COMPILATION: motion detector vs photogate (also smart pulley & CBR)

[Background: when I bought probes on grants for the neediest new Phoenix modelers, I didn t have enough funds to buy everything. Photogates are $40, and motion detectors are $65. I d heard that Dan and Kathy Malone, Phase 1 modelers in Pittsburgh, don t use photogates. Wanting to spread the equipment funds farther, I wrote them and queried them. Then I asked expert modelers David Braunschweig and Larry Dukerich for their advice. David's students' Force Concept Inventory posttest scores were superb, and David now is retired & consults for Vernier, so he knows technology especially well. Sean McKeever also contributed - since he now works for Pasco, he too is a technology/modeling expert. - Jane]

Date: Mon, 02 Oct 2000
From: Dan Malone <Dan_Malone@fcasd.edu>
Jane Jackson said:
>A long time ago, someone told me that you don't use photogates but
>use motion detectors in their place. Is that true? If so, many modelers
>could benefit (and new ones could save lots of money!) by doing this. Could you please post on how you do this?

Jane, as long as Modelers know how the motion detectors work, photogates are unnecessary. Labs are only modified from the point of view of using a motion detector. I do not ever use photogates any more and I suspect Kathy is the same.

I would buy motion detectors and LabPROs and forget the added expense of the photogates.

Date: Tue, 03 Oct 2000
From: David Braunschweig <Dbraunschw@aol.com>

It is good to have both photogates and motion detectors. In lab, 1 of each at each station would be good. Some labs like free fall acceleration are best done with photogates. Others, particularly to show position, velocity, and acceleration relationships, are best with motion detectors. For many labs such as conservation of momentum, I would have some groups using photogates while others would use motion detectors.

As for the black box nature of the motion detector: during unit 2, one could use sound and echoes as a constant velocity example. This could then be extended to the motion detector and how distance is determined -- velocity times time. Then you can use the idea of slope to determine the velocity graph from the position graph. When you get to unit 3, the acceleration graph can be determined by slope from the velocity graph. Anyway, I think students can understand the motion detector as easily as they can the photogate. I don't think the smart pulley and its data is as straightforward and easy to understand as the motion detector.

Finally, yes it would be nice to have both but I think if only one can be afforded, I would go for the motion detector. I firmly believe my students did as well as they did because we did so many graphs using the motion detector -- many activities beyond what is in the core modeling materials.

Date: Sun, 08 Oct 2000
From: Kathy Malone <klmalone+@pitt.edu>

For the Unit 3 acceleration lab I use the motion detector. The students in my class have used the motion detector previously by then to study constant + and - velocity. For the acceleration lab I have the students hold the cart at the top of the ramp with a meter stick (so that they are out of range of the ULI motion detector - UMD) and release while taking data.

Each group of students will do several runs so that they will be able to do data comparisons within groups. As a group the class talks about how the initial velocity should be as close to 0 as possible, so when they look at the d - t graphs for each run they are looking qualitatively for graphs that show as close to zero velocity as possible. It may take them a few runs before they get the hang of it.

This is different than Dan's classes. I believe that he has the students push the cart up the ramp and then has them select out the data from the top to the bottom of the ramp. I prefer my students not to see this type of motion until after the initial acceleration lab.

The students are only allowed to look at the position and velocity graphs. I do things a bit differently than in the original modeling lab. Instead of focusing only on the position graph I also have them predict the velocity - time graph for the situation. The students select out the data from Logger Pro and cut and paste it into Graphical Analysis. Therefore they only look at the distance, velocity and time.

The students then do curve fits, etc. They discover the d vs t square relation and the v vs t linear reality. During whiteboard sessions the students notice that the slope for both has the same values but that the value of the v vs t graph is twice the slope value of the d vs t graph. This leads to good discussions about what each slope represents. At some point someone usually says maybe the d vs t slope is one half the v vs t slope , and the class then reaches consensus to call the v vs t slope the acceleration.

I have both photogates and UMDs. If I had to buy one I'd buy the UMD. In the past I have allowed students to use either the photogate or UMD, but the results have not been that different, error-wise. Maybe I just don't know the best way to have them set up the photogates to get the best possible data, or maybe my students are careless when it comes to lining up the photogates and measuring the distance between them. So lately I don't mention using them unless some student asks. If they do, then I let them use the photogates.

