COMPILATION: Unit 5: modified Atwood lab.

Date: Wed, 15 Oct 1997
From: Jeff Hengesbach <JHengesbach@webb.org>
Subject: possible pitfalls with Atwood's lab

Earlier this week as I prepared to send my students on their merry way to gather data for the Modified Atwood's Machine lab, I experienced an epiphany of sorts. I shared my concerns with Don Yost, and later Larry and I thought many on the listserve would appreciate the same discussion we have since had at length. THIS is the question that started it all... which is not, by the way, even close to the same level of precariousness as asking Dr. Hestenes, "How would you define a Force?" I've blundered into that one before. So don't worry.

Don,

I started the force (Atwood's Machine) lab yesterday, but I have a bit of a problem. I purchased force sensors and was planning to use them in conjunction with this lab. There seems to me to be a challenge with this though. My students identified their system to be just the dynamics cart. The system schema proved especially helpful at this juncture by the way. Thus, the force probe becomes crucial in calculating the force acting on the system in the force vs. acceleration tests. Of course in this test the mass of the system (cart) is kept constant. No problem. But in the test of mass of system vs. acceleration, there seems to me to be a problem. Doesn't the force of tension on the string change as we change the mass of the cart? If so, aren't we changing two variables together when we are testing the acceleration of the system? After all, the Fg of the hanging mass doesn't change during this test; we keep it constant. BUT the force of tension in the string must be changing as the hanging mass accelerates at a different rate (sum of the forces being different), and thus, if my math is correct, aren't there two variables that are changing in the system? If this is the case, what is the point in having the force probe?

Should we just identify the system as the entire apparatus which is accelerating?

Date: Wed, 15 Oct 1997
From: Rich McNamara < richmcn@EARTHLINK.NET >

Jeff is dead right. There are two variables if we change the mass of the cart, force probe assembly. Force probes don't help here. The advantage of force probes is as Jeff indicated in the force vs acceleration lab. One thing in that lab that can be asked about is the force probe reading just before and just after the cart is released. There should be a small but perceptible difference between the two.

> Should we just identify the system as the entire apparatus which is
> accelerating?

The option here is to do just one lab instead of two. Because of the precision of the force sensor data, the slope of the acceleration vs. force graph is much closer to (mass of cart)^-1 than with traditional calculations. If the results are good enough, you may be able to get away with a single lab instead of two.

Date: Wed, 15 Oct 1997
From: Art Woodruff <woodruff_a@POPMAIL.FIRN.EDU>

>Jeff is dead right. There are two variables if we change the mass of the cart, force probe assembly. Force probes don't help here.

I get around this by only doing the varying force lab. But, I have each lab group use a different constant mass. Then, rather than using the combined proportionalities, one of the students usually notices that the slope always equals the mass before I bring it up.

I think this is easier than redefining the system, and the direct measurement of force with the probe makes more sense to my students than calculating force from the hanging mass.

Date: Thu, 16 Oct 1997
From: Rich McNamara < richmcn@EARTHLINK.NET >

Art Woodruff wrote:
> I get around this by only doing the varying force lab. But, I have each lab group use a different constant mass.

This is the first step in using a process called meta-analyis. For experiments where you wish you could test two independent variables, but don't have the time, meta-analysis allows this.

In designing the experiment, when the students select what must be constant, the teacher may assign the values for the constant. In the case of the Newton's 2nd Law lab, you can choose to make the applied force the independent variable and acceleration the dependent variable.

The students will have agreed that the mass must be kept constant to obtain meaningful results, but the teacher can assign each group a different mass. Each group will maintain a constant mass for their trials. After analyzing their data and drawing conclusions from their results, the teacher then has them collect data from each group. In this case the teacher would look at the mass from each group and compare it to the slope of each group's acceleration vs force graph. Students can then go back and analyze this data to draw conclusions from a larger data base.

Another example of meta-analysis would be in the pendulum lab, with the independent variable of string length and the dependent variable of time to complete a swing; one of the constants would be the mass of the pendulum bob. Each group could then be assigned a different mass for their bob. After finding the relationship between length and period, each group can be asked to use the results from other groups to look at mass versus period for a constant length using the data on length collected by another group.

