

Date _____ Per. _____

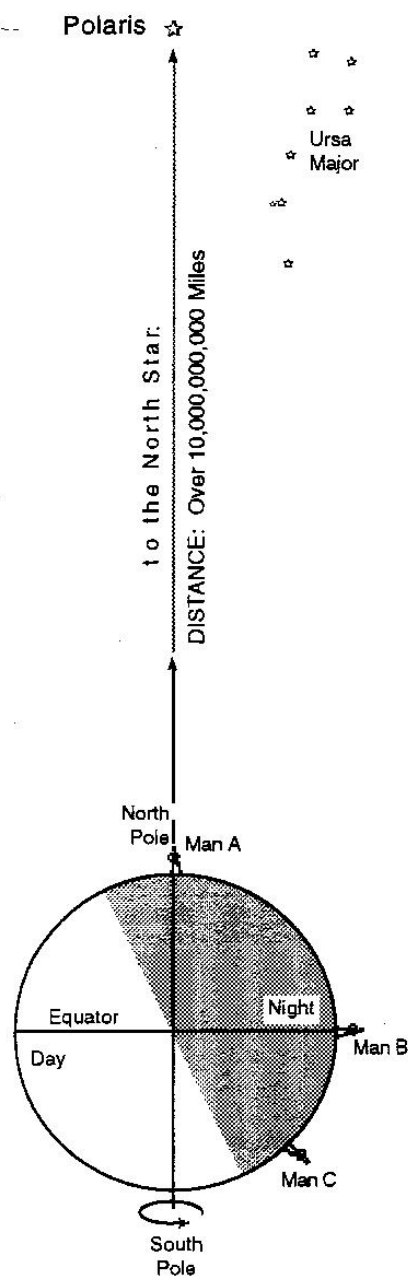


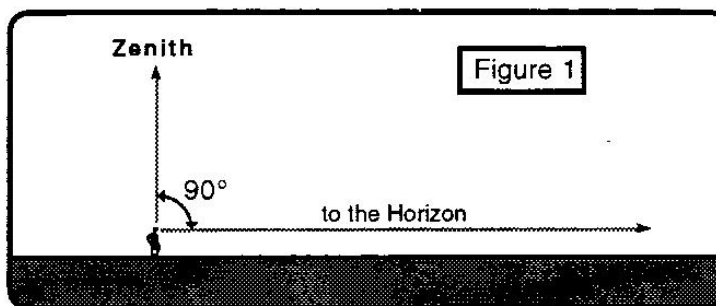
Figure 2

You may have wondered how people on ships far at sea, out of the sight of land, are able to tell where they are. For thousands of years mariners have navigated their ships by the stars. The procedure of finding your position through observations of the stars is called celestial navigation.

In theory, it's fairly easy.

It is important that you work through this activity step by step. Proceed slowly and with care. If you don't understand something, go back or ask for help. This is an important activity.

The point in the sky straight overhead is known as the **zenith**. The zenith is at an angular elevation 90° above the horizon. Figure 1, below, shows what we mean by the zenith.



1. Define **zenith**: _____
2. The zenith is located _____ $^\circ$ above the horizon.
3. In Figure 2, which observer will see Polaris at the zenith? _____
4. When people around the Earth look up, do they all see the same stars in the night sky? _____
(See Figure 2.)
5. In Figure 2, man A sees Polaris at the _____.
6. The latitude of the North Pole is _____ $^\circ$ _____.
7. At the North Pole, an observer would see Polaris _____ $^\circ$ above the horizon.
8. An observer at the equator would see Polaris _____ $^\circ$ above the horizon, and, at the equator, the latitude is _____ $^\circ$.

