COMPILATION: Units 3 and 5 - curve-fitting with the inclined plane lab & modified Atwood machine lab
(Note: this compilation follows the 1997 compilation about unit 5.)

Date: Tue, 21 Oct 1997
From: a new modeler
Subject: Unit III, Ball on Ramp

We just got done whiteboarding the paradigm lab for Unit III. I didn't have enough photogates so I had some groups use stopwatches and very small angles. It was frustrating to see that a fair number of groups found x~ t rather than x ~ t^2. Interestingly enough, results didn't seem to be correlated to whether or not photogates were used.

Date: Wed, 22 Oct 1997
From: V B JONES <VBJONES@AOL.COM>

Having had difficulty in other years with students being able to release a ball from rest, and also having fewer than 2 photogates per lab group, I decided to start the timer (ULI or even the old IIe photogate system) in the time between gates mode; I used a stereo phone plug and attached two alligator clips to the ends of red and black. Using a steel ball on an aluminum ramp the ball, by attaching one clip to the track, is used to complete the circuit. The second clip holds the ball in place at the appropriate position. When the circuit is complete the program interprets this as an unbroken light beam. When released the timer starts and then stops when the ball passes through the one photogate at the bottom of the track. This assures a starting velocity of zero. The only problem is that the timer automatically restarts after the ball passes through the second gate. After the ball is in place for the next trial, swipe your hand through the photogate to stop the timer and you are ready for the next trial. Ignore this large time (I tell students this is the time it took them between trials and is usually around 10 to 20 sec. By graphing x vs t we got excellent results. If you have any old broken photogates you can use the phone plug and wire from them instead of buying new parts.

Fall 1999 posts that resulted from posting the compilation above & the compilation on Unit 5:

Date: Mon, 11 Oct 1999
From: John Barrere <forcejb@YAHOO.COM>
Subject: ball on ramp lab

I too have had several groups find that the position vs time graph is quite linear. I instructed ALL groups to do a regression on the original data and then to linearize the data by whichever method looked to be the most sensible. Both graphs gave good linear fits (COR nearly = 1) but we talked about choosing the best representation of the data based upon both a "good" COR and a sensible intercept. The regression based on the time-squared data always gave an intercept much closer to zero and the kiddos had no trouble figuring out that zero was the true target value. The regression on the original data usually produced intercepts whose absolute value was >30% of the maximum position. This also helped a bit to dispel the lingering notion of some that data with a straight
line thru it is "linearized".

Date: Mon, 11 Oct 1999
From: Art Woodruff <woodruff_a@POPMAIL.FIRN.EDU>

>I instructed ALL groups to do a regression on the original data and then to linearize the data by
> whichever method looked to be the most sensible.

I finally gave in and had the students do automatic curve fitting. We used video analysis for the lab instead of using photogates. Each group got about 25 points of good data, nice smooth curves, but nearly impossible to get initial velocity = 0. Even though they had the equation, the students still could not identify the meaning of each of the terms. They were sure initial position was one of them, but other than saying the units of the others were the same as velocity and acceleration, they could not say for sure if that is what they were. When a student said one of the terms was velocity, either a student or I would ask "which velocity? Average, initial, final, ???

So we went on with the tangents as usual to get the velocity graphs. From the v vs t graph they could easily go back and identify what the terms in the quadratic were. We then derived the equation from area and slope of the v vs t graph to confirm.

With my best classes, we did discuss the linearization and why that did not work well.

Date: Mon, 11 Oct 1999
From: "Douglas A. Johnson" <djohnson44@ameritech.net>

There has been some discussion about students finding that X vs. t is linear for the constant acceleration lab.

We've had quite good results using steel balls and Pasco carts. We keep the angles at which the ramps are tilted small, which makes small errors in timing and in "letting go" less significant. Some students use stop watches and others use photogates with no discernible difference in the results.

We also keep an eye on the groups to make sure they get some data for small displacements (10 cm or less) and for displacements which use the maximum available length of track.

In the pre-lab we get the students to predict that the graph for this lab must be a curve since the graph of the constant velocity lab was a straight line. They usually are anxious to repeat the lab if their data doesn't fit a curve.

