I. Objectives

1. Calculate how longitudinal distance varies as a function of latitude.
2. Estimate distances along a given parallel.
3. Estimate longitude given a time difference from GMT.
4. Explore and locate various features based on common latitudes.

II. Introduction

Location, location, location. Knowing exactly where you are and being able to communicate this location with someone else is a fundamental scientific and technological need. The standard, almost universal system is to define location in terms of the latitude and longitude grid that bisects the Earth's almost spherical surface. This system is based on two reference lines: the equator, at latitude = 0^o, which traces out the plane that bisects the Earth perpendicular to its North and South axis; and the prime meridian, which runs orthogonal to lines of latitude and connects the poles, longitude = 0^o. Over geologic time, with polar wander, this system has some shortfalls but for life in the here and now, it will suffice.

III. Materials

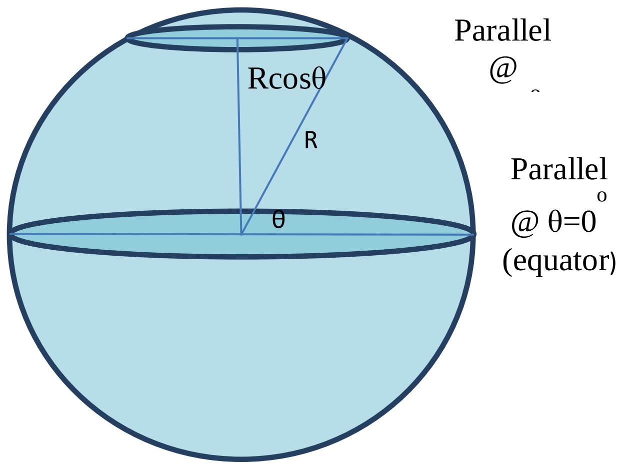
Calculator

IV. Theory and Calculations

The Earth's equatorial radius (R) is 6378 km and the shape of the Earth is very close to a sphere. Thus the Earth's equatorial circumference (C) is 40,074 km and there must be 111.32 km /degree at 0^o latitude. The same is not true at other latitudes. Figure 1 illustrates the basic geometry that defines how this unit of distance/degree changes as a function of latitude (θ). The formula for the circumference of a line of constant latitude (a parallel) is:

$$C = 2\pi R cos\theta \qquad (1)$$

This circumference is divided by 360 degrees to find the unit distance/degree. Sometimes it is convenient to use a graph to estimate cosine θ values, as can be done using Figure 2.



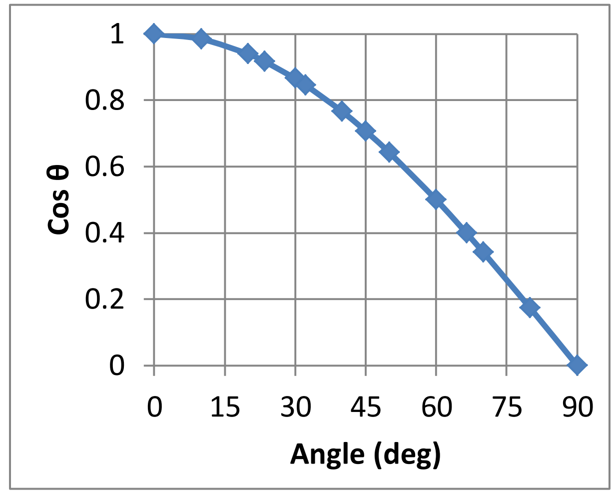


Figure 1 – Basic geometry

Figure 2 – cosine θ vs. angle (θ)

Linear Interpolation/extrapolation:

You may remember that it is possible to estimate distance or some other variable, if given a unit measure or known values. That is, if we know there are 111.32 km/deg, it is possible to find the distance between any two points at this latitude if we know their longitudinal separation angle, for example, 15°:

$$\frac{111.32\ km}{1\ deg} = \frac{x\ km}{15\ deg} \qquad (2)$$

$$15 * 111.32\ km = x \qquad (3)$$

V. Prelab Definitions

1. latitude

2. longitude

3. parallels

4. equator

5. Tropic of Cancer

6. Tropic of Capricorn

7. meridian

8. Prime meridian

9. International Date Line

10. GMT

11. UTC

12. Zulu

VI. Lab Procedure

Part A: Calculating Longitudinal Distance as a Function of Latitude

As one moves North or South along any line of a meridian, the distance represented by one degree is uniform. However, as one moves East or West along a line of a parallel, the distance represented by one degree varies as a function of latitude. Table 1 illustrates some of the basic relationships for some common geometric angles. Your task is to fill out Table 2 using cosines estimated from Figure 2 (above) or generated by a calculator for some other important latitudes. For your calculations, assume R = 6378 km.