Date: Thu, 16 Oct 1997
From: Larry Dukerich <dukerich@ASU.EDU>

Jeff brought up a concern about having two variables changing simultaneously when using the force probe during the a vs m experiment.

Rich and Art both suggested that one could get by with only the a vs F lab. Careful examination of the slope should reveal that it is very close to mass^-1. Two things occurred to me when I read these posts:

1. In the pre-lab discussion, didn't TWO independent variables naturally arise? How do you steer the kids into examining only one?

2. Rex Rice had noted in another lab that the slope is usually some function of variable(s) that are held constant. I think having a second chance to observe this is worth the extra hassle of doing both labs.

Date: Thu, 16 Oct 1997
From: Joseph Vanderway <jvanderway@EMAIL.CSUN.EDU>

I don't use the force probes. I lead the students to define the system as both the cart and the hanging mass (and the "massless" string). Acceleration is measured with motion sensors. A force is defined as an "interaction between two objects that results in some kind of push or pull." (This definition helps a whole lot when dealing with Newton's Third Law!) I think having two independent variables (finding that a is proportional to F and a is inversely proportional to m) and leading students through a method of constructing a model that combines both relationships is a fundamental step in modeling.

I have students calculate what the constant of proportionality must be for an "F = k m a" equation based on comparing the value of their slope and the value of their parameter. The class results always cluster pretty much around 1 and the students have no trouble recognizing that the constant is 1. I use this "compare the slope to the measured parameters" in nearly all subsequent labs (UCM, "Energy without Work", etc.) It even has an interesting twist when applied to power in electric circuits..

Joseph added,
Re: the post-lab in the constant acceleration lab

I do a "double bump" post-lab. The first objective is to determine a relationship between the position and time for the ball rolling down the incline plane. Students prepare and present WB on this relationship (x = k t^2 + 0m) with appropriate graphs. They are often tempted to call their slope the "rate at which the velocity is changing". I caution them against this and have a "mini post-lab."

In the mini post-lab, I define instantaneous velocity as the slope of the tangent line on the x vs t graph (going through a diminishing delta x, delta t kind of deal, with the two points getting closer and closer until they are indistinguishable... my calculus students often recognize this as the definition of the derivative, but I usually reply "so what?"). Anyway, armed with this definition, I have them go back and find the slope of at least 6 different tangents to their graph of x vs. t and plot a graph of v vs. t. (I explain that they must do at least one by hand and then show them how most of their calculators have "tangent slope finders".)

Students then WB their results for v vs. t and often recognize that the slope of the x vs t^2 graph is half of this new slope and we are off and running. The lab write-up then deals with both x vs. t and v vs. t. A final post-lab defines acceleration and derives the big four kinematic equations. I draw a generalized v vs. t graph where delta x is the area of a trapezoid and find this area both by using a 1/2*(b1+b2)*h formula and by dividing the area into a rectangle and triangle. Two of the kinematic equations fall out this way (the first comes directly from the v vs. t graph, and the fourth is a substitution). In the end, I appease the calculus students...

[Here s another post on Newton s 2nd law lab.]

Date: Thu, 17 Dec 1998
From: "Douglas A. Johnson" <djohnson44@ameritech.net>
Fran Poodry wrote:
I'm in real trouble right now because one of my classes found acceleration proportional to the square of force in the Newton's second law lab! eek!

Here are a couple of things you might try:
1) Use as much mass as makes sense. We had much better results this year than last (using Pasco carts and tracks and a sonic ranger) by keeping a brick (approx. 1.9 kg) on the cart. The accelerating force was on slotted "weights" hanging on a string over a pulley. We used a 100g, two 50g and two 20g masses for this. The slopes (= 1/mass) were predicting total masses within 10 grams of actual! We think the brick made the difference for us. Even if you are using stopwatches, making the time as large as possible ought to reduce the percent error in starting and stopping the stopwatches.

2) If you have no probes at all, don't try to eliminate friction. In my previous life I had the students pull a paper box loaded with a couple of textbooks using a spring scale. (It is easier, I think, to maintain a constant force if the acceleration is small and the force is big.) It wasn't real great, but it did give a straight enough line, and the x-intercept was large enough that even the kids saw that the "force" on the graph was the "applied force" and the force of friction was hidden in the negative y-intercept. I think that helped them see why the law is about the _net_ force.