9. In figure 2, would Man C be able to observe Polaris? _____
10. So, Polaris is visible only to observers north of... _____
11. If you are an observer north of the equator, what is the relationship between the altitude of Polaris above the horizon and your latitude? _____

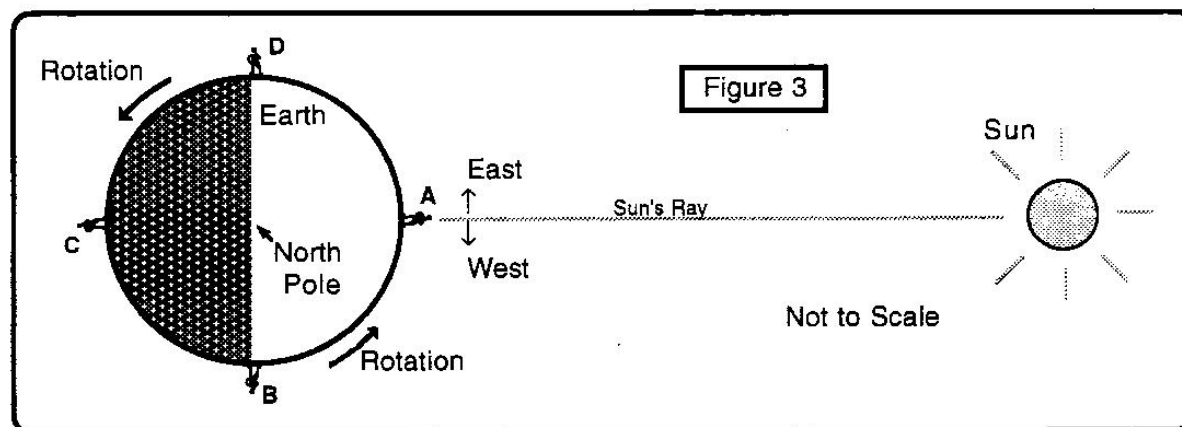
Important Fact #1:

The altitude of Polaris above the horizon is equal to the latitude of the observer. (North of the equator)

12. Copy the statement above in the space below.

13. So, an observer at 40° North latitude could observe Polaris _____ above the horizon.
14. A person at the equator would see the North Star _____ above the horizon, and his latitude is _____.

Finding your latitude is simple. Just measure the angle from the northern horizon up to Polaris. Polaris is easy to find because it is always visible in the northern sky. However, because of the rotation of the Earth, the sun and all the other stars appear to move through the sky as the Earth spins. Determination of your longitude requires the use of a very accurate clock, or a radio; both of them relatively modern technologies.



Note that in Figure 3 we are looking down from a point above the North Pole. We can see the Earth turning to the east.

15. In this view, is the Earth rotating clockwise or counterclockwise? _____

Answer the following questions based upon Figure 3.

16. If the sun is directly overhead for observer A, his local time must be _____.

17. For observer B, on the equator, where the sun is just rising, the local time is _____.

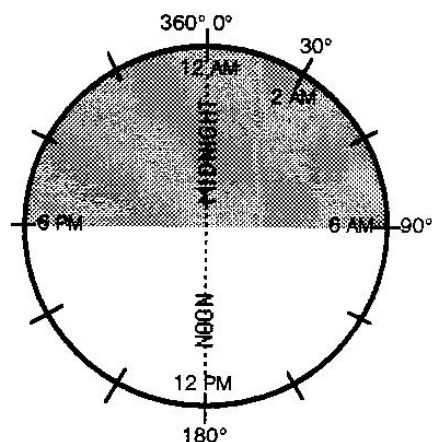
18. For man C, the local time is... _____.

Because different places around the Earth have different local times, we can determine our longitude.

First: On the outside of this circle, label every 30° from 0° around to 360° . Write them now.

Then: Notice that inside the circle some of the time intervals have been labeled like a 24 hour clock.

You should now label 4 AM, 8 AM, etc. so that every two hour interval has been labeled *inside* the circle.



19. Therefore, each 2 hours the Earth spins through _____ $^\circ$.

20. Every hour the Earth rotates through _____ $^\circ$.

21. _____ means the same as "spin".

The Earth can therefore be split into time zones based upon degrees of longitude.

22. Around the whole Earth is _____ $^\circ$, or, _____ hours.

23. Thus, two places 15° of longitude apart are _____ apart in time.

Important Fact #2: Every hour the Earth rotates through 15° .

