwich, England. Going eastward or westward from the prime meridian, longitude increases until we reach the middle of the Pacific Ocean, where we come to the 180° meridian, also known as the *international dateline*. Longitude is also expressed with its hemisphere notation (E or W, for east or west). Seattle’s longitude is written as: 122°20'W. While lines of latitude are always equally spaced, an important feature of lines of longitude is that they converge (get closer) as you move toward the poles.

*Figure 1.* Latitude and longitude coordinate system for the Earth. The prime meridian is 0° longitude, and the equator is 0° latitude. [After Nathaniel Bowditch, *American Practical Navigator*, Hydrologic Office Publication No. 9, U.S. Naval Oceanographic Office, 1966.]
Time and the Earth’s Rotation

Because the Earth rotates once on its axis in a 24-hour day, it can also be said that the rotation encompasses 360° (a full circle) of longitude in 24 hours. When the sun is directly overhead at Greenwich, England (longitude 0°), the local time there would be noon, whereas halfway around the Earth at 180° longitude, the local time would be midnight. The time zone at Greenwich is known by several interchangeable names: GMT (Greenwich Mean Time), UTC (Coordinated Universal Time), or Z (“Zulu”) time. If we know our longitude wherever we are on Earth, we can determine how many hours different we are from GMT by realizing that each hour corresponds to 360/24 = 15° of longitude. So for example, Los Angeles, which lies at about 118°W longitude, would technically have a local time 118/15 = 7.9 hours different from GMT. Time zones are longitude bands that use a rounded-off time conversion to make our timekeeping a little easier. So Los Angeles, which lies in the Pacific Standard Time zone, would have a local time 8 hours different (earlier) than GMT (7 hours during Daylight Savings Time).

Units of Distance and Speed (Also see the conversion table below.)

On land, distances are normally expressed in kilometers or statute miles (the usual “mile” we are familiar with). At sea, distances are expressed in nautical miles. One nautical mile is about 1.15 statute miles. Nautical miles are convenient to use in navigation, because one nautical mile is equal to 1’ of latitude (thus 1° of latitude is equal to 60 nautical miles).

On land, we usually express speed as miles per hour (mph) or kilometers per hour (kph). The unit of speed used at sea is the knot (abbreviated kt), which is defined as 1 nautical mile per hour. Note that it is incorrect to speak of “knots per hour”, since the per hour part is already implied. Since a nautical mile is a little bigger than a statute mile, it follows that a knot is a little faster than a mile per hour.

Useful Conversions

<table>
<thead>
<tr>
<th>Conversion</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 nautical mile = 1.15 statute miles = 6080 feet = 1853 meters = 1.853 km = 1’ of latitude</td>
<td></td>
</tr>
<tr>
<td>1 knot = 1.15 mph = 1.853 kph</td>
<td></td>
</tr>
<tr>
<td>1 statute mile = 0.87 nautical mile = 5280 feet = 1609 meters = 1.609 km</td>
<td></td>
</tr>
<tr>
<td>1 mph = 0.87 knots</td>
<td></td>
</tr>
<tr>
<td>1 kilometer (km) = 1000 meters (m)</td>
<td></td>
</tr>
<tr>
<td>15° of longitude = 1 hour time difference</td>
<td></td>
</tr>
</tbody>
</table>

Plotting a Course

In plotting a course at sea we must distinguish between magnetic north (to which the north-seeking needle of a magnetic compass points) and true north (the point corresponding to the axis of the Earth’s rotation). This necessity arises because on Earth the magnetic north pole and the true or geographic north pole are not at the place. The magnetic north pole is actually located within the Greenland subcontinent. Latitude and longitude, and almost all maps used in navigation, are referenced to true north. Therefore, if we are using a magnetic compass and trying to use a map for navigation, we must apply a correction to our compass-determined directions to account for the difference. This correction is known as the magnetic declination, and is indicated on nautical charts via the compass rose shown on most charts (Figure 2).
Directions used in navigation are referenced to a 360° circle, with 0° (true north at the top). The four **cardinal points** of the compass are north (0°), east (90°), south (180°), and west (270°). There are four intercardinal points, midway between the cardinal points – they are northeast, southeast, southwest, and northwest. Directions are usually expressed in terms of degrees rather than by points on a compass, except that cardinal and intercardinal points are used to indicate general directions, as in “northeast wind”.

A ship’s **course**, expressed in degrees, is the intended direction of travel, expressed in degrees relative to true north. For example, a course of 180° means the ship’s intended direction of travel is toward the south. However, winds, ocean currents, and other factors may prevent a ship from adhering to its intended course. A ship’s **heading** is the direction toward which the ship is actually moving, regardless of its intended course. A **bearing** is the direction from one point to another, also expressed as an angle relative to true north.

The traditional nautical expressions indicating bearings with respect to parts of a ship are shown in **Figure 3**. For example, “dead astern” means directly behind a vessel, and “broad on the starboard beam” means directly to the right of the vessel’s heading.

**Figure 2.** Sample compass rose. (Note: This is not from Puget Sound.)

**Figure 3.** Traditional nautical terminology for relative bearings.
Nautical Charts

Most marine charts include water depths, the configuration of the shoreline in coastal waters, and the locations of navigational aids such as buoys, lights, and landmarks. Depths may be given in feet, meters, or fathoms (equivalent to 6 feet). Charts that show depth contours are known as **bathymetric charts**. Nautical charts also include a compass rose, showing the magnetic declination for that region of the ocean, and latitude and longitude reference lines. For coastal areas, charts often include information on the nature of the bottom (e.g., sand, gravel, submerged rocks).
Oceanography LAB #1: 
Marine Charts and Navigation

Questions to Answer

In this lab and all other labs, always show your calculations, including units in every step, and/or explain your reasoning.

