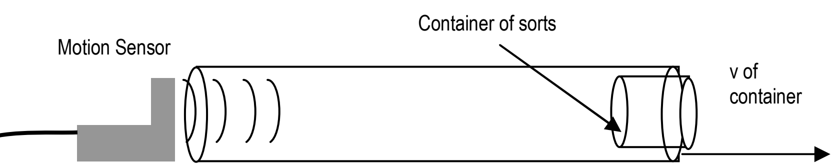
The Demonstration Corner

When is The End Not The End?

Column Editor:
Ernie McFarland
University of Guelph, Physics Dept.
elm@physics.uoguelph.ca

Diana Hall
Bell High School, Ottawa
Diana.Hall@ocdsb.ca

Here's a really easy way to show students that the pressure at the end of an open-air column doesn't change exactly at the physical end of the tube. It requires a motion sensor, a tube, and the right-sized insert for the tube. I happen to have a plexiglass tube into which a tub of play-doh fits just nicely. First set up the following…



Now, while collecting position vs. time data, slowly draw the play-doh container out of the tube. When you get to the physical end of the tube, stop and hold a few seconds. Now slowly continue to draw the container out further.

What you should see is that the sound waves from the motion sensor reflect off the container as it is drawn out. Once the container passes the physical end of the tube, the waves continue to reflect off the container until it is a few millimetres past the end. Then the sound waves will stop "seeing" the container as they notice the change in air pressure outside the tube and now reflect off the open end.

What's the point? On the d-t graph you will see that the place where the sound waves reflect off the open end is beyond the physical end of the tube. Not by much mind, but nevertheless beyond. (See Fig. 1)

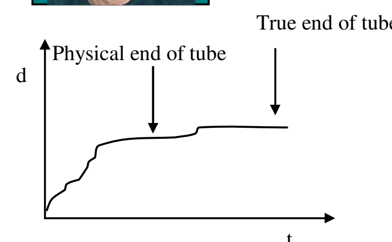
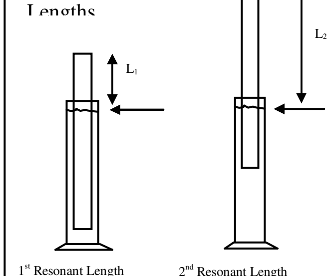


Fig. 1 Sketch of Data

Who Cares? When conducting a lab to determine the speed of sound using a tuning fork of known frequency and an air column open at one end, you will get better results by finding two resonant lengths and subtracting them to find $\lambda/2$ (where λ is the wavelength), instead of using the first resonance length (for example) to give $\lambda/4$. Each of the two resonant lengths measured will have the same error at the open end, and subtracting the lengths to give $\Delta L = \lambda/2$ also subtracts the open-end error. Fig. 2 shows two resonant lengths L_2 and L_1 measured from the top of water in the bottom container.

Student results for the speed of sound found by subtracting resonant lengths are typically within a few percent of the correct value, whereas results using a single resonant length can deviate by 10% or more from the correct value.

Fig. 2 Resonant Lengths



Column Editor: Ernie McFarland, Physics Department, University of Guelph, Guelph, Ontario, N1G 2W1
Email: elm@physics.uoguelph.ca
Submissions describing demonstrations will be gladly received by the column editor.

Modern Physics

Spacetime Diagrams: Seeing Special Relativity

Roberta Tevlin
(Danforth C.T.I.,
Perimeter Institute
Development
Teacher)
roberta@tevlin.ca

In the past I have found relativity really frustrating to teach because it consisted almost entirely of me explaining stuff to the students with very little for the students to do for themselves. A few years back I was introduced to using Minkowski spacetime diagrams. These diagrams allow you to visualize what's happening in different frames of reference and they can let the students explore simultaneity, the Doppler shift, the twin paradox and many other topics. To give you a brief taste of what can be done with spacetime diagram, we will look at relativistic velocities.

A spacetime diagram shows time and only one dimension of space. To distinguish it from a position-time graph, the time axis is vertical not horizontal. In order to show very fast speeds, the scales of the axes are in years and light-years.

Figure 1 shows the x and t axes for the Earth, a beam of light and the t' axis for a rocket moving at ½ c relative to the Earth. Notice how the choice of scale puts a light beam halfway between the two axes and how the rocket's slope is greater than that of the light because the time axis is vertical.

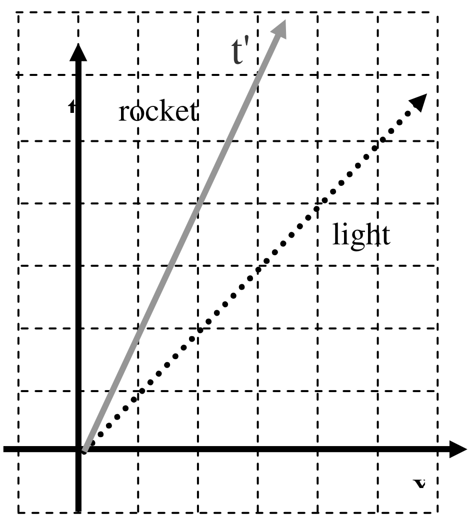


Figure 1

The speed of light is c in the Earth's frame but it must also be c in the rocket's frame. This won't be true if the two frames have the same x-axis. You can see this in figure 2, where the distance and time intervals are no longer the same.

