

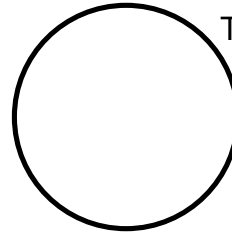
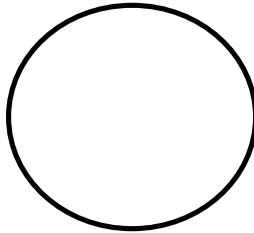
Chapter 2: MEASURING and MAPPING EARTH

We use lots of **models** in Earth science. **Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.** Models can be physical, like a globe; mental, like the model of the atom; mathematical, like an equation that describes the steepness (or slope) of a mountain as a number; or graphical, like a flowchart or map.

Earth's Shape

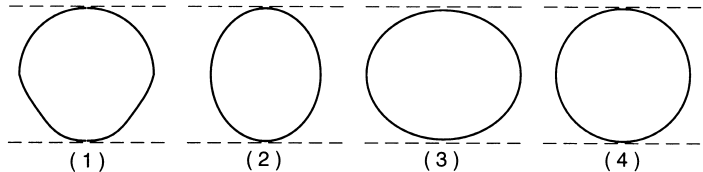
The Earth is not perfectly round and smooth, but is slightly oval in shape with a somewhat irregular surface (mountains and valleys). This shape is called an **oblate spheroid**. However, the Earth's oblate shape and irregular surface are very slight when compared to the overall size of the planet. In fact, when viewed from space by the naked eye, the Earth *appears* to be perfectly round and smooth. That's why the most accurate globes appear to be perfectly round and very smooth, like a billiard (pool) ball.

This exaggerated view shows the Earth is slightly flattened at the poles, and bulging at the Equator. In reality, this oblate shape is not visible to the naked eye.



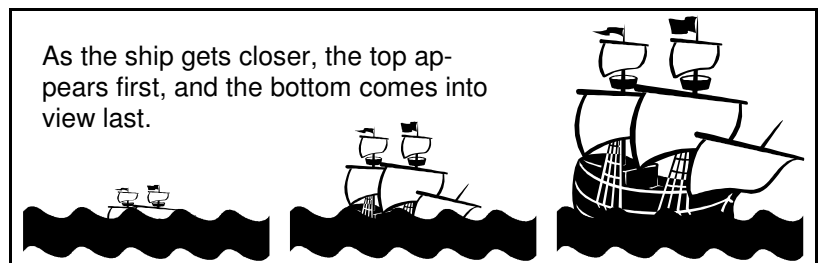
This is an accurate view of Earth. Earth *appears* to be perfectly round and very smooth.

Which of the shapes at right most closely approximates the Earth's true shape?
(HINT: What does the Earth actually look like when viewed from space?)

