Where Am I? or Trilaterate a Position Using GPS

Orbiting above the earth are a number of Global Positioning System (GPS) satellites that help us determine positions on Earth. The concepts behind GPS positioning are very simple, but the application and implementation require amazing precision.

GPS positioning works on two basic mathematical concepts. The first is known as "trilateration" which means "positioning from three distances." The second is the relationship between distance traveled, the rate (speed) of travel, and the amount of time spent traveling, or:

Distance = Rate X Time

In GPS positioning the rate is how fast the radio signal travels, which is equal to the speed of light (299,792,458 meters per second). Time is determined by how long it takes the signal to travel from the GPS satellite to a GPS receiver on earth. With a known rate and a known time we can solve for the distance between satellite and receiver. Once we have a distance from at least three satellites, we can determine a 3 dimensional position on the surface of the earth.

Overview:

In this exercise we are going to simulate GPS positioning using 4 satellites. You are going to pretend to be a GPS receiver somewhere on the map and will figure out where you are located based on the 4 "signals" you receive. The information in each "signal" will only tell you two things, where the satellite was when it sent the signal (marked with a letter on the map) and the amount of time it took the signal to reach you (in seconds). You will then use the equation Distance = Rate X Time to calculate your distance from each satellite.

Materials: (to be provided AS NEEDED)

- Laminated Map
- Tape
- Calculator(s)
- Push Pin or Thumb Tack
- 1 piece of cotton string (approximately 1 meter in length)
- Ruler
- 4 Vis-a-vis wet erase markers (fine tip, 4 different colors)

Procedure:

1. Lay the map flat on your table and tape down all four corners
2. Determine the distance from each satellite to your position by using the Distance = Rate X Time equation and record that information in the data table.

	Satellite A	**Satellite B**	**Satellite C**	**Satellite D**
RATE or Speed of Light (**m/s**)	299,792,458	299,792,458	299,792,458	299,792,458
TIME for signal to reach the GPS from the satellite (**s**)	0.0013861	0.0012509	0.0014538	0.0011833
DISTANCE from the satellite (**m**)				
Scaled Distance (m)				
Scaled Distance (cm)				

3. The distance calculated is the actual distance to the satellite. This value needs to be scaled down to match the map scale. The map you are using has a scale of 1 inch = 16 miles. The equivalent scale in the SI system is 1 m = 1,013,543 m. This means that 1 meter on the map equals 1,013,543 meters on the earth's surface. Calculate the Scaled Distance in meters by dividing the distance from each satellite by the scale factor (1,013,543) and recording those values in the table.
4. Converting the units to centimeters will make measuring easier – Convert from meters to centimeters by moving the decimal two places to the right for each of your Scaled Distance values and record in the data table.
5. The Scaled Distance (cm) will be used to mark your location on the map. Choose a color to represent satellite A and tie the string around the color marker near the marking tip. Use the ruler to accurately measure from the center of the marker along the string. When you reach the Scaled Distance for Satellite A, put the push pin through the string to mark the distance. Measure the distance AGAIN to confirm the accuracy of your measurement.
6. Place the push pin point on the location marked A on your map. Hold the tip firmly against the table but DON'T stick it into the table! Pull the marker and attached string tight and mark an arc (part of a circle) on your map. This arc represents ALL of the possible locations that you could be based on the amount of time it took the signal to reach you from satellite A.
7. Complete steps 5 and 6 for each of the remaining satellites – use a different color and the correct scaled distance for each of the remaining satellites.
8. You should now have a series of arcs and circles that overlap in only a few places. There should be only ONE place on the map where all of the lines intersect or almost intersect each other.

Wrap Up:

GPS satellites are continually sending out their location and the time they sent their signal.

GPS receivers receive those signals and do the calculations to determine their location. The only difference is that you did the calculations from four simulated satellites, your GPSr (GPS receiver) does these calculations for up to 28 satellites AND as soon as it completes the calculations, it starts again – just in case you moved since the last time it did the calculations!