And maybe we've been lucky!

Date: Mon, 11 Oct 1999
From: Geraldine Fouts <gfouts@PIXI.COM>

I tell you guys, and gals, Rex Rice's disk on the long dowel rods gives great data! I demo the setup after they have decided which variables they need to measure in order to detect a change in velocity. The disk rolls down the 1.5 m ramp and offers all kinds of opportunities to get good data. I found linear data when they clustered their points within a 50 cm range, and they found linear data if the rods were held too close together and friction from the disk rubbing the sides of the rods occurred. But actually both of these points were discussed in pre-lab, and it was only those who were not taking notes who had the problems. Otherwise, the graphs were really great.

Oh, the little golf tees have a tendency to come off by the time they have been used 20 or 30 times, so I keep the old glue gun out and they get to check their equipment beforehand and make any repairs they see fit. They decide how to collect the data, and they try all kinds of ways. And each way produced a nice curve which flattened to a nice line with t^2 .

Date: Tue, 12 Oct 1999
From: Gregg Swackhamer<pswackhamer@GLENBROOK.K12.IL.US>
Subject: Curve Fitting? Not for me anymore.

I have played around with several ways to develop the kinematic relationships for uniformly accelerated particles, and I think that I will rule out some things I have tried.

First, I use MacMotion with Pasco carts. This has the advantage of giving a clear curve for the portion of data that is relevant. That is nice. No more wondering about whether to use a linear fit or not. But what to do about the equation of the curve? I have let them do curve fitting, and I do not think that it is very profitable option. Too many curves can fit, and I have not found a simple way to guide them to using a second order polynomial. Therefore, I will not try to fit this curve anymore.

The v-t graph is straight, and we can fit it fine and interpret it, as you all know. The area under this portion of the graph can then be identified to be the change in position on the basis of our first lab and by comparing with x-t data. I will lead them to the generic expression for this area in post-lab discussion, I think, using the area of a rectangle plus the area of the triangle. This will be the way to get the expression for the position of an object undergoing constant acceleration as opposed to the curve fitting of the x-t graph. Other than introducing definitions, there seems to be no difficulty about why and how to do it this way.

The data from the same run also contain v and x. Selecting and exporting these data to Graphical Analysis allows the linearization of v vs x. But, as you may well know, there are still some problems here. We want to graph v vs change in x, not against x. So, I do this as a post-lab extension so as not to overload the lab report. I pose the question "How does v depend on how far the cart travels from its initial position?" This sets up the desired variables, v and change in x, as the focal points. Some discussion follows about how to get the desired data into Graphical Analysis, and then we just linearize the v vs delta x curve.

There are still problems with this, but this is the smoothest that I have been able to contrive so far. In my opinion, there is some work that needs to be done to optimize this stuff. I think it could be done more efficiently.

Date: Wed, 13 Oct 1999
From: Joseph Vanderway <jvanderway@CSUN.EDU>
Subject: Re: Curve Fitting? Not for me anymore.

Here's what I do for constant a, and I really like it:

Pre-lab: establish that the const. V model breaks down with a ball rolling down an incline plane (as an example of an object with a changing v).

Lab: Students collect data on x vs. t for the ball on the I. P. in the analysis of the data, they linearize the x vs. t graph to x vs. t^2 and find the slope and get an equation for the curve.

"Mini" Post Lab: I establish through discussion that the slope of the tangent to this curve will be instantaneous v. (We argue away the intercept as a systematic error that occurs because the ball rolls a bit before reaching the first gate.)

Secondary analysis: Students take six different time values on their carefully graphed x vs t graph and find the slope of six different tangent lines. (The TI calculators will do this nicely - I have one done by hand, and the rest use the "slope finder" in the calc.) They then graph v vs. t and get a straight line with a slope twice that of their x vs t eq.

Post Lab: I generate stacks of graphs and relate slopes and areas... One great move is to generate the kinematic eqs. from the graphs alone (at least three of them): One comes from the line of the v vs t graph, and two more come from delta x = area under the graph. Take the area (have an intercept!) as a rectangle + triangle, and then again as a trapezoid. The fourth eq comes from solving the first for time and substituting into the third.