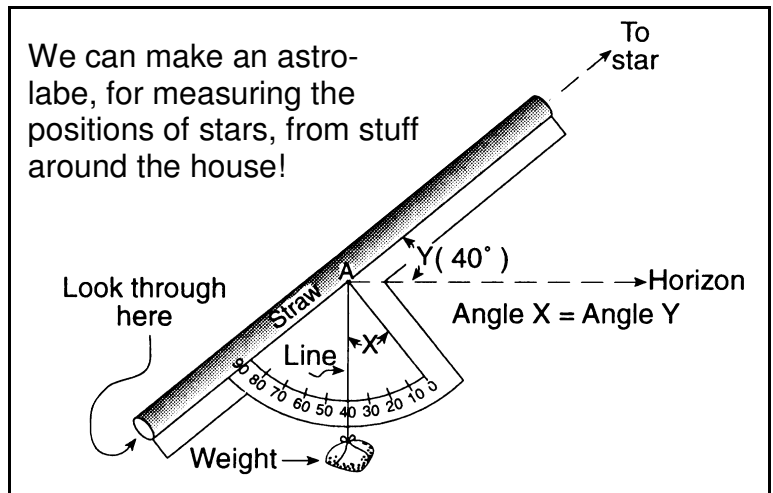
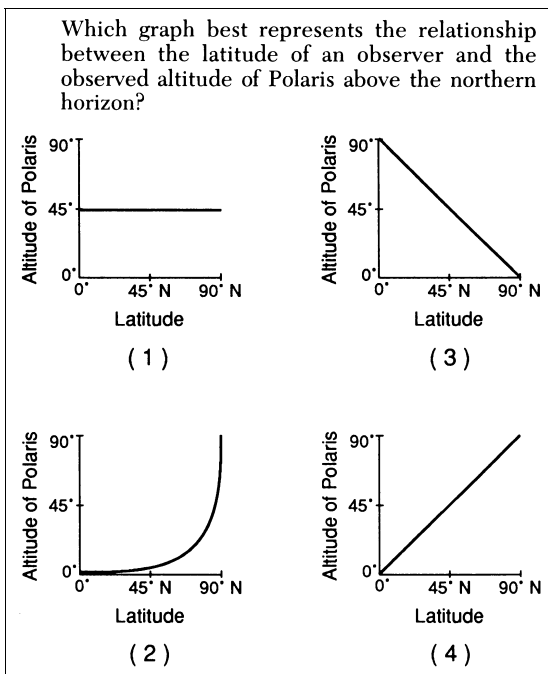
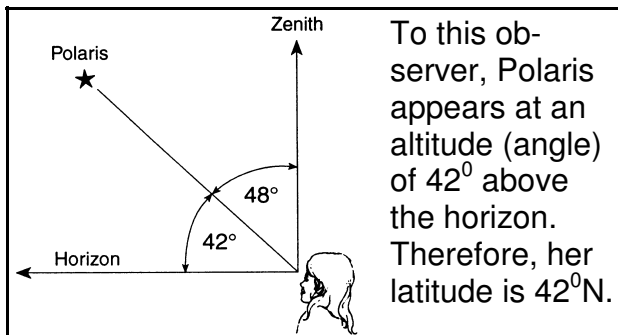
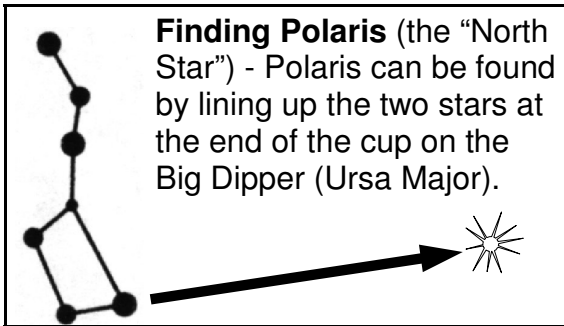
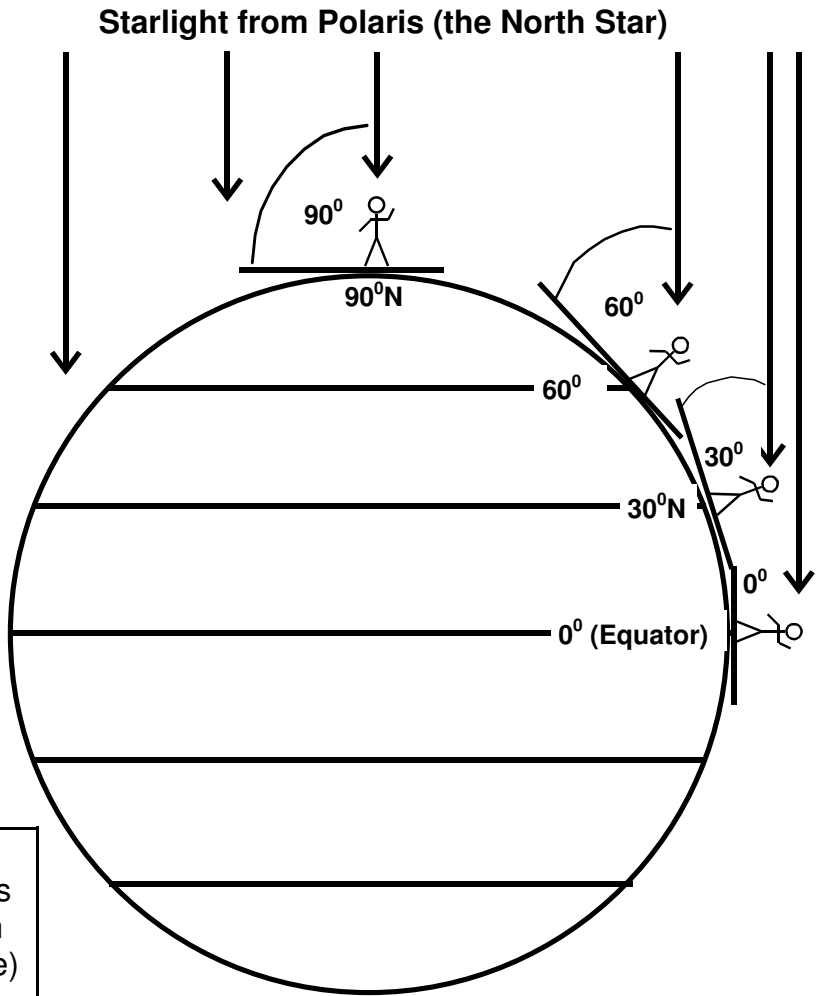


