Mission 4
Calculating Stellar Travel Time

How Long Would It Take to Travel to the Stars

Notes

In Mission 3, *students learned how to measure the distance to a star. In science fiction, starships cross the galaxy in minutes, and so space travel to distant stars seems like reasonable option to many students.*

Overview

In Mission 4.1, students consider the enormous amount of time that it would take to travel to Sirius, the brightest naked eye star, using various modes of transportation–some practical, and some whimsical. This knowledge should lead students to question the practicality of physically traveling to another star system or attempting interstellar communication with an extraterrestrial society by sending a spaceship to them.

Mission 4.1
Materials

For Each Team

- Scissors
- Tape or glue
- “Bike-Years! (Blank Chart)” worksheet (page xx)
- “Bike-Years! (Scrambled Chart)” worksheet (page xx)

For Each Student

- “Bike-Years! (Questions)” worksheet (page xx)
- *(optional)* “Bike-Years vs. Light-Years” worksheet (page xx)
- Pencil

Getting Ready

1. Copy the worksheets: “Bike-Years! (Blank Chart)” and “Bike-Years! (Scrambled Chart)” for each team; the “Bike-Years! (Questions)” worksheet for each student; and the “Bike-Years *vs*. Light-Years” worksheet for each student, if used.

Classroom Action

1. **Discussion.** Tell students that they will be figuring out how long it would take to get to Sirius, a star in the constellation Canis Major, using six different modes of transportation, including walking and riding a bicycle.

   Sirius appears as the brightest star, except for our Sun. Sirius is a relatively close star, but its distance from Earth is still 8.6 light-years. But what is a "light-year"? *(Visible light, as well as all other types of radiation in the electromagnetic spectrum, travels at the speed of light. The distance that light travels in one year is called a light-year, which is about 5.8 trillion miles, or* 9.5 *trillion kilometers!)* So how long would it take to travel to Sirius? *(It depends upon the speed of our vehicle.)*

Teacher's Note: ***See page xx, Part II, for the calculation of the distance in km for a light-year.***

   If we were traveling on a bicycle, which is obviously impossible, how long would it take to get to Sirius? *(We could figure that out by considering "bike-years."*") So what is a bike year? *(Following the same type of logic as is used to define a light-year, it would be the distance that a bicycle rider could ride his/her bike in one year, without ever stopping to eat sleep, or anything else!)* Note that light-years and bike-years are both distance measurements, not time measurements. However, if we know the distance to our destination, we can calculate how long it would take to travel there, if we also know the speed of our vehicle.

   It might take a long time to get to Sirius on a bike, but how about on a spacecraft? *(Again, it depends upon the speed of our vehicle.)*

   Teacher's Note: *The speed of the* Voyager *spacecraft is actually variable. It left Earth with a velocity of about 97,000 km/hr; but the pull of the Sun initially slowed its velocity. We give 56,000 km/hr as an arbitrary number for comparison. As* Voyager *approached and then passed planets, the "slingshot effect" increases its velocity.*

   The *Voyager* spacecraft were equipped with phonograph records that contain pictures and sounds depicting our world. Suppose the *Voyager* spacecraft was actually headed toward Sirius. If there is an intelligent civilization living on a planet near that star, how many years would it be until *Voyager* reaches it? *(About 170,000 years.)*

2. **Activity.** Divide the class into teams of two to three students each. Hand out the worksheets "Bike-Years! (Blank Chart)" and "Bike-Years! (Scrambled Chart)" to each team. Distribute scissors, and glue or tape. Students follow the directions given on their worksheets. They should cut the scrambled data into blocks, which should then be pasted onto their blank data charts. Teams should brainstorm together. The only clue that they have to work with is their ability to rank the modes of travel from slowest to fastest.

   Optional: Have students do all the calculations on the data chart. If you choose to do the lesson in this way, do not hand out the scrambled data. Additionally, students estimate the speeds for the six modes of travel before giving them the actual accepted values.