If you look at very old maps, you will find that the measurements of latitude are fairly accurate. But longitude measurements are poor. The determination of longitude depends upon the use of a clock set to standard time. For this use, the ship's clock had to remain accurate after many weeks at sea. An error of only one hour would mean an error of 15° of longitude on a map.

The British dominated exploration and map making in the 1600s and 1700s. They set their clocks to observations of the sun made at the Royal Observatory in Greenwich, near London. Greenwich Mean Time (GMT) therefore became the standard upon which longitude was based.

Very accurate maps could not be made until mariners could use precise clocks that would keep very accurate time on a long ocean voyage.

If the navigator knew both Greenwich time, and his local time, based upon observations of the sun and stars, he could calculate his longitude.

24. What instrument made accurate measurements of longitude possible? _____

25. To what time did the navigators set their clocks? _____

26. How far does the Earth rotate in one hour? _____

If the ship clock set to Greenwich Mean Time (GMT) reads 12 noon, but it takes one more hour for the sun to reach its highest point in the sky (your local noon), the ship must be 1 hour, or, 15° west of the Prime Meridian.

27. If the local time is 3 hours behind GMT, the ship's longitude must be _____ $^\circ$ West. (Hint: $3 \times 15^\circ$)

28. If the local time is 2 hours ahead of GMT, the ship is _____ $^\circ$ East.

29. If GMT and the local time are 12 hours apart, the ship is _____ $^\circ$ from the Prime Meridian.

So, longitude is calculated by comparing local time with Greenwich time.

Important Fact #3:

Longitude = Time Difference (in hours) from GMT $\times 15^\circ$ / hour.

30. Copy the statement from the box above into the space below.

31. What star is used to determine your latitude? _____

32. If an observer sees Polaris 42° above the horizon, his latitude must be... _____

33. To calculate your longitude, you need a clock set to _____

34. What object in the sky is used to determine the local time? _____

35. How many degrees does the Earth rotate each hour? _____

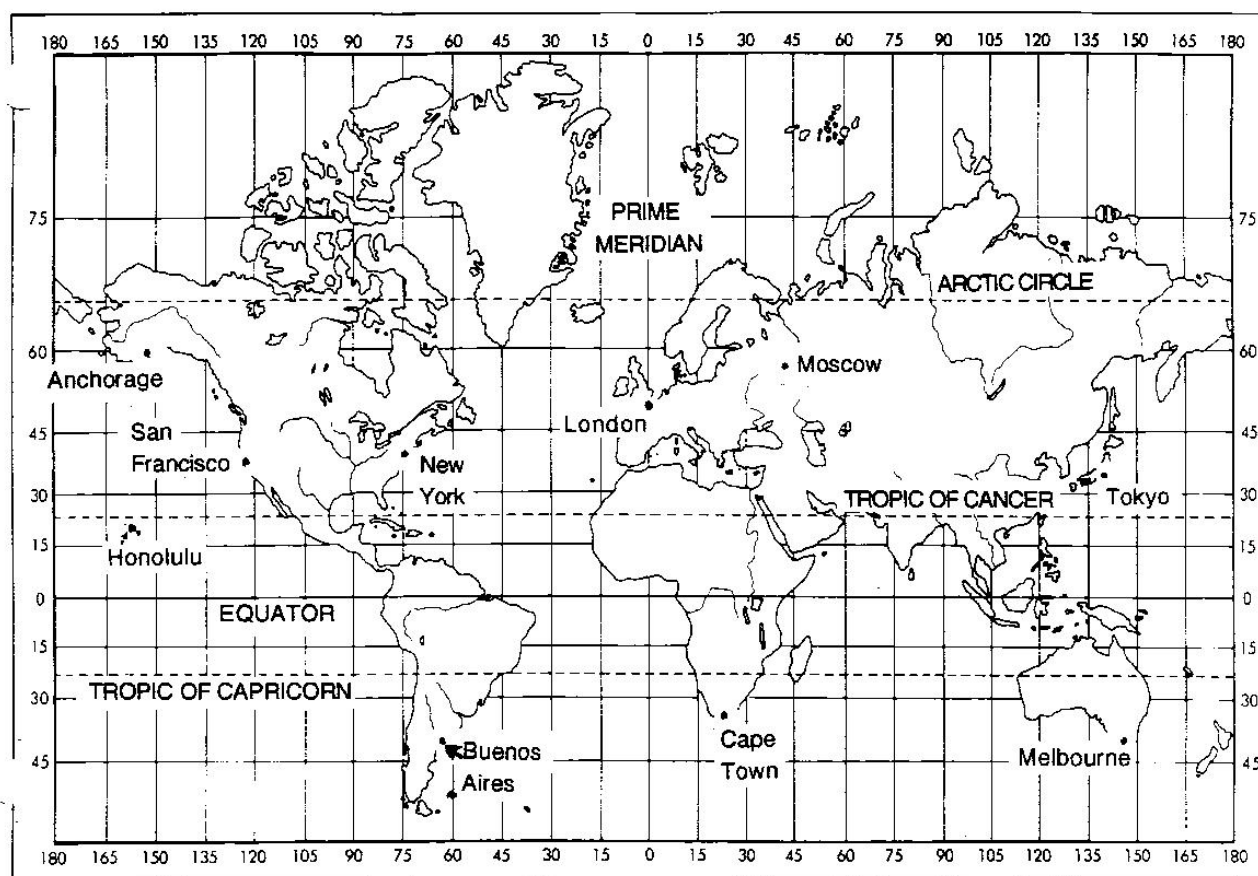
36. How many degrees does the Earth turn through in 4 hours? _____