Evidence of Earth's Shape

1. **Photos from space** are the best evidence we have of the Earth's very spherical shape.
2. **Gravity measurements** show that objects weigh more at the poles than at the Equator. That's because at the poles you're closer to the Earth's center than at the Equator.
3. **Ships at Sea** gradually disappear over the horizon as they sail away. The bottom of the ship disappears first and the top of the ship is the last part still visible. The process reverses as the ship returns. The only possible explanation is that the Earth's surface is curved - even the ocean.
4. **The altitude of Polaris** gradually increases as one travels from the Equator to the North Pole (see diagram on p. 2). Since Polaris, also known as the *North Star* or *Pole Star*, is in line with the Earth's axis, it always appears exactly north in the sky, and is always at a constant altitude, or angle, in the sky from any one location. In fact, the altitude of Polaris at any location is always equal to the latitude of that location, from 0° at the Equator to 90° at the North Pole. However, since Polaris is directly above the North Pole, it's never visible in the Southern Hemisphere.



Altitude (Angle) of Polaris - the diagram at right shows four observers at four different latitudes. For the observer at the Equator (0° latitude), Polaris appears at an angle of 0° in the sky. For an observer at 30°N latitude, Polaris appears to be 30° above the horizon. Since Polaris is directly above the North Pole, it always appears at an altitude of 90° , or directly overhead, when viewed from the North Pole.



Earth's Size

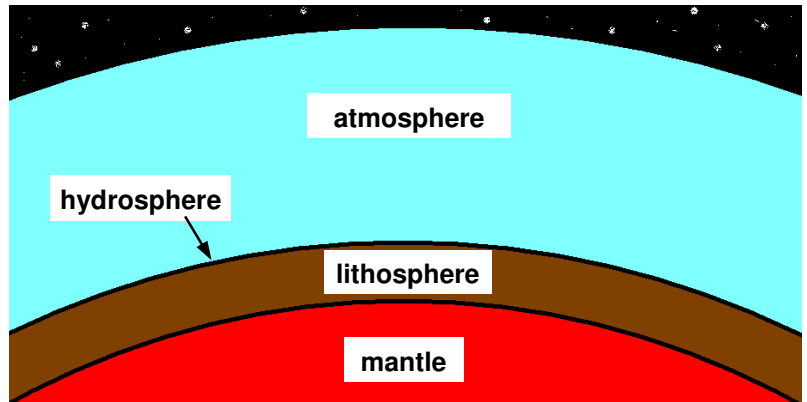
Many Earth statistics can be found in the ESRT. Page 15 gives the Earth's Equatorial diameter (distance across at the Equator), mass and average density. Earth's Equatorial diameter is about 40km greater than its Polar diameter. When compared to the overall diameter (more than 12,700km), the difference is tiny (the bulge at the Equator is about 0.3%). That's why the Earth looks perfectly round.

Earth's Outer Layers

We're going to look more "in depth" (sorry) at the interior of Earth later in the course. Right now we're concerned with the outer layers.

Atmosphere - the layer of **gases** surrounding the Earth. This gas layer is the **thickest** of the three, but is also the **least dense**. It actually has four distinct layers, composed of different gases, with different characteristics (ESRT p. 14).

Hydrosphere - the **water** layer is in the middle, resting on top of the rocky lithosphere below. In spite of covering almost 3/4 of the "water planet," it's the **thinnest** layer by far (averaging only about 3km deep). It includes the oceans, ice caps, glaciers, ground water, lakes, rivers, etc.

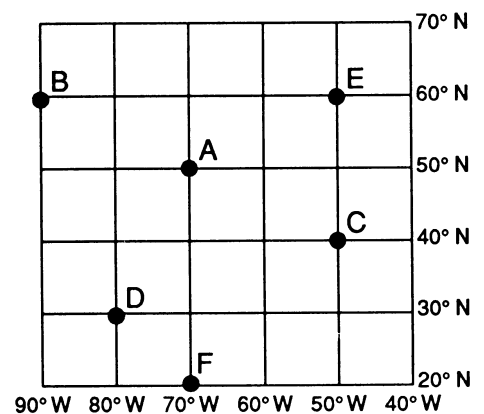


Lithosphere - the **solid**, rocky crust of the Earth. Since it's solid, it's the **most dense** layer.