3. **Discussion.** After students have completed the “Bike-Years! (Blank Chart)” worksheet, engage them in a class discussion about anything that they found unusual or surprising, making sure to cover the correct answers on their worksheet.

   Some students may believe that a supersonic jet travels faster than the space shuttle. Ask them to consider traveling around Earth in a jet plane. How long would it take? How long does the space shuttle take to orbit Earth once? *(In one of the world's fastest jets, the “Blackbird” [1,500 mph] about 17 hours. The space shuttle takes 1-1/2 hours.)*

   This may help them to see the difference. Ask them to also consider that the space shuttle is meant for local travel, while the *Voyager* spacecraft were designed to travel much farther and much faster! Now that they know the speeds of some very fast objects, ask students how fast light travels. Write down all reasonable responses on the whiteboard. Write down the accepted value of approximately 300,000 km/second. So what distance is a light-year? *(About 5.8 trillion miles or 9.5 trillion kilometers!)*

   Challenge students to calculate how far away Sirius is in kilometers given that Sirius is 8.6 light-years from Earth. *(Sirius is a mind-boggling 8.2 x 10^{13} km from Earth.)* Ask students to write this number without scientific notation. Is there a name for this large a number? (*82 trillion km.)* If necessary, review scientific notation with students. Considering the time and distance constraints that interstellar travel imposes, what are the possibilities of the interception of the *Voyager* probe and the message it carries by extraterrestrials?

4. **Homework.** Hand out the “Bike-Years! (Questions)” worksheet to each student. Students complete this worksheet in class or as homework. Students can complete the “Bike-Years *vs.* Light-Years” optional worksheet in class or as homework.

Going Further

Activity: A Sunny Day

Students work out how long it takes light to travel from the Sun to Earth. *(It takes sunlight 8.3 minutes to reach Earth.)* As an example to help students grasp the speed of light: in one second, a ray of light could travel around the equator seven times.

Teacher's Note: *The Sun is 93,000,000 miles or 150,000,000 km distant.*

Activity: Thunder and Lightning

Compare the speed of sound to the speed of light by discussing thunder and lightning. One can see lightning before it can be heard as thunder. This is a handy example for proving to students that light travels faster than sound. Pose math problems in which students must determine their distance from a bolt of lightning based on the amount of time that passes before they hear the thunder. *(Roughly, sound travels 1,000 feet per second through air: Light covers the same distance nearly instantly. Thus, the number of seconds between the flash and the thunder gives* *the distance in 1,000's of feet from the bolt to the observer; for example, five seconds would indicate a distance of 5,000 feet or about one mile. Three seconds would equal one kilometer.)*

Discussion: It's All Relative

Explore with your students what would happen if they wished to have a spacecraft that traveled at a speed approaching the speed of light. How much energy would it take to get a spacecraft to these incredible speeds? Could anyone afford it? According to Einstein's relativity theory, what would happen to the spacecraft as it approached the speed of light? *(As the spacecraft approaches the speed of light, the elapsed time for those on the spacecraft would approach zero; its length, as measured by someone not on the spacecraft, would approach zero; and its mass would approach infinity.)*

The Theory of Special Relativity, dealing with frames of reference for a constant relative velocity, was formulated in 1905 by Albert Einstein. This theory has implications for space travel:

1. Nothing can go faster than the speed of light.

2. It is impossible for a spacecraft to achieve the speed of light because it would take infinite energy to accelerate a spacecraft to that speed. As velocity approaches the speed of light, these two postulates require the following transformations of length, mass, and time: First convert velocity into a contraction coefficient (gamma)–$y = (1-(V^2/c^2))^{1/2}$, where c =the speed of light, and V =the speed of the object. Then, elapsed time on the spacecraft will be $T' = T_* y$, where T = elapsed time for people who aren't moving. This means that elapsed time for people in the moving spacecraft will be less than elapsed time for the people back home. They will not age as quickly. The length of the spacecraft will be $L' = L_* y$, where L = its length when it isn't moving, which means that the moving spacecraft will be shorter than it is when it isn't moving. The mass of the spacecraft will be $M' = M/y$, where M = the mass when not moving, which means that the moving spaceship will have more mass than it does when not moving. If the spacecraft is traveling at 9/10 the speed of light (or V = 0.9c), then y = 0.436.