Table 1: Examples of Latitudinal Variation in Angular Distance				
latitude (θ)°	cos θ	radius (θ) = R cos θ	circumference	distance for 1° of longitude (km/1°)
0° (Equator)	1.0	R	2πR	111.32
30°	0.866	$R^*\sqrt{3}/2$	$\pi\sqrt{3}$ R	96.40
60°	0.50	R*½	π R	55.66
90° (Poles)	0	0	0	0

Table 2: Angular Distances for 5 Selected Angles			
latitude (θ)°	cos θ	circumference = 2πR cosθ	circumference/360 (km/1°)
23.5°			
32.2°			
45°			
50°			
66.5°			

Part B: Estimating Distances Along a Given Parallel

Now we are going to use this information to calculate how far Tucson is from the Prime Meridian and the International Date Line. Then use Google maps of some other map to find the point at Tucson's latitude that is furthest away (on "opposite side" of the Earth). How far away are these locations? Complete Table 3.

Table 3: Longitude Differences and Distances		
Factors: Tucson Lat. ~ 32.2 ^{o}N; Long. ~ 111.2 ^{o}W; km/1^{o}= _______		
location	longitude difference	distance in km
Prime Meridian longitude =_____		
International Date Line longitude ~_____		
Furthest away point longitude =_____ country = _____________		

Part C: Estimating Longitude Given a Time Difference from GMT

This problem is related to the historical problem of finding a ship's longitude based on a time difference between observed solar noon and the time given by an accurate reference clock which provides Greenwich Mean Time (GMT). The ship's clock had to be wound once a day, a critical task as a stopped clock erased any hope of estimating ones longitude. If you are interested in this topic, see the book called "Longitude - The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time" by Dava Sobel.

Your task is to fill out Table 4 for the following scenario: A ship sails east from Newfoundland, Canada toward London, England. Estimate the longitude based on the time difference, calculate an average rate of travel and then estimate how many days the whole journey will take. We actually do not need to convert to kilometers for this problem – we can stick with a measure of speed of degrees/day.

Table 4: Speed and Estimated Day of Arrival				
Factors: Assume latitude = 50^o N; London longitude = ________				
day	reference clock (GMT)	difference	longitude	speed in degrees/day
0	16:00	16-12 = 4 hrs	4*15 = 60 W	-
5	15:03			
10	13:57			
arrival day: _______	12:00	0	0	average: days left:

<u>Part D: Exploring and Locating Various Features Based on Common Latitudes</u>

Here are some fun things you can do to further explore the Earth and practice using latitude and longitude. You will need Google Earth or a good atlas or Globe. You will need to turn the latitude/longitude grid “on” in Google Earth. Do this by checking “grid” from the “view” tab. Note: most cities will not show up if your eye elevation is above 1000 km.

1. Find 3 cities on the Tropic of Cancer (±0.5^o)
   a.

   b.

   c.

2. Find 3 cities on the Tropic of Capricorn (±0.5^o)
   a.

   b.

   c.

VII. Lab Discussion

1. What meridian lies just east of the Rocky Mountains?

2. What is significant about the 49th parallel?

3. What is the predominant land cover/climate regime along the two tropics? Why?

4. What might be some differences in the type of agriculture that is practiced east and west of the meridian you defined in question 1?

5. The accuracy requirement set for the winning ship's chronometer (clock) in the Grand Prize competition of 1714 was half a degree of a great circle. Since the Earth rotates at 15^{o}/hr, this amounts to an error of 2 minutes or 30 nautical miles. If a clock lost 4 seconds a day over a 40 day voyage, would it win the prize? If not, how many sec/day could it lose? (2 pts)

Lab courtesy of Dr. Jim Washburne