Locating Positions on Earth's surface

To locate and map positions on Earth, we use a coordinate system, like a graph. Every point on Earth has two coordinates - latitude (x) and longitude (y). Latitude is always stated first, so we don't mix them up. You can think of this coordinate system like a graph, as in the following example. The diagram at right shows a part of Earth's surface. Numerous locations are mapped as points on the latitude-longitude grid. Thus the position of location A is 50°N latitude and 70°W longitude, or 50°N, 70°W.

But you can't accurately model a round object on a flat surface, and the Earth is very round, so paper maps have limitations. On flat maps of the world, the polar areas are especially inaccurate, because they have to be distorted to fit the rectangular shape. Clearly, the best model of Earth is round - like a globe!



Give the coordinates for the following locations (latitude first, and don't forget the compass direction)

B: _____

D: _____

E: _____

OK, so we definitely need a round map to accurately show a spherical planet's surface - a **globe**! But how do you graph a round surface in order to use a coordinate system of locating positions? The diagram at right shows the coordinate system we use. It is based on observations of stars and the Sun (which is itself, of course, a star).

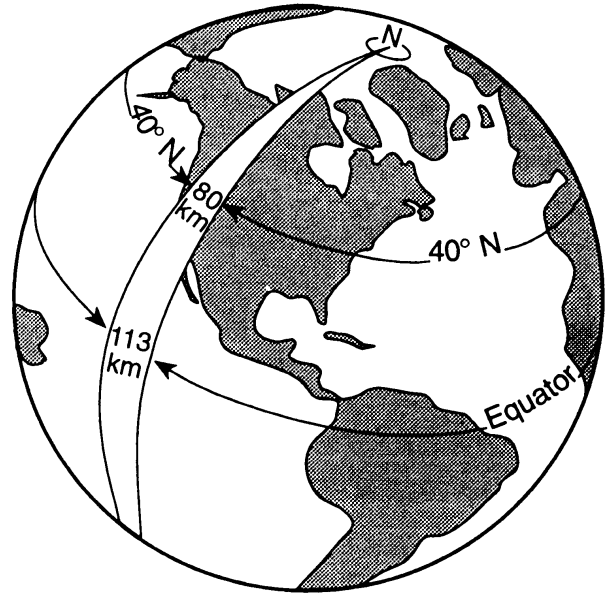
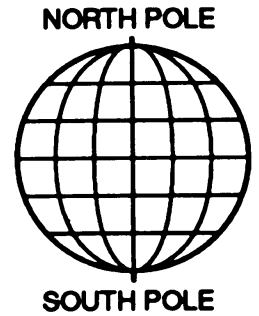
Latitude is the distance, in degrees, north or south of the Equator (0°). The highest possible latitude is 90° (the North or South Poles). The imaginary "lines of latitude" are great circles called **parallels**, because they run parallel to the Equator (W - E). The diagram at right clearly shows that parallels are parallel, like the rungs of a ladder (**latitude - ladder**). The distance between each parallel is pretty much the same at all locations (1° of latitude ~ 111 km).

Longitude is the distance, in degrees, east or west of the **Prime Meridian** (0°), which runs north - south through Greenwich, England. The highest possible longitude is 180° (the International Date Line). The imaginary "lines of longitude" are great arcs (not circles) running N - S and are called **meridians**. Meridians are NOT parallel, but converge at the poles, in order to accommodate the round shape of Earth. Because of this convergence, the distance between meridians varies with latitude, from about 113 km at the Equator to zero at the poles (see diagram at right).

