UNIT 3 compilation: INCLINED RAIL LAB 1997

Date: Mon, 29 Sep 1997
From: Don Yost <DoYost@AOL.COM>
Subject: Instantaneous Velocity

A great source of data for the acceleration lab is available using a cart and smart pulley. There are enough data points to provide a smooth curve of X vs T. Students can then draw tangents and from that data, plot V vs T. To show instantaneous velocity, plot any curve on Graphical Analysis, then using the magnifying glass, outline a small square around a point on the curve and expand it. You can do that twice, and you get a straight line, showing that for very small delta T, average and instantaneous velocity are the same. That magnifying glass is a nice feature of GA.

Date: Thu, 2 Oct 1997
From: Rich McNamara

Brad Katuna wrote:
> We've just completed the incline plane lab, so the kids have
> position/time data. Tomorrow I figure I'll spend a bit of time using
> Graphical Analysis to show how to go from x vs. t to v vs. t, by hand,
> since it appears the MAC version 2.0 can't give the slope of the best
> fit curve (is this right?), and then they'll be whiteboarding and
> presenting their lab results (the benefits of block scheduling).
>
> I note from my summer notebook that it isn't the intent to establish
> x=1/2 at^2 at this point. Is the only REAL point from this lab that
> x is proportional to t^2?
>
> And why did we do the lab extension? It appears that the lab
extension has the kids developing a v vs. t graph. Can't they be
expected to do this from the initial lab simply by calculating the slope of the x vs.t?

Hi Brad,
When I get to this lab much later in the year (I start with CASTLE electricity), I introduce the idea of a changing velocity in the prelab discussion. Before getting to the lab, I video a ball rolling down a ramp and plot position vs. time. Students want velocity to be constant but the plot is not. As a group activity we plot the data and discuss what might be happening to the velocity. We calculate the slope between each pair of points and plot the average slope vs. time.

Based on that graph having a constant slope, we introduce the idea of acceleration. I then let the students do the lab two ways. I let them use time as the ind. variable and position as the dep. variable. Before attempting to linearize the data, I ask that they estimate what the rate of velocity change is for their data. Then they linearize the data by squaring time and if the initial velocity was zero, they end up with a slope that approximates one half the acceleration rate.

The other students use distance as the independent variable and velocity as the dependent variable. After estimating their rate of velocity change, they linearize the data by squaring the instantaneous velocity. The slope of their linear graph is two times the acceleration.

By leading the introduction the acceleration concept and then asking them to employ it during the analysis of the lab, I think the students get a better handle on all three of the traditional kinematics
equations.
a= delta v/ delta t, delta x = vt +1/2*a*t^2 and vf^2 = vo^2 + 2a deltax

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Date: Thu, 2 Oct 1997
From: gheri fouts <gfouts@pixi.com >
Brad: Look again at the data. This is the lab where we go one step further and take tangents on the curve line of position vs time. They should see that the tangents produce the slope at that point in time and that slope (from unit II) is the velocity (instantaneous). If they graph all those slopes and times, they will get a nice straight line (hmmm) and there you go. I like it better than the old way, and this could be done on a graphing calculator.

Date: Fri, 3 Oct 1997
From: Mervin Koehlinger

Brad Katuna wrote:
> I note from my summer notebook that it isn't the intent to establish
> x=1/2at^2 at this point. Is the only REAL point from this lab that x
is proportional to t^2?

My students collected the data for position and time. They graphed it and determined the power relationship. Then they used Graphical Analysis to determine the slope at various times (which they know is velocity) and graphed velocity vs. time. We defined acceleration as the slope of the velocity graph (just as we previously had defined velocity as the slope of the position vs. time graph). Then they graphed velocity vs. position. We noted that the constant in the x-t relationship was one-half the acceleration and that the constant in the v-x relationship was twice the acceleration. Overall, it went well. They had collected some pretty good data.

Date: Sun, 5 Oct 1997
From: Don Yost <DoYost@AOL.COM>

Merv, how did you use G.A. to find tangent at points so you could find slope????

Some mention of students not being able to picture the motion in some graphing problems. May I suggest that you have a sonic ranger set up when you whiteboard these problems, and have students walk the solutions as the ranger graphs their motion. Sure makes acceleration problems go easier, too.

Date: Sat, 4 Oct 1997
From: Larry Dukerich <dukerich@ASU.EDU>
Hi Folks,
Brad Katuna requested help regarding slopes of tangents to the position-time graph for the incline lab. He hoped that GA 2.0 for Mac would have a feature to do this. He also asked about determining areas under curves. He got helpful replies.