$$\gamma = \sqrt{1-(\frac{.9C}{1C})^2} = 0.436$$

This means that for everyone hour that passes for nonmoving people back home, 0.436 hours will have passed on the spacecraft; for every meter long the spacecraft is when not moving, it will be only 0.436 meters long at this speed (as seen by someone who is not moving); and for every metric ton the spaceship weighs in the rest frame, it will weigh 2.29 metric tons when moving at this speed. However, the effects of the transformations are minimal until the velocity is quite close to the speed of light. Even astronauts on the space shuttle for a year would only age 30 billions of a second less than their relatives back on Earth!

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Bike-Years!–Teacher's Key

Table 4.1–Teacher's Key for Bike Years.

Mode of Travel, Slowest to Fastest	**Average Speed**	**Distance Covered in One Year**	**Time to Get to Sirius**
1. Walking	7 km/hr	61,320 km	1.33 billion years
2. Bike	25 km/hr	219,000 km	373 million years
3. Car	80 km/hr	700,800 km	117 million years
4. Supersonic Jet Plane	800 km/hr	7 million km	11.7 million years
5. Space Shuttle	40,000 km/hr	350 million km	233,000 years
6. *Voyage*r Spacecraft	56,000 km/hr	490 million km	170,000 years

1. Probably not, because these modes require enormous amounts of time, certainly longer than anyone's lifetime or even multiple generations. Also, obviously bikes, planes, and so on cannot travel through space.

2. Answers will vary. The civilization would have to intercept *Voyager* in space, because it would burn up if it entered the planet's atmosphere.

3. Radio, television, and microwaves in the electromagnetic spectrum. In fact, all of the radiation in the electromagnetic spectrum can carry information.

4. Send it as radio waves or television waves because it requires no mass and travels at the fastest speed possible, the speed of light.

5. The message would have been sent from Sirius 8.6 years ago because Sirius is 8.6 light-years away, and radio waves travel at the speed of light.

6. Radio signals would be strongest from stars that are the closest to us. Also, if we receive a message from a star system and we want to respond, the message would take the same number of years to travel there as it did to come here. So, for practical purposes, we are listening to star systems that are close to us.

7. The light would have left Proxima Centauri 4.3 light-years ago because light travels at the speed of light and the star is 4.3 light-years away.

8. Anyone traveling to Pandora would be dead long before their starship could get to even the nearest stars if they are traveling at speeds we know are attainable with present day or even foreseeable technology!

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Bike-Years vs. Light-Years–Teacher's Key

Part I.

Figure out how far a bicycle can travel in one year, assuming a rate of speed of 25 km per hour, with the rider never stopping to eat, drink, or sleep. This computed distance will equal 1 bike-year, or the distance that a bicycle can travel in one year.

Remember, distance traveled = speed x time traveled.

> The bicycle travels at a speed = 25 km per hour
>
> 25 km per hour x *24 hours per day* = 600 km per day
>
> 600 km per day x *365 days per year* = 2.19×10^5 km per year

This is the distance a bike goes in one year, or this is a distance of one bike-year.

Part II.

Figure out how far light can travel in one year.

This computed distance is considered 1 light-year; the distance that light can travel in one year.

Remember, distance traveled = speed x time traveled.

Light travels at a speed of 300,000 km per second. To convert a light year into kilometers, convert its speed in *km per second* = *km per year* as shown below:

> 300,000 km per second x *60 seconds per minute* = 1.80×10^7 km per minute
>
> $1.80 \text{ X } 10^7$ km per minute x *60 minutes per hour* = 1.08×10^9 km per hour
>
> 1.08×10^9 km per hour x *24 hours per day* = 2.59×10^{10} km per day
>
> 2.59×10^{10} km per day x *365 days per year* = 9.46×10^{12} km per year

This is the distance light travels in one year. This is one light year: 9.46×10^{12} km per year.

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