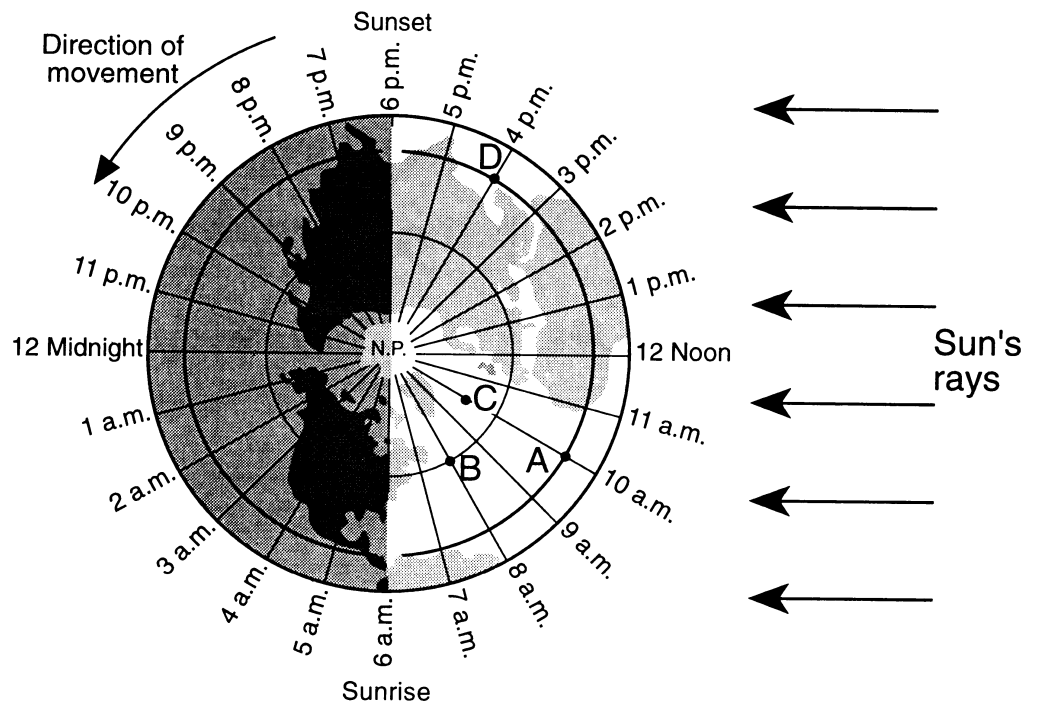
When viewed from a pole, like in the diagram below, parallels of latitude appear as concentric circles. Meridians of longitude appear as spokes radiating out.

We already learned that latitude can be determined from the stars - Polaris in the Northern Hemisphere, and another cluster of stars if you're in the Southern Hemisphere (the "Southern Cross").

Longitude is based on another star - the Sun. Since Earth rotates 360° in 24 hours, its rate of rotation is 15° every hour ($360^{\circ} / 24\text{hr}$). If the Sun is due south (~ 12 noon) in Ballston Spa, one hour later the Sun is due south 15° west of us (when it's noon there). That's why time zones are 15° apart (see diagram at right). The boundaries are often crooked where they run around populated areas.



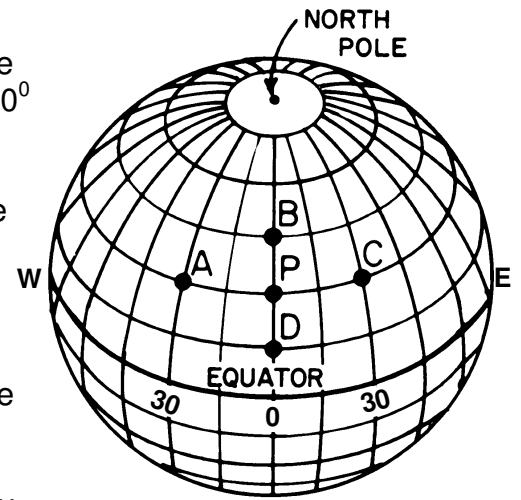
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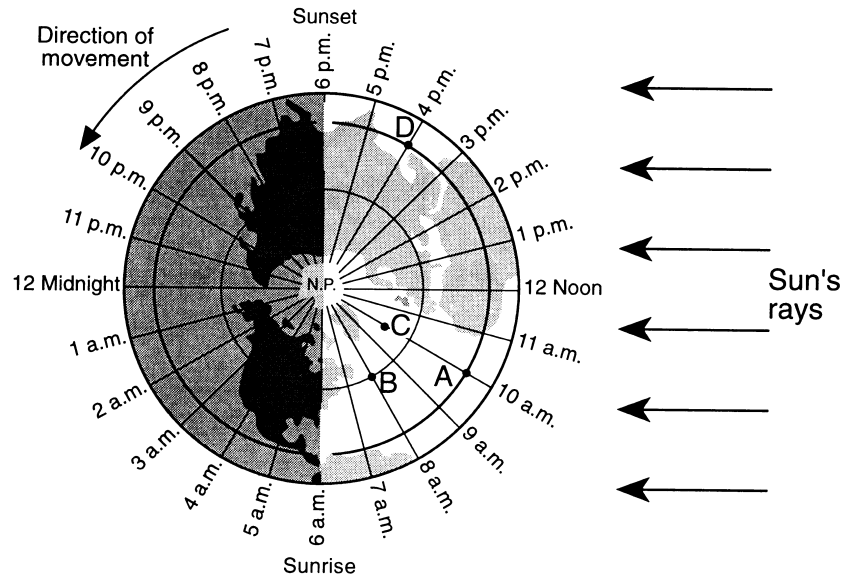
The diagram at right shows parallels and meridians drawn on a globe. We can tell that the parallels are 15° apart because there are six sections between the Equator and the North Pole, and 90° divided by 6 equals 15° each.