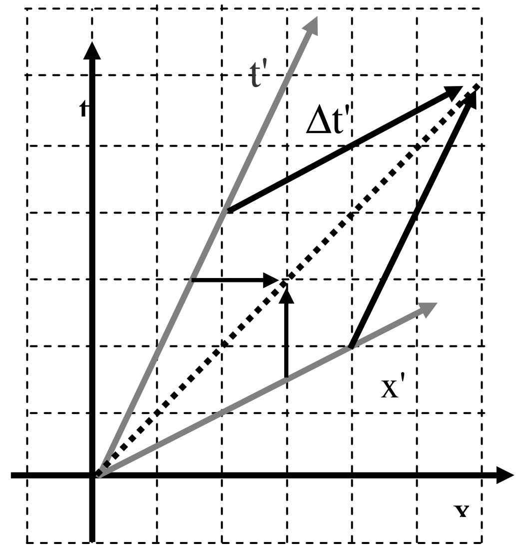


Figure 2

A constant speed, c, means that space and time must be connected together and they must be different in frames moving relative to each other. As Hermann Minkowski said in a lecture in 1908 " Henceforth space on its own and time on its own will decline into mere shadows, and only a kind of union between the two will preserve its independence…"

The x' axis must be placed symmetrically relative to the light ray as shown in figure 3

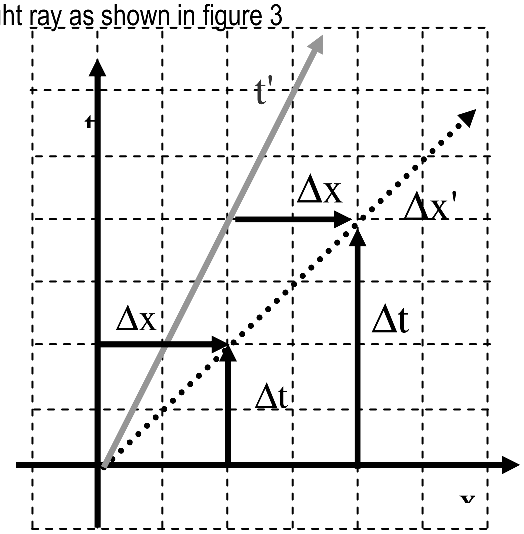


Figure 3

Notice how the space and time intervals are now symmetric, whether they are measured in the Earth's frame or the rocket's frame.

Now that we have a diagram for both frames, we can determine what happens when we add velocities. Suppose that the rocket launches a space pod at ½ c relative to itself. How fast will the Earth see it moving?

It can't be v = ½ c + ½ c = c, can it?

The pod will travel two units of space in four units of time in the rocket's frame as shown in figure 4. Therefore, the pod follows the dashed line.

How fast is the pod moving relative to the Earth? This can be determined by using intervals in the Earth's frame. The dashed line shows that in 5 years it has gone 4 light-years. This means that it is travelling at 4/5 c, which is faster than ½ c but not c.

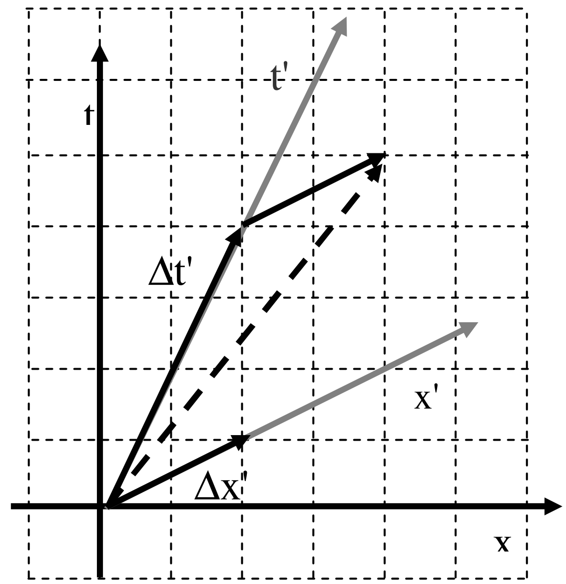
This value can be checked against the equation for adding velocities in relativity

$$\begin{aligned} v &= (v_1 + v_2)/(1 + v_1 v_2/c^2) \\ &= (\tfrac{1}{2} + \tfrac{1}{2})c/(1 + \tfrac{1}{4}) \\ &= 4/5\ c \end{aligned}$$

The website at www.cco.caltech.edu/~phys1/java/phys1/Einstein/Einstein.html animates the addition of velocities for a tossed textbook and car headlights from the car's frame and the road's frame. As well as animating the motion, it also provides the related spacetime diagrams. Dave Harrison has great animations for relativity and some diagrams at http://www.upscale.utoronto.ca/GeneralInterest/Harrison/Flash/#relativity . I have posted a set of exercises at http://roberta.tevlin.ca. For a more thorough treatment, I strongly recommend that you get "Very Special Relativity: An Illustrated Guide" by Sander Bais or Thomas Moore's "A Traveller's Guide to Spacetime". Please contact me if you have any suggestions or questions at roberta@tevlin.ca.

