Module 2: Far Away Is Long Ago

Objectives/Key Points

Students will be able to:
1. Define and use the unit LY or "light years" as a unit of distance.
2. Apply the knowledge that when you observe an object, you are looking back in time, which becomes a noticeable effect on astronomical scales.
3. Calculate the time difference between an observed event and an actual event.

Unit Home

One dimensional kinematics.

Prerequisites

Module1, linear motion equation d=vt, should know light has a constant speed c

Time

60 minutes including handing out materials; can be split after #6 for a shorter class period

Materials

video http://www.youtube.com/watch?v=Yh1burSYVlM illustrating sound-light delay [if link disappears, literally google (with typos): "World largest fireworks! (48 inches shell !!)"]

pre-made graph paper (appended to this document), with ticks every 100 m on vertical axis ("distance") and every 1 second on horizontal ("time"), at least 5 boxes wide and 11 tall

Sticking Points

1. Students often get confused about the term "light years" (a unit of distance, not time!), and it's easy to mix up the x and y axes when making the distance vs. time plot in light years (LY) vs. years. Be careful to do this correctly so the students emulate you.

2. If your students have not yet worked with logarithms or powers of ten much, you may want to do a warm-up involving these skills.

3. People often reverse the concepts of age and lookback time, thinking that the oldest objects would have the largest lookback times when in fact the youngest ones do.

Warm-Up

Optional: Show a distance vs. time plot and ask students to identify the physical significance of the slope. (Answer: the slope is the velocity.)

Pre-Lesson

1. Show the video to illustrate that sound takes time to travel (30 sec). Ask the class: what other phenomena in their experience behave similarly? (answers could include: thunder & lightning, baseball bat hit & sound, clapping in large stadium, foot race starting gun powder vs. sound, band phasing)

2. Ask the class to recall the relationship between distance, velocity, and time in equation form. How could you measure the speed of sound knowing the time between when you see and hear a firework explosion and knowing how far away from you it is? [A: $v_{sound}=d/\Delta t$]

Main Lesson

3. Define light year (LY) = "the distance light travels in one year" on the board or in ppt. Point out this implies light has a finite travel time (even if very fast!). Discuss common examples of light taking time to travel (e.g. 8 minutes from Sun to Earth).

4. *Concept checks*.  (Put on board or in powerpoint; students answer individually then discuss in pairs, then go over as a class.)

a) In the original Star Wars movie, Han Solo says to Obi-Wan Kenobi, "You've never heard of the Millennium Falcon? She's the ship that made the Kessel Run in less than 12 parsecs. She's fast enough for you, old man. What's the cargo?" A parsec is a unit equal to about 3 LY. What is wrong with Han Solo's statement? [A: "parsecs" is used as if it were a unit of time.]

b) The Sun develops a new sunspot. Who notices first, Earthlings or Plutonians? Why? Why do Earthlings and astronauts on the International Space Station (in orbit 220 miles above the Earth) seem to notice at the same time? [A: Earthlings, because light takes less time to get to Earth than Pluto. However the travel time to Earth vs. the ISS is practically identical.]

c) A news story by Seth Borenstein, AP Science Writer, said "Astronomers believe they've found the oldest thing they've ever seen in the universe: It's a galaxy far, far away from a time long, long ago…a small smudge of light that European astronomers now calculate is a galaxy from 13.1 billion years ago. That's a time when the universe was very young, just shy of 600 million years old…" What is wrong with this story? [A: It's not the "oldest" thing, but the youngest.]

5. Discuss together as a class:

If a star explodes ("goes supernova") it gives off so much energy that it could destroy the Earth. The nearest star that might go supernova in our lifetimes is 150 LY away. If it explodes tomorrow, in what year will anyone on Earth see it? If you see it light up in the sky on this day next year, when did it explode? [A: Current year + 150. Second part: 149 years before today.]

6-7. *Graphing Problems to measure the speeds of sound and light.*  Teacher should point out that light is so fast that it seems to travel instantaneously over short distances, so we will start out practicing how to use a graph to measure the speed of sound, which is noticeably non-instantaneous even for short distances, then we will extend this method to the speed of light, which will require considering large distances expressed in powers of ten notation.

6. (a) [Put on board or in powerpoint; go through plotting one point together as a class on board o or in ppt; students finish individually and discuss in pairs on teacher signal; wrap up with discussion of answers.] You hear three thunderclaps, which occur 1, 2, and 3 seconds after you see their respective lightning strikes. On the graph paper provided, plot the distance to where the lightning struck as a function of the delay time between the lightning and thunder. You may use the speed of sound v_s=344 m/s. What is the slope of the line? What is its physical meaning? What kinematics equation does the graph represent?

(b) [Perform individually and discuss in pairs on teacher signal; discuss as a class.] Suppose that most people do not notice a light/sound time delay less than 0.2 seconds. If a lightning bolt strikes at the other end of a football field from you (about 100m away), will you notice the time delay?

7. (a) [Provide log-log graph paper; if necessary explain how it works, e.g. using the example of area plotted vs. side length of a square (values: side=1,10,100 and area=1, 100, 10000) to *motivate why ordinary graph paper isn't useful*. For students making a log graph for the first time, it helps to make a transparency of blank log-log graph paper and have them label the axes and make the graph with you.] Three galaxies like the Milky Way are located 10^7, 10^8, and 10^9 light years away. Plot each galaxy's distance as a function of the time since the light we see coming from the galaxy left it. Show the units on each axis. What is the slope of the line connecting the dots? What is its physical meaning? What kinematics equation does your graph represent?

(b)[Teacher give students hint to convert times when dinosaurs lived to scientific notation.] If there were dinosaurs on an Earth-like planet in each of these three galaxies living at the same time as the dinosaurs on our Earth, which galaxy are we seeing as it was in the age of the dinosaurs? Explain. Hint: dinosaurs lived on Earth from roughly 230 million years ago to 65 million years ago, when they became extinct.

Summarizer 

Ask students to confer with a partner and answer on a sheet of paper they turn in:
"How do astronomers look back in time?"

Enrichment

What does the finite speed of light mean for our ability to communicate across large distances? If we detect alien signals, are the aliens likely to be still alive? Why or why not?

Post-Lesson

None.