Locations A, P and C are on the same parallel, so they have the same latitude (30°N). From any of these locations, Polaris will always be seen exactly north in the sky, at exactly 30° in altitude.

Locations B, P and D are on the same meridian, so they all have the same longitude, and therefore, the same time as well. For each of these locations, the Sun will be exactly south in the sky (at what's called "solar noon") at exactly the same time each day.



In the second diagram, we can see that the Earth rotates counterclockwise as viewed from the north. It is noon in North Africa and Western Europe, while it is 6 am on the East Coast of the US. Time is always earlier to the west, and later to the east, by 1 hour for every 15° of difference.



Use the third diagram, below, to consider the following questions.

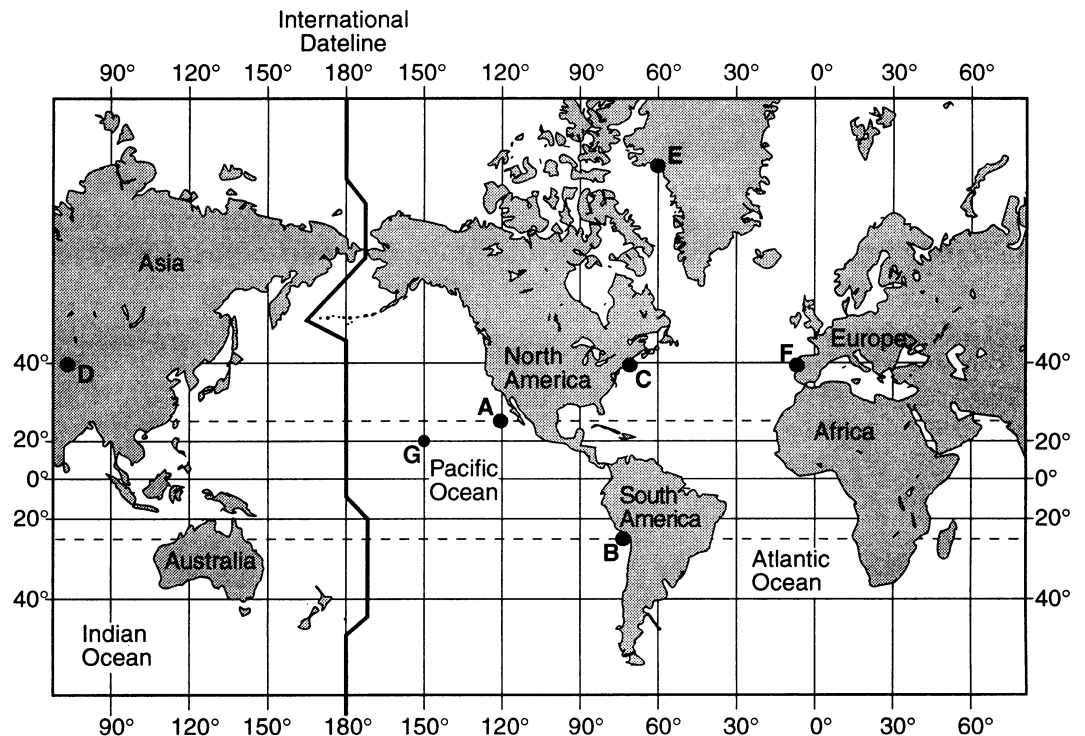
1. What are the coordinates of location

G? _____

2. What is the altitude of Polaris when viewed from location C?

3. How many hours separate locations A and E?

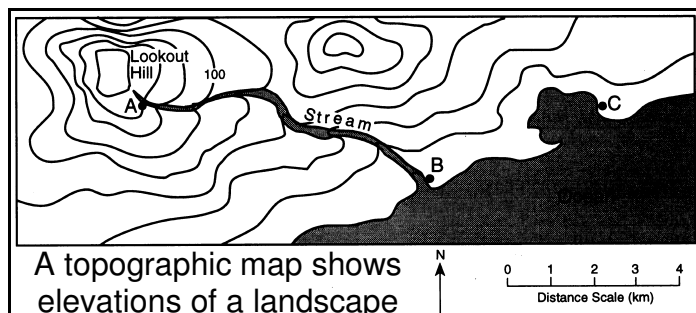
4. If it's 5pm at the Prime Meridian, what time is it at location A?