I do use photogates for determining acceleration due to gravity and collisions. In the case of collisions, the motion detector graphs seem to confuse the students at times. I m still working on this one.

Date: 19 Oct 2001 (UPDATE to his post of Oct. 2000)
From: Larry Dukerich <dukerich@asu.edu>

I think there are good arguments for having both photogates and motion detectors.

I find that for students photogates are one step removed from human-operated stopwatches. You can use the photogates for pulse timing (time between two gates), two-gate timing (useful for determining the velocity of a launched projectile), free fall, determining acceleration with a picket fence or with a smart pulley, for conservation of momentum during collisions.

I think the motion detector is great for qualitative measurements (position match), and for quantitative measurements of more complex motion (cart up and down the ramp, simple harmonic motion, and for impulse-delta momentum interactions). I think it's important to spend some time helping students understand how the MD and software "automagically" give you x vs t, v vs t and a vs t graphs. If that's done properly, then MD's can be wonderful tools for the physics lab.

Jane s comments (10-00):
At the AAPT Summer 2000 meeting in Guelph, Canada, Elizabeth George of Wittenberg University in Ohio gave a talk & poster on a research study in which 38 introductory physics students did collision experiments to learn momentum and energy conservation principles. Some groups used photogates and other groups used motion detectors. Compared to the photogate students, students who used motion detectors performed better on two conceptual questions. They were also more likely to draw appropriate conclusions from the data they obtained in lab. They also had more discussion during lab about the concepts. (See p. 98 in AAPT Announcer. egeorge@wittenberg.edu)

Date: Wed, 18 Oct 2000
From: Sean McKeever <mckeever@PASCO.COM>

The recent post on motion sensors vs. photogates brings to mind my own experience with these tools and I'd like to share my thoughts. Prior to working at PASCO, I used photogates exclusively for quantitative experiments and motion sensors only for qualitative "match graph" type of activities. Like Larry, I felt that the data from the motion sensor wasn't as reliable as the photogate.

After trying a few quantitative experiments with the Motion Sensor II, I realized something I had never thought of before. The photogate is always limited to a very small snapshot of the motion and thus obscures the rest of the motion. For instance, during a collision between two dynamics carts, photogates could be used to find the velocity of the carts both before and after the collision. However, the motion sensor allows students to "see" the velocity of the carts before, during and after the collision! In addition, students can see the effects of friction on the velocity of the carts as they roll down the track. No, they're not actually frictionless. This is just one example of how motion sensors allow students to see the whole picture, instead of a small portion of the picture.

The difficulty with motion sensors is their data can be more easily corrupted by student mistakes. For example, objects along the length of the track can be detected if they are too close. I'm not in sales here, but a very cool feature of the PASCO motion sensor is a switch that optimized its use with the dynamics cart. This switch leads to less interference from other objects and better overall data. I hope this helps!

Sean McKeever
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Date: Wed, 18 Oct 2000
From: Jerry Loomer <jerryloomer@HOTMAIL.COM>

May I add my two cents worth on motion detectors and photogates.

There were lots of problems with the early motion detectors (sonic rangers) so I've avoided them. They may be better now.

Photogates give single or dual point data, which may not be enough for a given experiment.

I like SMART PULLEYS. The SMART PULLEY is a calibrated pulley wheel with 10 spokes that mounts on a photogate. As the experimental object moves, it pulls a string which runs on the SMART PULLEY and the photogate determines both time and distance traveled data for the string pulled by the moving object. The data can be displayed as time as a function of distance (numerical data), distance vs time graph, velocity vs time graph, acceleration vs time graph. I use it for constant velocity as well as accelerated motion.

If I could buy only one type of detector, it would be the SMART PULLEY (from Pasco, Vernier has the same thing but by a different name). Also, when I take the pulley off, I can use the photogate as a photogate (like for dropping picket fences for acceleration due to gravity labs).

Date: Wed, 18 Oct 2000
From: Joseph Vanderway <jvanderway@CSUN.EDU>
Just an observation:
A photogate is a 0-dimensional position-time device.
A Motion Detector is a 1-dimensional position-time device.
A video camera is a 2-dimensional position-time device.