Part 1 - Coordinates and Distances

1. Use this table of data to answer the questions below (“a” through “i”):

<table>
<thead>
<tr>
<th>City</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York, New York</td>
<td>40°38’ N</td>
<td>73°50’ W</td>
</tr>
<tr>
<td>Reno, Nevada</td>
<td>39°30’ N</td>
<td>119°46’ W</td>
</tr>
<tr>
<td>Los Angeles, California</td>
<td>33°42’ N</td>
<td>118°15’ W</td>
</tr>
<tr>
<td>Honolulu, Hawaii</td>
<td>21°18’ N</td>
<td>157°50’ W</td>
</tr>
<tr>
<td>San Francisco, California</td>
<td>37°19’ N</td>
<td>122°25’ W</td>
</tr>
<tr>
<td>Seattle, Washington</td>
<td>47°36’ N</td>
<td>122°20’ W</td>
</tr>
<tr>
<td>Anchorage, Alaska</td>
<td>61°10’ N</td>
<td>150°01’ W</td>
</tr>
<tr>
<td>Santiago, Chile</td>
<td>33°27’ S</td>
<td>70°42’ W</td>
</tr>
</tbody>
</table>

a) Which city is farthest north?
b) Which city is farthest south?
c) Which city is farthest west?
d) Which city is farthest east?
e) Is Reno east or west of Los Angeles?
f) Is Santiago east or west of New York City?
g) How far north of San Francisco is Seattle?

______________________ nautical miles
______________________ statute miles
h) What is the time difference (to the nearest hour) between New York and Honolulu? (Calculate it from the data table above; don't just look it up!)

i) Here in Seattle/Bellevue, how many hours different is our local time zone (assume PST) from Greenwich Mean Time (GMT)? (Calculate it from the data table above; don't just look it up!)

2. The distance between two points is 80 statute miles. Convert that distance to nautical miles, using the conversion factor of 1.15 statute miles per nautical mile (or the conversion factor of 0.87 nautical miles per statute mile).

3. A speedboat is traveling 40 knots. How fast is that in miles per hour?

4. If your navigator tells you your position is 0.7 nautical miles from the West Point light, how far is that in feet? And how far is it in meters?

**Part 2 - Directions and Headings**

5. Using the following website, determine the angular difference between true north and magnetic north (that is, the “magnetic declination”) in your location, and how the declination is changing:

   Website: [http://www.ngdc.noaa.gov/geomag-web/#declination](http://www.ngdc.noaa.gov/geomag-web/#declination)

   **Step 1** = Enter your ZIP code_________________
   
   Record your latitude in decimal degrees (N or S)________________ *
   
   Record your longitude in decimal degrees (E or W)_____________ *
   
   * **Note:** These are the only places in the lab that will use decimal degrees. Throughout the rest of the lab, use degrees-minutes-seconds (DMS).

   **Step 2** = Click on “Compute Declination”, and record the following:

   Your magnetic declination in DMS, and in which direction (E or W)____________
   
   Your annual variation (“changing by how much per year”) in DMS (E or W)______per year
6. Now use the Puget Sound compass rose in Figure 4 below to answer the following questions (a PDF of Figure 4 that you can zoom in on and read more easily is linked at our course site):
   a) Puget Sound magnetic declination in DMS, and in which direction (E or W)__________ measured in year ______
   b) Puget Sound annual variation in DMS (E or W)__________per year
   c) Puget Sound magnetic declination today: ________________ (Show your calculation!)

![Figure 4. A compass rose from Puget Sound bathymetric map, near Edmonds (for reference/use in Question #6). Zoomable color image is posted on the course site.](image)

7. a) By how much do the declination and annual variation values in Question #5 differ from the declination and annual variation values in Question #6?

   Declination difference:

   Annual variation difference:

b) What is the practical importance of this information? If we are navigating by compass in different places, could we use the same magnetic declination and annual variation values everywhere? Why or why not? Explain your reasoning.
8. A ship is on course 90 degrees true. The navigator wants to anchor when a certain lighthouse is “broad on the starboard beam”. What is the true compass bearing to the lighthouse at that point? Explain in words how you got your answer. (Hint: Use the information in Figure 3 in the background information section.)

9. If you are cruising in Puget Sound (this year), and magnetic north is dead astern, what is your boat’s heading (in degrees true)? Explain in words how you got your answer. (Hint: Be sure to use the information from Question #6 above.)

**Part 3 - Bathymetric Charts**

*Figure 5* (the chart below) is a bathymetric chart of part the ocean floor, contoured in **meters below sea level**. Answer the following questions based on this chart. Remember to include units.

**Consult a world map if necessary.**

Sources you may wish to use include the following – but find ones that work for you:

- Figure 1-9 of Segar 4th edition
- [http://plateboundary.rice.edu/topo.11.17.pdf](http://plateboundary.rice.edu/topo.11.17.pdf)

10. In which ocean is this section of the seafloor located?____________________

11. The region covered by the map is closest to what coastline? Be specific.

12. Locate the point 46° 09’ N, 129° 47’ W. What is the approximate water depth at this location? What is the topography like here (fairly steep, or flat)? How can you tell? Explain.

13. Locate the feature 46° 10’ N, 129° 49’ W. What is the approximate water depth at this location? Is this feature a basin, an underwater mountain, or some other type of feature? Explain.

14. Locate the deepest area found on this map. Give the approximate latitude and longitude of this deep spot, and the depth of this deep spot.
Figure 5. Bathymetric chart for use in Questions #10-14. Depths are in meters below sea level.