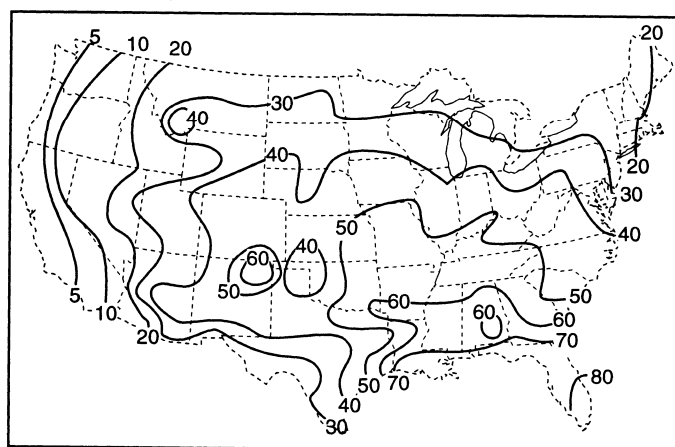
Mapping Earth's Physical Characteristics

There are many physical characteristics of the Earth that are measured and mapped by scientists and people in other fields. Elevations, water levels, pollution concentrations, temperatures, pressures, noise levels, and even smells can be mapped. For example, surveyors and geologists regularly measure elevations of the land, then plot them on a map. A “**topographic**” or “**contour**” map can show the shape of the land by connecting points of equal elevation with “**contour lines**.” Using such maps, distances and elevations can also be determined with great accuracy. Engineers and landscape architects can make 3D models of the land from contour maps. Planners use contour maps to study surface water flow and predict flood levels. Emergency management officials use these maps to determine the safest routes for evacuation and rescue.

Scientists can also map pollution concentrations from well water samples. By monitoring changes in the concentrations of pollutants over time, the location of the source of the pollution and the direction that the pollutants are moving underground can be determined. Outdoor enthusiasts use topographic maps for hiking and camping in wild areas. Artists even use contour maps to construct accurate side views of real landscapes as base drawings for landscape paintings. Of course meteorologists use maps of temperature and pressure daily in analyzing and forecasting the weather. A field map of average thunderstorm numbers is shown at right. Since the Earth is constantly changing, measured data and the resulting maps must be periodically updated.



Average Number of Thunderstorms Each Year



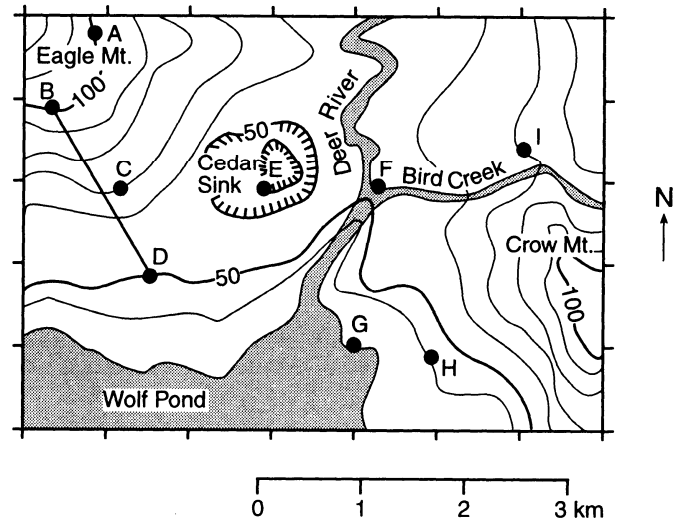
Fields

A **field** is a region of space with some measurable quantity at every point. If you were to measure the noise levels at 100 locations around an airport, the area would be called a noise field. When meteorologists show a temperature map of the US, the map is a temperature field. In this course, we will use lots of temperature and pressure field maps when we study weather. During this unit though, most of the fields studied will be fields of **elevation**, or height above sea level.

To map a field, we measure the field at numerous points and plot the data on a base map. We then draw lines called **isolines** on the map which connect points of equal value. For any of the lines on the map shown above, every point on that line has the same elevation. Isolines on an elevation field map are called **contour lines**. Isolines on a temperature field map are called **isotherms**, and isolines on a pressure field map are called **isobars**. The difference in field value between each line on a field map is called the **interval**. On a topographic or contour map, the difference in value between each line is called the **contour interval**. Usually the interval is given on a map key, but even if not provided, the interval can be determined if the field values of at least two lines are known. On the map above, the 100-foot contour line is shown to be separated from the ocean (which is at 0 feet elevation) by five spaces (RULE: always count spaces, not lines). The contour interval of this map, then, is 20 feet ($100' / 5 \text{ spaces}$).

