The Solar System Lesson Plan

Time: 50 minutes

Goals: To gain an understanding of the size of the Solar System and the methods used to calculate distance.

Objectives: Students will:

- Watch the "Solar System" segment of the "How far away is it" video book
- Optionally, connect to the Jet Propulsion Laboratory website.
- Measure parallax
- Take a short quiz

Materials:

- Protractor
- Tape measure
- Calculator for computing trigonometric functions
- Internet connection with a computer for viewing "The Solar System" segment on YouTube

Directions:

- Introduce the Solar System segment as our first step off the planet. Point out that we'll be constructing a new rung of our distance ladder called parallax.
- Show the video.
- Review what they saw:
    - How mankind moved from believing that the Earth was at the center of our system to knowing that the Sun was actually at the center.
    - How gravity holds the solar system together.
    - How we use parallax to measure distances to the planets.
    - How we use geometry to measure the distance to the Sun.
    - How we calculated the Earth's speed as it revolves around the Sun.
    - How we use geometry to calculate the speed of light.

- With a computer connection: Go to the Jet Propulsion Laboratory website: http://www.jpl.nasa.gov/
    - Hover over 'Missions' in the main screen's navigation bar.
    - Click on the pull down item 'Current".
    - Scroll down to 'Mars Science Laboratory Curiosity Rover' and click on it.
    - Take a look at what is happening on Mars.

Assessment options: Here are two assessment options based on prerequisites:

1. Without Trigonometry: Take a simple quiz. Print and distribute the quiz on page 3. Here are the answers:

    - What new invention enabled Galileo to see the moons of Jupiter?
      Answer: c) Telescope
    - What was the first successful method used to calculate the Moon's distance?
      Answer: a) Parallax measurement
    - Remembering that light travels at around 186,000 miles per second, how long would it take light to go the 120 miles from San Diego to LA?
      Answer: d) t = d/v = 120 miles / 186000 miles/sec = .000645 seconds

2. With Trigonometry: Demonstrate that when distance to an object gets larger, the parallax angle for the object gets smaller.

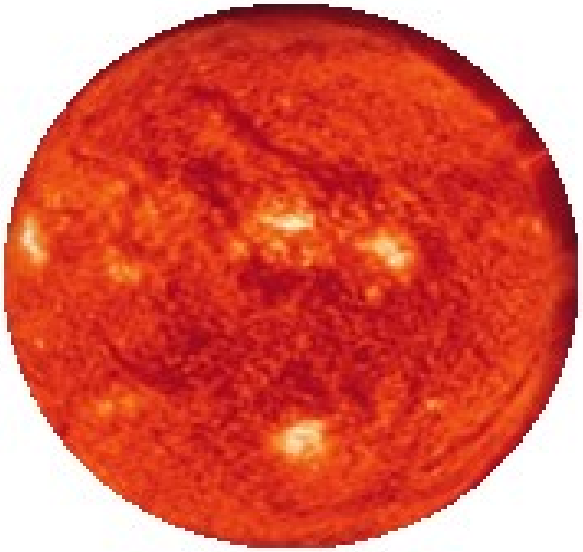
    - Mark 5 points on the floor such that:
        - They all fall on a line.
        - The distance between points is 12 feet.
    - From the point, A, at one end of the line, move 12 feet perpendicularly to the right or left and mark point B.
    - Measure the angle to this point from each of the other 4 points. These are the parallax angles: $\alpha_0, \alpha_1, \alpha_2, \alpha_3$.
    - Calculate what the angles are using the arctangent formula $\alpha = \tan^{-1}(12/d)$ where d is the distance.
    - Calculate what the parallax angle would be if d = 468 miles. (There are 5280 feet in a mile.)
        - Note that 468 miles is the flying distance from San Diego to San Francisco.
    - Solutions:
        - With d_0 = 12 ft; $\tan(\alpha_0) = (12 \text{ ft})/(12 \text{ ft}) = 1$; $\tan^{-1}(1) = 45.0^o$
        - With d_1 = 24 ft; $\tan(\alpha_1) = (12 \text{ ft})/(24 \text{ ft}) = .5$; $\tan^{-1}(.5) = 26.6^o$
        - With d_2 = 36 ft; $\tan(\alpha_2) = (12 \text{ ft})/(36 \text{ ft}) = .33$; $\tan^{-1}(.33) = 18.4^o$
        - With d_3 = 48 ft; $\tan(\alpha_3) = (12 \text{ ft})/(48 \text{ ft}) = .25$; $\tan^{-1}(.25) = 14.0^o$
        - With d = 468 mi; $\tan(\alpha) = (12 \text{ ft})/(2473199 \text{ ft}) = .000004852$; $\tan^{-1}(.000004852) = .000278^o$ This is equal to 1 arcsecond.
            a. Astronomers use the Earth's baseline of 186 million miles instead of the 12 feet we used here.
            b. With that as a baseline, the distance that has 1 arc second for its parallax is called a Parsec and is approximately 19 trillion miles.

The Solar System quiz

- What new invention enabled Galileo to see the moons of Jupiter?
  a) Theodolite
  b) Microscope
  c) Telescope
  d) Sextant

- What was the first successful method used to calculate the Moon's distance?
  a) Parallax measurement
  b) Bouncing light there and back
  c) Going there
  d) None of the above

- Remembering that light travels at around 186,000 miles per second, how long would it take light to go the 120 miles from San Diego to LA?
  a) 6.45 seconds
  b) .645 seconds
  c) .00645 seconds
  d) .000645 seconds



The Solar System Exercise

Mark 5 points on the floor such that:

- They all fall on a line.
- The distance between each point is 12 feet.

From the point (A) at one end of the line, move 12 feet perpendicularly to the right or left and mark point B.

Measure the angle to this point B from each of the other 4 points.

These are the parallax angles: $\alpha_0, \alpha_1, \alpha_2, \alpha_3$

Calculate the angles using $\alpha_i = \tan^{-1}(12/d_i)$ for i = 0, 1, 2, and 3

Explain the differences between the measured and calculated numbers.

Calculate what the parallax angle would be if d = 468 miles. (There are 5280 feet in a mile.)

Note that 468 miles is the flying distance from San Diego to San Francisco.