For what it's worth, here's my 2 cents: I am generally uncomfortable about having kids use software that does a lot of work for them automagically until they have a glimmering about how they could do it manually or with less powerful tools. For example, one COULD have GA do curve fitting to generate the equation for the position-time behavior, but I prefer to have students make a conscious decision about what modification is required in order to linearize the data. I want THEM to write the equation of the line; resurrecting alg 1 skills and giving them some sense that they learned something worthwhile there.

OK, we make a BIG deal about how one can deduce v-t behavior by determining slopes of x-t. So, when we discuss how we can determine the velocity of an object that is constantly changing, they are ready for concept of slope of the tangent to the curve. I have them use their graphing calculators to draw tangents and find slopes, then plot velocity vs time for two reasons:
1) it gives them a chance to use the skills learned in math in a physics context with data they own, and 2) the process takes enough time for them to reflect a bit on what they're doing, but not so long to be tedious. When they write the equation for the v-t graph, we examine the meaning of this slope as well. Then, after we write v =3D at for this line, we review the linearized graph of x vs t^2. The kids quickly see that this slope is 1/2 the value of the slope for the v-t graph. So, it follows that when you start at rest and at the origin, then x =3D 1/2 a*t^2.

Can you get the slopes of the tangents using MacMotion or ULI timer software? Absolutely! It's much easier to do it this way. For that matter, you can get the software to display a v-t graph and examine the slope to get acceleration, w/o even thinking about it. But on the first pass through this, I want to slow down the process so they have a chance of understanding what's going on.

Date: Fri, 3 Oct 1997
From: Art Woodruff <woodruff_a@POPMAIL.FIRN.EDU>
Brad Katuna wrote:
>And why did we do the lab extension?

The v vs t graph in the extension is for changing velocity. By going this route the steps in concept are smaller. From the v vs t graph you will get back to x=1/2at^2 but in a more concrete way. It helps reinforce that a is result? of a change in velocity.

SEPT 1999 UPDATE BY ART WOODRUFF:

Art says:

Besides echoing Larry's thoughts, I would add the importance of making acceleration a function of change in velocity. I often have students who want to divide distance by the time squared because the units match. By having them do the tangents and a velocity vs time graph, they then develop their definition of acceleration from the slope of a velocity graph knowing where the velocities came from.

Date: Fri, 3 Oct 1997

From: Sean McKeever <McKeeverSean@hotmail.com>

I believe one of the most important reasons for performing the inclined rail lab is distinguishing between instantaneous velocity and average velocity. In addition, the constant acceleration equations can be developed from the equation for the linear v vs. t graph. A nice way to get the instantaneous velocities from the position vs. time data is by using a TI-82, 83, or 85 calculator to draw the tangents at various points of the x vs. t graph. I have instructions for doing this if you are interested!

COMPILATION: unit 3: ball on ramp lab in 2000

Date: Sat, 07 Oct 2000
From: mitchell johnson <johnsonm@lvcm.com>
Subject: acceleration labs
I see a lot of discussion on the constant acceleration labs for x vs t and v vs t, but for the last two years I have had my honors also find v vs d for the third equation. Then the slopes of their lines all have units of m/s^2 but are multiples of each other 2a, a, 1/2 a. Last year was fine for all three graphs, we use 2 m PASCO tracks; but this year the v vs d graph was linear for a lot of groups and wasn't near the 2a value for those that weren't, even though with the units I tried to convince them that it should be v^2 vs d. Has anyone had this difficulty with the v^2 graph? How did you handle it? I have not been able to determine a cause.

UPDATE FROM MITCH, the next year:
Date: Wed, 03 Oct 2001
From: mitchell johnson
Subject: Re: How did you resolve this problem last fall?
YES we solved the problem. On the position vs time squared graph it was necessary to subtract any initial time before the experiment began. Second, because the Pasco equipment uses 2 positions to calculate the instantaneous velocity, position must be taken to be a point well before the end of the track where the cart collides with the end stop. Then the v^2 vs distance comes out. The average of the v squared graph was about 10% from 2 while the average for x vs t^2 was within 5 %. Close enough to get the results.

