What Do You Think?

Einstein’s Theory of Special Relativity predicts that time goes more slowly for objects moving close to the speed of light than for you. If you could travel close to the speed of light, you would age more slowly than if you remained on Earth. This prediction doesn’t fit our “common sense.”

- **Does this prediction make sense to you?**
  Explain your thinking.
- **What do you mean by “common sense”?**

Record your ideas about these questions in your *Active Physics* log. Be prepared to discuss your responses with your small group and the class.
For You To Do

1. A muon is a small particle similar to an electron. Muons pour down on you all the time at a constant rate. If 500 muons arrive at a muon detector in one second, then 500 muons will arrive during the next second.

Muons have a half-life of 2 microseconds. (A microsecond is 1 millionth of a second, or $1 \times 10^{-6}$ s.) Beginning with 500 muons, after 2 microseconds there will be about 250 muons left. (That is 1 half-life.) After 4 microseconds (2 half-lives) there will be about 125 muons left. After 6 microseconds (3 half-lives) there will be about 62 muons left.

a) How many muons would be left after 4 half-lives?

2. The half-life of muons provides you with a muon clock. Plot a graph of the number of muons versus time. Use 500 muons as the size of the sample. This graph will become your clock.

a) If 125 muons remain, how much time has elapsed?

b) If 31 muons remain, how much time has elapsed?

c) If 300 muons remain, how much time has elapsed?

d) If 400 muons remain, how much time has elapsed?

3. Measurements show that 500 muons fall on the top of Mt. Washington, altitude 2000 m. Muons travel at 99% the speed of light or $0.99 \times 3.0 \times 10^8$ m/s.

a) Calculate the time in microseconds it would take muons to travel from the top of Mt. Washington to its base.

b) Use your calculation and the muon clock graph to find how many muons should reach the bottom of Mt. Washington.

4. Experiments show that the actual number of muons that reach the base of Mt. Washington is 400.

a) According to your muon clock graph, how much time has elapsed if 400 muons reach the base of Mt. Washington?

b) By what factor do the times you found differ?

c) Suggest an explanation for this difference.
Albert Einstein had an answer. The muon’s time is different than your time because muons travel at about the speed of light. He found that the time for the muon’s trip (at their speed) should be 0.8 microseconds. That is the time that the muon’s radioactive clock predicts.

d) As strange as that explanation may sound, it accurately predicts what happens. Work with your group to come up with another plausible explanation.
Physics and Pseudoscience

Physics, like all branches of science, is a game played by rather strict rules. There are certain criteria that a theory must meet if it is to be accepted as good science. First, the predictions of a scientific theory must agree with all valid observations of the world. The word valid is key. A valid observation can be repeated by other observers using a variety of experimental techniques. The observation is not biased, and is not the result of a statistical mistake.

Second, a new theory must account for the consequences of old, well-established theories. A replacement for the Theory of Special Relativity must reproduce the results of special relativity that have already been solidly established by experiments.

Third, a new theory must advance the understanding of the world around us. It must tie separate observations together and predict new phenomena to be observed. Without making detailed, testable predictions, a theory has little value in science.

Finally, a scientific theory must be as simple and as general as possible. A theory that explains only one or two observations made under very limited conditions has little value in science. Such a theory is not generally taken very seriously.

The Theory of Special Relativity meets all the criteria of good science. When the relative speeds of objects and observers are very small compared to the speed of light, time dilation, space contraction, and mass changes disappear. You are left with the well-established predictions of Newton’s Laws of Motion. On the other hand, all the observations predicted by the Theory of Special Relativity have been seen repeatedly in many laboratories.

By contrast, psychic researchers do not have a theory for psychic phenomena. The psychic phenomena themselves cannot be reliably reproduced. Psychic researchers are unable to make predictions of new observations. Thus, physicists do not consider psychic phenomena as a part of science.

Reflecting on the Activity and the Challenge

One of the strangest predictions of special relativity is that time is different for different observers. Physicists tell a story about twins saying good-bye as one sets off on a journey to another star system. When she returns, her brother (who stayed on Earth) had aged 30 years but she had aged only 2 years. Commonsense physicists trust this far-fetched idea because there is experimental evidence that supports it. The muon experiment supports the idea. There is no better explanation for the events in the muon experiment than the Theory of Special Relativity. The theory is simple but it seems to go against common sense. But common sense is not the final test of a theory. Experimental evidence is the final test.
One of the criteria for funding research is whether the experiment can prove the theory false. If muons had the same lifetime when at rest and when moving at high speed, the Theory of Special Relativity would be shown to be wrong. Many theories of pseudoscience cannot be proven false. According to pseudoscientific theories, any experimental evidence is okay. There is no way to disprove the theory. Any evidence that doesn’t fit causes the “pseudoscientists” to adjust the theory a bit or explain it a bit differently so that the evidence “fits” the theory.

The proposal you will fund should be both supportable and able to be disproved. The experimental evidence will then settle the matter—either supporting the theory or showing it to be wrong.
Physics To Go

1. Use the half-life of muons to plot a graph of the number of muons vs. time for a sample of 1000 muons.
   a) If 1000 muons remain, how much time has elapsed?
   b) If 250 muons remain, how much time has elapsed?
   c) How many muons are left after 6 half-lives?
   d) How many muons are left after 8 half-lives?

2. If the speed of light were 20 mph . . .

You don't experience time dilation or length contraction in everyday life. Those effects occur only when objects travel at speeds near the speed of light relative to people observing them. Imagine that the speed of light is about 20 mph. That means that observers moving near 20 mph would see the effects of time dilation and space contraction for objects traveling near 20 mph. Nothing could travel faster than 20 mph. As objects approach this speed, they would become increasingly harder to accelerate.

Write a description of an ordinary day in this imaginary world. Include things you typically do in a school day. Use your imagination and have fun with the relativistic effects.