Name: _____

Astro Navigation (i.e. Celestial Navigation)

Over the course of human lifetimes, the stars don't appear to change positions much. We can use that in order to determine locations on Earth.

One thing that messes up those location determinations is that Earth spins and also orbits around the Sun so our perspective changes all the time but does so in a very predictable way. The US Naval Observatory and their UK partners produce data tables to help the person who wants to use the stars to determine where they are. This lab is designed to help the budding AstroNavigator use the various equipment and publications to determine earthly positions.

Find the Vanderbilt AstroNavigation website. https://my.vanderbilt.edu/astronav/

Part 1: Overview

First, watch the ***Overview*** video to set up the context.

1. Circle the LOW-tech things that one uses for celestial navigation (i.e., astronavigation).

sextant	smartphone	visible horizon
GPS	celestial bodies	time (i.e. clocks)

2. Give at least two reasons why AstroNav is important *(you can use the video and your reactions thereto).*

3. Who do you think might be interested in being an astronavigator? Give at least three types of people.

Next, we're going to watch the video about ***Coordinate Systems***. After this video, you will be doing a "Test Your Understanding" quiz so pay attention. Note that you can start and stop this video (and all future videos) as many times as you like.

During the video, answer the following questions:

4. What is the range of latitude? _____ to _____ going N & S or E & W

   What is the range of longitude? _____ to _____ going N & S or E & W

5. Please give short definitions of the following terms:

   Greenwich Hour Angle (GHA) Similar to *(circle one)* – latitude longitude

   Declination (Dec) Similar to *(circle one)* – latitude longitude

Now it's time for the "Test Your Understanding" quiz!
During this quiz (and future ones), please don't use the "Back" button. You won't be penalized for wrong answers at all – we're just trying to improve our videos using your feedback.

6. What is your chosen username/phrase? Remember it cannot have your name in it. You must use this same name through the AstroNav course!

7. When you're at the geographic position of a celestial body, where do you look to see that celestial body?

8. Why are the publications we use especially useful?

Part 2: Plotting a Line of Position (LOP)

This video describes the major task we need to accomplish by the end of the video series – actually plotting your position on special graph paper.
Following along with the questions, you will do parts of the plotting while watching other videos to determine all of the information necessary to do the plotting and how to fill out the all-important ***Sight Reduction Form***. Once you finish watching and answering questions for all of the videos, then you will complete the plot.

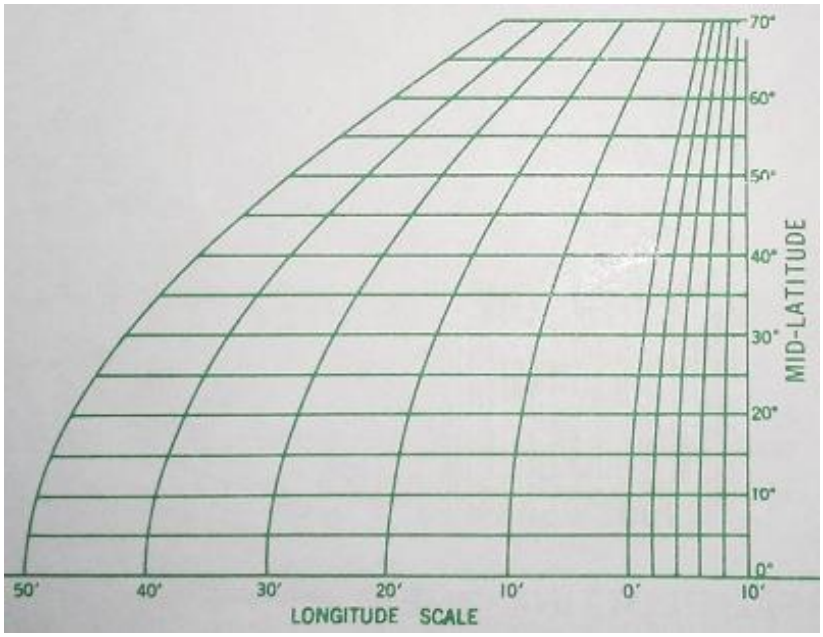
9. During the first 3 minutes of the video, you will get data for an observation of the Sun. You will have to go on to the next question at about 2:40 so you should have the information by then.

   DR latitude _____

   DR longitude _____

   Time of Observation (GMT) _____

10. At timestamp 2:40, please stop this video and answer the following question using the image below.



   Let's say you're at latitude South 45°. On the image above, circle or highlight the entire line you need to use to determine your longitude spacing and label it "for lat 45°". This is the kind of thing you use to help set up your plotting sheet when you plot.