Date: Sat, 07 Oct 2000
From: Jim Schmitt <jschmitt@ECASD.K12.WI.US>

This year I varied the ball on the ramp a bit...and got great results. I had 10 setups (3 per group):

*Air track, slight angle, with photogate
*Air track, slight angle, with photogate through LoggerPro
*Air track, slight angle, videotape (camera follows very closely, so as to pick up the scale)
*Hot Wheels Track and car, about 25, with photogate
*Hot Wheels Track and car, about 35, with photogate
*Pasco Track, slight angle, with photogate
*Ball (golf ball) on ramp, slight angle, with photogate
*Ball (steel ball) on ramp, slight angle, with photogate
*Bagel (yes, bagel, from an old TPT article) dropped free fall in front of a gridded board, videotaped
*Nerf ball dropped free fall in front of a gridded board, videotaped

All of these gave great x vs. t graphs (can't forget to use the "free point" of x=0 at t=0). What I liked is that the discussion was very rich on the differences and similarities in results. One example...aside from a great difference in slope, those who videotaped never had an intercept above 5% of the max vertical value. They didn't have to worry about being just in front of the first gate. The other groups did not always have intercepts below 5%.

One other feature is that by using a photogate, your independent variable is position, and dependent is time. When you videotape, your independent is time (because you must choose which frames you will look at), and dependent is position. This leads into a great discussion of variables and which axes they go on, and why we often prefer to use time on the horizontal axis...and how the method of collecting data can dictate independence and dependence.

Date: Sun, 8 Oct 2000
From: John Barrer <forcejb@YAHOO.COM>
Altho I haven't done the math, at least part of the explanation of "linear" x vs. t results may have to do with some of the system energy showing up as rotational KE of the ball.
We got good results with HAND TIMING with a shallow (maybe 10-15 degrees) and long (8ft) ramp. I also had one class group that was able to successfully estimate g by hand timing a 3m free-fall.

Date: Sun, 8 Oct 2000
From: Thomas J Gordon <tomgordon@JUNO.COM>
Subject: Re: ball on ramp
Add a racketball ball that's filled with water. GET A NEEDLE FROM YOUR DOCTOR OR VET. Prepare the balls in her office in a bucket of water with the needle just barely inserted and in upward orientation. Squeeze and release repeatedly until no more bubbles are released by the needle. You'll probably find this ball will be the quickest down the incline (remember the soup cans?)

Date: Sat, 07 Oct 2000
From: Bob Baker <bob.baker@WORLDNET.ATT.NET>
Subject: Developing acceleration from the rail lab
When developing acceleration, it has been my experience that the students' first exposure to the concept determines their conceptual understanding. Traditionally in modeling, I have developed acceleration from the rail lab as the change in velocity as determined by the change in slope of the position-clock reading graph. This year with regular physics I developed acceleration from the motion map of the rail lab. After each group presented the rail lab, the discourse with students went as follows: T: teacher question. S: student response.

T: Can you draw a motion map of the rail lab?
S: students draw the motion maps horizontally.
T: Did the ball go horizontally on the rail or did it move horizontally and down?
S: students redraw motion maps at an angle
T: What do the dots on the motion map represent?
S: time, clock readings, position
T: What is the clock reading of the third dot?
S: students discover they must count dots, 0, 1, 2 to get two seconds for the third dot.
T: What else do the dots represent?
S: position?
T: In the rail lab, what is the position of the first dot?
S: zero
T: How do you show that on the motion map?
S: students draw an X-axis as the frame of reference for the motion map.
T: What do the arrows on the motion map represent?
S: velocity
T: Why do the arrows get longer?
S: the ball rolls faster and faster
T: Why do the dots get farther apart?
S: the ball rolls faster and faster
T: Does the first dot have an arrow?
S: some yes, some no
T: How fast was the ball traveling the instant it was let go?
S: it was not moving
T: How long should the arrow be for the first dot?
S: there should be no arrow on the first dot. (Students erase arrow on first dot.)

T: Suppose the second arrow represents 4m/s and the third arrow represents 6m/s.Write these numbers above the arrows. How long is the second arrow?
S: 2 m/s, students write a 2 above the arrow.
T: What is the difference in velocity between the second and third arrow?
S: 2 m/s
T: What is the difference in velocity between the first and second arrow?
S: 2 m/s
T: Under the second arrow starting at the dot, can you draw a new arrow that is 2 long using half an arrow head?
S: students draw the arrow.
T: What does the 2 arrow represent?
S: the change in velocity
T: Under the third arrow starting at the dot, can you draw a new arrow that is 2 long using half an arrow head?
S: students draw this arrow and an arrow under the second dot
T: What do these arrows represent?
S: the change in velocity
T: Should the first dot have an arrow like the other arrows with half an arrowhead?
S: some say yes, some say no
T: How fast is the ball moving at the first dot?
S: 0 m/s
T: How fast is the ball moving at the second dot?
S: 2 m/s
T: Was there a change in velocity?
S: yes
T: Should you draw a half arrowhead arrow at the first dot?
S: yes, students draw arrow with half arrowhead
T: What do the lengths of the half arrowhead arrows represent?
S: the change in velocity
T: How long does it take for the velocity to change 2 m/s?
S: one second
T: What do the lengths of the half arrowhead arrows represent in terms of your last two answers?
S: the change in velocity each second
T: Is there a name we could give to the change in velocity each second?
S: acceleration
T: What can we say about the acceleration of the ball based on the acceleration arrow lengths?
S: the acceleration is constant
T: Does acceleration have direction?