I've really liked the results with this approach. It avoids graphing v vs delta x and keeps all the graphs in a "something" vs t form ready for easy stacking.

Date: Fri, 15 Oct 1999
From: Mark Barner <markbarner1@cox.net>
Subject: Graphing Analysis with I.P. and Mod Atwood

There has been a lot of discussion about curve fitting and identifying the system to analyze motion. We have had good success with both the inclined plane lab and the modified Atwood lab.

For the I.P lab each group considered a different component of motion to investigate. One group did the traditional modeling lab with a near rest start. Another group let the ball already be in motion when it crossed the first gate thus always starting from the same position behind the gate (sort of a negative X of 0). Other groups investigated final velocity vs time (both from rest and a starting velocity) and still others investigated final velocity vs change in position (delta X) again from rest and a starting velocity. If there were intercepts they were allowed to use automatic or manual curve fitting and since they had ranges that had almost a 500% change in the dependent variable there were good fits. They were already proficient in graphical analysis from Unit 1 and they did not try anything wield like log and exp fits. They were surprised at how closely the intercepts matched their parameters (initial position and velocity). We used the same apparatus as shown in modeling training except we used either the CBL or Sensor-Net to get the time and velocity of the ball as it passed each gate. The presentations were great and I continued the analysis by showing how their results related to each other. We essentially derived all the kinematics empirically and then derived them.

For the modified Atwood machine we are doing essentially the same thing as others discussed. I agree that you have to carefully define your system to determine relevant forces and masses to measure. I had one group that insisted that only the cart should be considered. We had tried pulling the cart with force probes before but the students have a hard time maintaining a near-constant force. For this group I set up a full Atwood machine and they used photogates to measure velocity and timing. The results were not nearly as close as using a cart, and there are other considerations such as using the mean times between passes, etc. Still it is one way to deal with this difficulty and I am sure with careful measurements they would do better.

We used the Sensor-Net program to calculate the accelerations automatically (I believe it uses mid-times) and we investigated acceleration vs mass, force and delta x. The results were impressive and the students again see that acceleration is not velocity. They also found that a zero slope linear fit is sometimes appropriate as in a vs delta x.

Curve fitting can be done carefully if the students take the time to examine units and interpret the physical meaning and reasonableness of the equations. My students are in AP classes but I have gotten good results also in regular physics. Just be careful in helping them define the system.

UPDATES, in fall 2002.
I asked teachers above if they still use the same procedure.

Date: Tue, 22 Oct 2002
From: Joseph Vanderway <hrggh003@csun.edu>
Hello Jane-
Yes, I still use the same procedure. I would add this:
I use photogates (yes, this makes time the "dependent" variable, but I still graph it on the horizontal axis by convention).
I have students use a position of 10 cm or less as their smallest data point and a largest position of greater than 1.00 m for the largest. This just about assures that they will be able to see the curve in the x vs. t graph.
I like how this works.

Date: Mon, 21 Oct 2002
From: gheri fouts <gfouts@pixi.com>

Hi Jane,
The best data my students ever got was with Rex's wooden disk with golf tees glued on. I am now at Maryknoll High School and I used the metal ramp and steel ball last year and this year, and it does not work as well. About half of them get a linear relationship between x and t. Once I have convinced them it is a curve, I put them up to the computers and Graphical Analysis and I give them data as an extended exercise. They graph that, see the curve, linearize it, find the tangents for the points that give tangents, graph the tangents knowing they are instantaneous velocities, and voila! they get a straight line with a slope that is usable. They also recognize that the slope here is twice the value of the slope of the x-t^2 line which makes the other kinematics equations easy to explain.
Next time I do this, I am going back to the disk and golf tees and make a hard nose comparison again.

Date: Tue, 22 Oct 2002
From: John Barrer <forcejb@yahoo.com>
Jane - Yes, I still do this. I think it's worthwhile to keep beating on the students that they shouldn't rely on the appearance of the graph. The y-intercept has real physical significance and I want them (as much as possible) to think physically.