PERIMETER PI INSTITUTE FOR THEORETICAL PHYSICS

The Perimeter Institute has produced a wonderful DVD entitled The Mystery of Dark Matter. To obtain a free copy along with worksheets and background information go to www.perimeterinstitute.ca and select perimeter explorations



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High School Physics

How to Create Simulations for Physics Using The Geometer's Sketchpad® (GSP)

Rolly Meisel
rollym@vaxxine.com

The Geometer's Sketchpad® (GSP) is a powerful dynamic geometry software package that is licensed for use in Ontario public schools, including student and teacher home use. It can be applied to many purposes, including the creation of dynamic simulations of some of the concepts on the Ontario physics curriculum.

A tutorial for creating a GSP sketch that simulates the superposition of two pulses travelling in a spring in opposite directions has been posted on the OAPT web site at www.oapt.org, in Word and PDF format. The final sketch has also been posted. Note: you must have GSP installed on your computer in order to use the sketch. The site administrator at your school can provide you with a copy of the educational version of GSP.

You can apply the skills that you learn by working through the tutorial to the creation of other simulations.

Many GSP sketches have already been created for simulations in physics. You can find them by performing a search using the keywords "sketchpad" and "physics". Add other keywords if you are looking for something specific.

Some starter sites are:

www.dynamicgeometry.com/general_resources/advanced_sketch_gallery/index.php
www.teacherlink.org/content/math/relatedlinks/sketchpad.html
mathgateway.maa.org/do/SearchForm?search=sketchpad

Students can use GSP to create simulations as possible projects. The learning curve is short and not very steep. Furthermore, many students will already have experience with GSP from mathematics classes. GSP sketches can be used like Java applets, but are much easier to create. Simple GSP sketches can be converted to Java applets using the Java Sketchpad feature included with GSP.

Although GSP is not as powerful, from a physics point of view, as dedicated software such as Interactive Physics®, it is freely available to Ontario teachers and students, whereas IP requires expensive site licences.

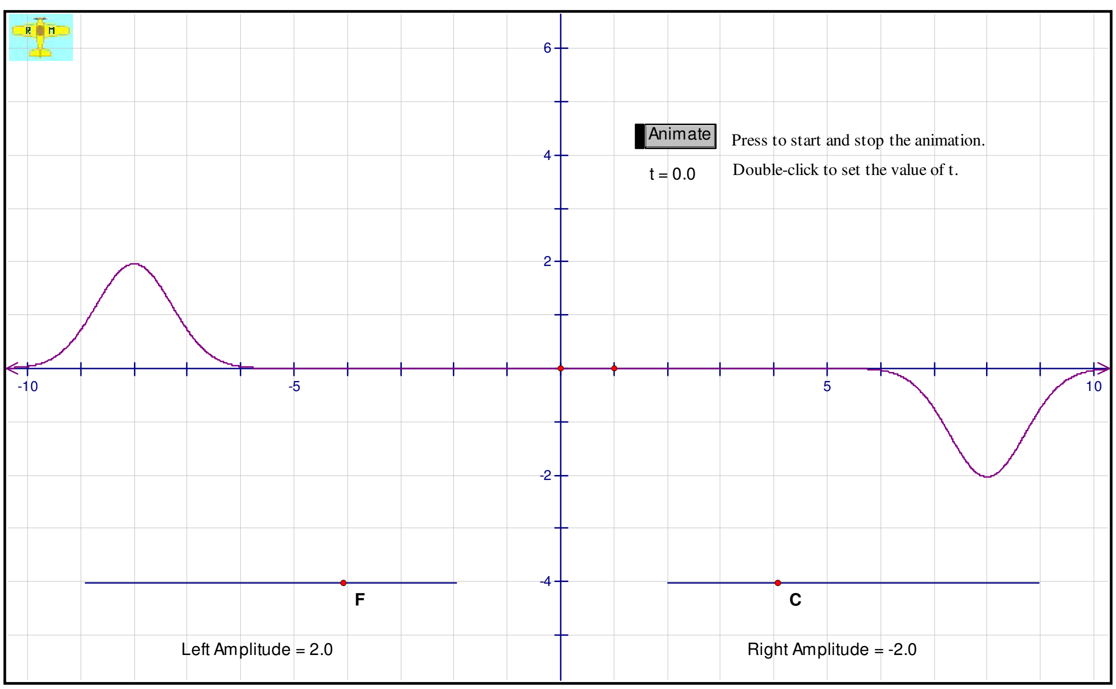

Figure 1: Screen Shot of the Superposition Sketch