The discussion continues until the students are convinced that acceleration has direction.

Date: Fri, 12 Oct 2001
From: Larry Dukerich <dukerich@asu.edu>
Subject: Re: questions & questioning strategies
To: jane.jackson@asu.edu (Jane Jackson)

You wrote about the idea of using Bob Baker's Q&A session as a springboard for how we could ask good questions during a white-boarding session. I think these are OK, so long as we remind teachers that the art of the profession is in knowing when to dig deeper and when to let it go for the time being. There is no one-size-fits-all script that will magically make white-boarding come alive.

COMPILATION: Unit 3: Acceleration Lab — 2001

Date: Thu, 27 Sep 2001
From: mitchell johnson <mitchjohnson@EARTHLINK.NET>

I just had egg on my face during the acceleration lab.

When students let their Pasco carts run down the ramp, I forgot to catch the students so they could reset their time to zero instead of the time that the computer gave them. This may be the problem linearizing the graph but my parabola was very evident. This is a serious problem for me because I can't get the 1/2 for the at^2 because the 2 seconds ^2 is a lot smaller than 4^2. Unfortunately I didn't catch it until they were gone. I guess we will be rewhiteboarding that one!

Date: Fri, 28 Sep 2001
From: Stan Hutto <shutto@AHISD.NET>
Subject: Re: Acceleration Lab

I did the lab two different ways.

(1) AP class: Use PASCO track and carts, with an small Al pie pan attached to the cart. I got the best results by using a separate support to hold the motion detector away from the end of the track. Secondly we started the carts at the bottom and gave them a push up the track. That way it was only gravity doing the "release" at the top. Also we double checked that the detector was indeed detecting the cart by slowing moving the cart up pushing with a meter stick from behind and checking the correlating position on the screen graph.

Got great results. Did the lab at several angles and plotted acceleration vs. sin of angle and then extrapolated to 90 degrees and compared to accepted g for San Antonio g=9.793 and got great results - typically less than 1% error.

(2) Pre-AP: Did the lab using 1" steel ball-bearing and rail made from utility shelving support - about 4 feet length. We set the shelving rail on the PASCO tracks and then used photogate pair set at the pulse mode (Vernier experiment folder - Sensors - Pulse). I set the first photogate at the 2-cm mark thus allowing room to place the ball bearing on the rail close to the photogate, and then we placed the second gate at positions of 10-cm intervals (12-cm, 22, 32, etc.) Did at least five runs per position. Collected 10 data points. Got excellent results.

Using the PASCO track allowed the students to easily mark the photogate position by lining up the light opening with the tape rule on the track and then raising the gate until the light just blinks off. Then they are consistently measuring the same portion of the ball - which can be determined by moving the ball through the gate with a ruler and marking the points where the light goes on and off (enter length for velocity data).

Once again classes got great results. When we analyzed the P-T graph slopes for velocity and plotted vs. time we got very straight lines and then the V-squared vs. Position graphs were also good, with a nice correlation of the slopes. The ratio of slopes of the V^2-P, V-T, and the quadratic variable from P-T curve gave the expected ratios.

Date: Sat, 29 Sep 2001
From: John Barrere <forcejb@YAHOO.COM>

In my current low-tech environment, I’ve done the ball on the ramp quite successfully (ie, graph is a parabola) using a group of students who simply hand-time the ball’s delta position. Eight foot ramp (0.5" aluminum channel) at a shallow angle works well.

Date: Wed, 3 Oct 2001
From: Glenn Wagner <GWAGNER@CWDHS.UGDSB.ON.CA>

I hope someone can help me with this experimental problem. Using sonic rangers we let a Pasco cart roll down the track collecting the d-t data. We get the parabolic nice curve. BUT when we go to linearize (squaring the time) the first 1/4 to 0.5 seconds has distinct non-linear part (almost a square root behavior in the time) followed by the linear part as expected. Does anyone else experience this problem and does someone have a solution?