37. How many degrees does the Earth rotate through in 24 hours? _____

38. An observer who sees Polaris straight overhead must be at the... _____

39. How many degrees above the horizon is the zenith? _____

Use the map below to answer the questions on this page.



Terrestrial Coordinates

Name of City	Latitude	Longitude	Name of City	Latitude	Longitude
40. _____	36°N	122°W	41. _____	33°S	18°E
42. _____	35°N	140°E	43. _____	55°N	37°E
44. New York	_____	_____	45. London	_____	_____
46. Melbourne	_____	_____	47. Honolulu	_____	_____

48. The sun appears to move from East to West. At which city will noon come first? San Francisco, or, New York
49. Is it noon in Moscow before or after it is noon in London.
50. A person in Rome, 42° North latitude and a person in Denver, also 42° North latitude, both see Polaris on the same night. Which, if either, will see it higher in the sky? _____

51. Briefly explain a way to find your latitude by measurement.

52. Briefly explain a way to find your longitude by measurement.

53. There is a time lag of 3 hours between New York and California.
How many degrees of longitude separate these two places?

Use the map on Page 5 to answer the following questions:

54. What is the angular elevation of Polaris in Westchester?

55. If it is noon in London, what time is it in New York?

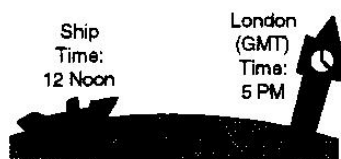
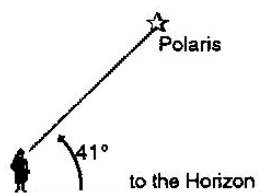
56. If it is noon in Tokyo, what time is it in Melbourne?

57. How high above the horizon is Polaris in Cape Town, South Africa?

58. The diagrams below show two sets of measurements taken by an observer on a ship entering a harbor.

What are the ship's terrestrial coordinates? Latitude: _____ Longitude: _____

Where is the ship? (Use the map on page 5) _____



59. As an observer travels due east or due west, what happens to the angle of Polaris? _____

60. Lines of equal _____ run East and West, but they measure how far North or South you are.

61. The _____ is the reference line for latitude, and the _____ is the
reference line for measurements of longitude. Both lines are at a coordinate angle of _____°.

62. Define **latitude**: _____