11. Set up your plotting sheet with the appropriate latitude and longitude lines correctly labeled. You should use the whole numbers of latitude and longitude closest to those for your DR from Q 9.

12. Using your DR position from Q 9, what ocean/continent are you in/on and what is closest well-known country/island is. *(hint: use Google Maps (just basic latitude and longitude with no arcmin) and zoom out until you find names)*

    On the graphic below, mark where this DR position (roughly) is.

13. Continue watching until timestamp 3:50

    Let's say you're at latitude North 33°. On the image on page 3, draw the line you need in order to measure 47 arcminutes of longitude and label it "arcmin for lat 33°". This is the kind of thing you use for plotting the Dead Reckoning (DR) and the Assumed Position (AP).

14. Plot the Dead Reckoning (DR) position. Follow the instructions in the "Plotting a Line of Position" video starting around 2:40 to about 3:55.

    _____ *checkmark when done*

Once you have completed Q 11 and Q14, you can turn in your plotting paper to your instructor for review.

Now you know how to correctly set up plotting paper! You can watch the rest of the plotting video now. We will watch it again later, so don't worry about retaining all the concepts. Plotting takes a lot of practice and there is a level of confusion that you have to be comfortable with until you get that practice in.

Part 3: Filling out the *Sight Reduction Form*

Now you need to know how to get the data to actually plot that LOP.
You will need to watch the videos (in order), **follow along, and complete** a blank ***Sight Reduction Form*** along the way for the Sun.
For each video, we have a couple of questions that we'd like you to do.

Section I: Observations and Corrections

Section I of the Sight Reduction Form is used to calculate the ***Observed Altitude*** **(*ho*),** which is then used in Section IV to calculate the ***Altitude Intercept***.

Choosing a Celestial Body

15. What is a ***celestial body***? Give at least 4 specific examples.

Make sure you're recording data in a blank Sight Reduction Form!

Apparent Altitude

16. What instrument is used to determine the ***Sextant Altitude*** of a celestial body?

Observed Altitude

17. Why is it best to avoid celestial bodies within 10 degrees of the horizon?

18. Why do we have to know if we're looking at the Sun's upper or lower limb?

19. When doing addition and subtraction in arcminutes, you have to be careful about what happens when you get close to 60 (because there's only 60 arcminutes in a degree, not 100). What is the answer to the following equations?
    a. $55^\circ\ 10' - 30' =$
    b. $70^\circ\ 42' + 25' =$
    c. $82^\circ\ 7' - 22' =$

    (you can check your answers on the bottom of page 7)

Section II: Time and Dead Reckoning

Section II is used to record the Greenwich Mean Time (*GMT*) and date when the measurement was taken, as well as the dead reckoning (*DR*) position. **Big Hint:** From our perspective, celestial bodies are constantly moving, so noting the time down to the second of a sextant measurement will yield the most accurate result.

20. By using your speed and direction, you can determine a "best guess" of your position. What is that "best guess" called?

On your plotting sheet, make sure you've plotting the DR position in the proper place.

Section III: Latitude and Longitude

Section III of the Sight Reduction Form is used to find the Local Hour Angle (***LHA***) and ***Declination*** of a celestial body. These are the two angles which define the location of position of a celestial body on the celestial sphere. Together with ***Assumed Latitude***, these will be used to find the values needed to plot a Line of Position.

Greenwich Hour Angle

21. The ***Greenwich Hour Angle*** is the angle between which two things?

22. What publication do you look up the ***Tabulated GHA*** in?
(circle one) Nautical Almanac Pub 229

23. What publication do you look up the ***GHA Increment*** in?
(circle one) Nautical Almanac Pub 229

Local Hour Angle

24. The ***Local Hour Angle*** is the angle between which two things?

25. In general, when writing down ***Assumed Latitude***, you just re-copy the same arcminutes as was in the previous box (from ***Total GHA***). When do you subtract that number from 60?

Declination

26. What is the ***declination*** of a celestial body?

27. What publication do you look up the ***Declination*** in?
(circle one) Nautical Almanac Pub 229

28. What publication do you look up the ***Declination Increment*** in?
(circle one) Nautical Almanac Pub 229

Assumed Latitude

29. If you're at a latitude of N36° and the celestial body you're looking at is at a declination of S10°, you consider this to be: *(circle one)* Same Contrary

30. Now it's time to plot your Assumed Position. Do so using the instructions from the "Plotting a Line of Position" video starting around 3:50 until 4:25.
_____ checkmark when done

Section IV: Determining a Line of Position

Section IV of the Sight Reduction Form is used to find the ***Computed Altitude***, ***Altitude Intercept*** , ***Azimuth Angle***, and ***Azimuth***, in order to determine a Line of Position.