Date: Thu, 4 Oct 2001
From: Jeff Steinert <jsteinert@AUBURNSCHL.EDU>
Subject: Constant Acceleration Lab/Sonic Rangers

Glenn Wagner wrote: ’... Does anyone else experience this problem and does someone have a solution? ’

I believe this can arise in two possible ways:

1) If the car is moving initially (more than a few mm/s, check the velocity vs. time graph), then squaring the time will not linearize the graph due to the presence of the "initial velocity x time" term. In this case, squaring the time values gives a side-opening parabola, the later parts of which may appear to be straight.

2) A more common experience with motion detectors is that the time is not equal to zero at the same instant that the velocity is equal to zero. If this is true, it is possible to

linearize the graph, but you first must adjust your graph so that v=0 at t=0. I'm not sure most students will understand why this is necessary, but I'd use the following procedure:

First, determine the time at which the velocity is equal to zero using the v vs. t graph (say, for example v=0 at t=1.3 s).
Second, create a new column of values (t') equal to your original times minus the 1.3 s (t'=t-1.3s). This will shift the v=0 point to t'=0.

Finally, square the values of t' and plot displacement vs. t'^2. This should nicely linearize the data, but may confuse the issue for most if not all students.

Another option is to use photogates and small picket fences to do this experiment. You will still encounter the difficulty of getting an initial velocity close to zero, but since timing does not begin until the gate is blocked, there is no need to shift the times to achieve a linear graph.

Date: Thu, 4 Oct 2001
From: Matt Green <matt_green@CARYACADEMY.ORG>

I have observed this with some of my lab groups, and not with others. My suspicion is that the start button is pushed before the cart is released so that there is a period of zero velocity at the beginning of the motion. It seems easier to time this correctly if the cart is pushed up the incline and start is pressed when it reaches the peak. However, this may introduce some complicated issues earlier than you might want.

Date: Thu, 4 Oct 2001
From: Sean McKeever <mckeever@PASCO.COM>

The problem with your motion sensor data could be related to data collection starting before or after the cart is moving. You could try using a photogate as a trigger to begin the data run, while using the motion sensor to collect the position-time data.

First, you would specify a start condition that will start timing when the photogate is blocked.
Put a picket fence on the cart and position the cart so the flag is just outside the gate.
Release the cart and the photogate will start the data collection.

The motion sensor will then begin capturing position-time data.

In addition, it would be useful to specify a stop condition to automatically stop data collection when the cart is 0.9 meters from the motion sensor.

Date: Fri, 5 Oct 2001
From: Andrew Schuetze <aschuetze@ACADEMICPLANET.COM>

Here's an idea that just came to mind when reading the suggestion to use photogates and a picket fence on the cart. The issue is to start the data run the instant the cart starts moving. How about a smart pulley. You can program a start condition and don't have to worry about the cart position relative to the sensor. Place the pulley on the uphill side of the ramp and use just the mass hanger. I wouldn't expect that the mass of the system is going to effect the results that you are looking for in this case.

Date: Fri, 5 Oct 2001
From: Jerel Welker <jwelker@LPS.ORG>
Subject: Linearizing parabolic data

From the math view:
Jeff Steinert's comment about linearizing parabolic or quadratic data when t=0 does not occur when v=0 is exactly correct. Linearization produces

y = (1/2)a*t^2 + c

where a is acceleration and c is the initial position. In mathematical terms this leaves out the "bx" from

y=ax^2 + bx + c.

The "bx" term is initial velocity in the physics model. If initial velocity is present, linearization adds it to "c".

The vertex form

y = (1/2)a(t - h)^2 + k

shows the vertex of the parabola which is where the velocity is zero. h is the time when the velocity is zero and k is the distance.

Note: If h is not zero and you multiply out the model, there is an initial velocity term.

If you'd like to see more with actual data, quadratic regressions, etc, visit the following site and follow the analysis of the data.

<http://lhs.lps.org/instruct/ballramp.htm>

Date: Sat, 6 Oct 2001
From: Mears Brian <Sidney313@AOL.COM>
Subject: How to model without money?

[My] school is well known for its ... financial problems. ... I need to come up with models without the use of standard equipment (including computers).

For the accelerated particle model, I had the students use long pieces of used molding, steel balls, and stop watches to observe, and measure the rate of the balls at specific positions on the molding (track).