I have been able to get very reliable data from UMDs. I use them for the modified atwood machine, friction, energy and work and free-fall labs. I use photogates in the early labs because I feel that students can more easily connect to the "where, when" idea of the gate. Once they are familiar with that idea we use the UMD to measure free-fall.

Date: Wed, 18 Oct 2000
From: Jean Oostens <oostens@CAMPBELLSVIL.EDU>

On Wed, 18 Oct 2000, Joseph Vanderway wrote:
> I have been able to get very reliable data from UMDs. I use them for the
> modified atwood machine, friction, energy and work and free-fall labs.

Let me add my experience as well.

I used photogates in the mid-80's, with the Apple II computer, with accurate results, amongst other to insure straightness of airtracks I had to assemble. One gives the track a very small inclination. If then one plots V^2 at the end of the track versus release position one obtain a wiggly line (instead of a straight one as expected) when one put the track together for the first time. One has then to adjust the posts supporting the track, using the information from the graph. One then iterates the process a couple of time, till a nice straight line is obtained. One is sensitive to a fraction of mm deviation from straightness.

When the ball bearing pulleys first came out (the light tan ones with 3 holes), my first reaction was to provide them with a build-in photogate, later coined smart pulley. At that time, I was running my lab on COCOII computers from Radio-Shack, where the time base had a resolution of only 1/60 th second. I obtained reasonable results with an Atwood Machine, as long as I kept the velocity within reason.

I used the sonic ranger for the first time in Akron, in 1996, and used it at Campbellsville with the CBL with good acceptance by the students. Then nearly two years ago, I acquired out of my own money a CBR, which can be connected directly to my own TI83. Twice did I take it with me overseas and got my grand-nephews and grand-nieces interested in playing with it. I registered the level of the water in my sister's swimming pool while one kid jumped into the water, and the other manned the calculator. Another time, I used it to graph the motion of a large church bell being driven into resonance.

Last week, I replaced the CBR from my Atwood Machine by a 10 spoke smart pulley, and am very happy about it: I gain 0.40 meter of range, & otherwise I had to place the CBR on the floor and pray that the descending mass would not shatter my equipment.

All of this to tell you my very best choice is the CBR, costing about 20 dollars extra, but more flexible than the regular unit.

Date: Thu, 19 Oct 2000
From: Jerel Welker <jwelker@LPS.ORG>

From a math perspective, there is a definite difference between the motion detector and the photogate with a picket fence or smart pulley. I must point out that in my opinion, there is a place for both.

The picket fence/smart pulley provide very accurate results and in some situations are much easier to set up. We frequently get correlation coefficients up to 6 nines (R = 0.999999) with the picket fence. When we want extremely accurate results, we use the picket fence.

The problem with the picket fence is that it only interprets motion in one direction. If you roll a cart up an incline through a picket fence and have it reverse direction before clearing the picket fence through the photogate, the motion is interpreted to be increasing in distance when in reality the distance from the origin is increasing and then decreasing. Mathematically, when an object rolls up and back down, we want to see the parabolic motion, and without special programming for the photogate, this is hard to demonstrate. On the other hand, an object rolling up and then back down the ramp is very easily shown using the motion detector.

I side with many others in that if I can choose only one, I'll pick the motion detector because it is a much more versatile tool. If I have the money and want increased accuracy, I'll use the photogate with fence or pulley if it will record the motion I intend to analyze.

Date: Thu, 19 Oct 2000
From: Brad Katuna <bkatuna@HOTMAIL.COM>

I don't like smart pulleys. The intuitive element about how the data obtained is, in my mind, lost in the simplicity of the setup. With the photogates, the "time between two gates" makes clear sense and if instantaneous velocity is desired, it's pretty clear what adjustments need to made. I like these types of dialogues with my students.

Date: Fri, 20 Oct 2000

From: DoYost@AOL.COM
Subject: Re: motion detectors vs photogates

I think when we use equipment, we must always consider that the choice involves data collection, but it also involves conceptual development. Some choices may give poorer data, but help the student construct a conceptual framework.

Date: Wed, 25 Oct 2000
From: craig koch <ckoch@EXECPC.COM>

I've been using smart pulleys for 13 years. The concept is the same as the photogate except, because of its cyclical construction, you can collect many more sets of data. The major drawback is when motion changes direction. For that, go with a CBR.