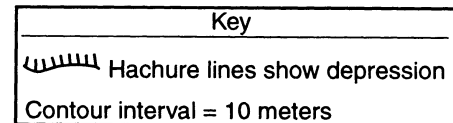
Topographic (Contour) Maps

Besides showing elevations, “topo” maps show symbols for various features, like buildings, bridges, dams, fences, power lines, cemeteries, forests, fields, swamps, marshes, rapids, glaciers, etc. The map at right is a simplified topographic, or contour, map. The contour interval is shown to be 10 meters. Since Wolf Pond is not the ocean, its elevation is not 0. We don’t know exactly what the elevation of Wolf Pond is, but we know it’s somewhere between 30 and 40 meters because it’s below the 40-meter contour line. The peak of Eagle Mountain is above 100 meters, but less than 110 meters (since there’s no 110-meter contour line).



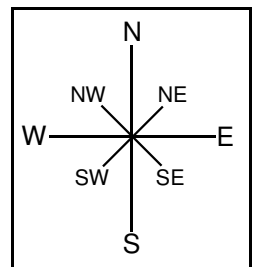
Depressions

A depression is an area of low elevation surrounded by higher elevations (such as an open pit mine, swamp or a sink hole). The symbol for a depression is shown on the map key. It is a contour line with little “hachure” lines on the downhill side. The outermost, highest line of a depression is the same elevation as the lowest regular line next to it. The depression at right is in between two regular contour lines - the 50-meter and 60-meter lines. Since depressions always take the value of the lowest adjacent line, the first depression contour is at 50-meters. As you go farther into the depression, the elevations get lower. We know the elevation of the bottom is lower than 40 meters, and higher than 30 meters (because there’s no 30-meter contour line). Therefore, the lowest possible elevation of the bottom, to the nearest meter, is 31 meters.



Compass Direction

Compass direction is usually shown by an arrow pointing north. We need to know how to determine eight different compass directions, as shown by the compass rose at right.



Determining Distance

Straight-line distances between two points can be measured using the **distance scale** on the map together with a scrap sheet of paper, as follows:

1. Put a straight edge of your scrap sheet along an imaginary line between the two points.
2. Pencil a fine mark on the edge of the scrap sheet at the exact location of each point.
3. Move the scrap sheet down to the distance scale on the map to measure the distance between the two points. Make sure one point is at zero on the scale. If the distance between the points is greater than the length of the scale, make a mark on the scrap sheet at the end of the scale, then move that mark to zero and add the two distances together.

Determining the Direction of Water Flow

Contrary to what some people think, water can flow in any compass direction - north, south, east, west or any direction in between. So on the map on page 7, how can we tell whether the Deer River is an inlet or an outlet to Wolf Pond? There are two ways to tell.

1. The simplest way is to look at the elevations of the contour lines along the river. If there aren't enough elevations shown, write some more in on the blank lines. If one part of a river or stream is at a lower elevation than another part, then the water is flowing in that direction.

Water flows from higher to lower elevations.

2. Another way to tell which way the water is flowing is to notice the way the contour lines bend to form a "U-shape" or "V-shape" when they cross a valley or stream. **The "Vs" point uphill** (NOT in the direction of flow!).

On the map below, the creek is flowing toward the northeast. We can tell because the north end is below 3,800 feet, while the southwest end is above 4200 feet. Also, note how the contour lines bend as they cross the creek, and they point **uphill**, toward the south and west.

Gradient

When we study a field, we often need to know the rate of change in the field from place to place. The amount of change that occurs in a field between two locations can be expressed mathematically as the amount of change in the field value divided by the distance between the two points. For example, if two cities 100km apart have a difference in temperature of 5°C, then the rate of temperature change between the two cities is 5°C / 100km = 0.05°C / km. This change in a field value over a given distance is called **gradient** (see ESRT p. 1). To find the gradient between two points, find the difference in field value between the points, then divide that by the distance between them.

$$\text{Gradient} = \frac{\text{change in field value}}{\text{distance}} = \frac{\text{difference}}{\text{distance}}$$

As a rule of thumb, **if the isolines are close together, the gradient is high (steep slope). If the isolines are far apart, the gradient is low (gentle slope).**

The map below shows a creek. If I were to try running the rapids from point A to point B, I'd want to know what the gradient was (as a rule of thumb, I avoid drops of more than 20 feet per mile). To find the gradient, use the formula:

$$\begin{aligned}\text{Gradient} &= \frac{\text{change in field value}}{\text{distance}} \\ \text{Gradient} &= \frac{4200' - 4000'}{5 \text{ miles}} \\ \text{Gradient} &= \frac{200 \text{ feet}}{5 \text{ miles}} \\ \text{Gradient} &= 40\text{ft/m}\end{aligned}$$

Too steep to run in a canoe!