Computed Altitude (*hc*)

31. Your ***computed altitude (hc)*** is looked up in which publication?
(circle one) Nautical Almanac Pub 229

32. The little "***d***" value (next to ***hc***) is looked up in which publication?
(circle one) Nautical Almanac Pub 229

Altitude Intercept

33. What is the intercept value (i.e. the distance from the Assumed Position) if ***ho*** is 4° 5′ and ***hc*** is 5° 2′?
_____ Toward/Away

Azimuth

34. What is the definition of ***Azimuth Angle***?

35. What publication do you look up the ***Azimuth Angle*** in?
(circle one) Nautical Almanac Pub 229

Answers to Q 19: a) 54° 40′ b) 71° 07′ c) 81° 45′

Part 4: Plotting Practice

Now it is time to use all of those numbers that you just so painstakingly found.
You'll need to make sure that you finish watching the "Plotting a Line of Position" video AND that you complete the "Test Your Understanding" exercise

36. Using the procedure below, finish your plot. Make checkmarks next to each one as you complete them. You may need to re-watch parts of the "Plotting an LOP" video. You have already done the first few so check them off!

    ___ Label latitude lines
    ___ Make the longitude lines and label them
    ___ Mark the DR position
    ___ Mark the Assumed Position (AP) for your Celestial Body (CB)
    Determine the direction of the CB:
        ___ Use the compass at center of paper, mark the Azimuth (Zn) of the Celestial Body (CB), clockwise from north.
        ___ With a ruler, connect the center of the compass with the Azimuth (Zn) mark.
        ___ Move that ruler to the AP using a rolling ruler making sure to keep the ruler parallel to the original direction.
        ___ Draw the azimuth line and an arrowhead in the direction of the CB and label.
    ___ Mark the intercept distance from the AP, towards or away from the CB
    ___ Draw a perpendicular line to the azimuth line at the intercept distance; label it with the GMT time and name of the Celestial Body (CB).

Check your plot against the video at 6:22.

Add more Celestial Bodies (CBs) to triangulate your position

You just plotted information for the Sun – at GMT 13:35:09. Now we are going to add more observations (i.e., lines of position) to try to get a "fix" on our position (which is in the Atlantic, somewhere southeast of Bermuda).

SCENARIO: You decided to stop sailing and put down your anchor. You make the observation of the Sun at GMT 13:35:09 and plot it (you did this above). Now you've decided to wait until twilight and make observations of two bright stars so you can plot them too – the relevant information for those stars is below.

You should fill out additional ***Sight Reduction Forms (SRF)*** for both stars but they won't be very full as we aren't giving you all of the data to reduce like you did for the Sun. We are going to let the Naval Observatory calculate that information for us.

The questions below will help you fill out the ***SRFs*** for two additional stars so we can get a 3-star fix:

37. Given that you put down anchor, what should your ***Dead Reckoning*** position be for both stars below? *(and put info in the **SRFs**)*

38. Given that you are using the same sextant, what should your ***Index Correction*** be for both stars below? *(and put info in the **SRFs**)*

Put all info in Sight Reduction Forms!

	Diphda	**Capella**
Time (GMT)	21:57:05	22:02:25
Total Observed Altitude (ho)	41° 27.1′	31° 42.3′
Assumed Latitude	N 30°	N 30°
Assumed Longitude	W 60° 31.0′	W 60° 28.8′
Total Computed Altitude (hc)	41° 28.6′	31° 1.5′
Azimuth (Zn)	169.8°	51.5°

Note that you must calculate the intercept.

39. Note that the ***Assumed Longitude*** is different for both stars even though you're anchored. This is not a mistake.
    a. Where does one get the value for arcminutes in the ***Assumed Longitude***? (see ***SRF***)

    b. Earth spins and so hour angles change. How does this information help you see why the Assumed Longitudes are different?

40. Now it's time to plot your new data for these stars! Make sure you label the lines appropriately. You may wish to use the checklist on p. 8 to help you.

41. Now that you have your three lines of position drawn and labeled, the triangle that they form is your **"fix"** – a small region that you COULD be in. Lightly shade in this triangle.

Congratulations! You have found a position with an accuracy within a few miles!
If you'd like to check your drawing, you will find it in the "Supplemental Material" area under "Plotting Exercise".

Turn in both your Site Reduction Form and your 3-star fix plot to your instructor for review.

Part 6: Wrap-up

42. Please compete the "Exit Survey" in the "Course Complete" section - we use the information to improve the website and this lab exercise.

    ____ checkmark when done

43. Reflect on three interesting things you learned during this module.