**Falling chain lab:**

I am working on this lab so it if very rough. I can do it as a demo but it is difficult to explain it to others so that they can do it. It is an excellent discrepant event for students in the physics course for science and engineering.

One starts with a motion sensor pointing downward at a force probe (or WDSS) facing upward. A tray is attached to the force probe (a pie tin works). A bit of cloth is placed in the tray as a cushion so that falling objects don’t bounce out. The distance between the motion sensor and the force probe must be greater than the length of a chain that will be lowered and then dropped onto the tray.

The motion sensor has to be able to see the upper end of the chain so a small ball (a pith ball or table tennis ball) is attached to one end (which will be the upper end).

Motion sensor

Small ball

Tray

Force sensor

chain

Set up LoggerPro to display a graph of force as a function of distance. Hold the chain so that the lower end is just barely above the tray. Make sure your hand is lower than the top of the chain so that the motion sensor sees the small ball. Zero the force probe and the motion sensor.

Click collect and *slowly* lower the chain onto the tray. The graph of force vs. position starts out at the origin (since both were zeroed) and rises in a straight line. The slope of that line is the weight of the chain per unit of length. If the chain has mass *m* and length *L*, the slope of the line is *mg/L* and the force graph has a maximum value of *mg*. Make a linear fit of the graph and save the data.

Now prepare to repeat the experiment but this time drop the chain. This is the tricky part because you have to get your hand out of the way, bringing it downward faster than 9.8 meters per second squared. That isn’t hard to do with practice but it is very hard to explain to somebody else. So I am working on another way of dropping the chain.

Ask the student to predict the shape of the graph of force vs. position when the chain is dropped. Some will predict that it will look the same. Some will predict that the shape will be a parabola. I’ve never heard a student predict it correctly.

Do the experiment. The new graph of force vs. position is again a pretty straight line through the origin. It is noisier so a linear fit is very useful here. Save the data. The result is crystal clear and very puzzling to students. It is another straight line but the slope is three times the slope of the first graph. Of course once the chain has stopped moving the force drops from a maximum value of “*3 mg*” back down to “*mg*” which was the maximum value value found in the first experiment.

Where does that factor of three come from?

This opens the door to dealing with some high powered concepts, detailed problem solving, and learning by inquiry at the same time. Those three don’t come together that often.

With the data that the students already have they can find the velocity of the chain as a function of time (this is just “*g t*” but they can measure it). They can find the mass of the portion of the chain that is not yet on the tray (the position data tells them the length of the chain that is not yet on the tray, and they can derive a little equation for it, too). From mass and velocity they can get the momentum of the chain as a function of time. From that they can find the rate of change of momentum (*dp/dt*) which turns out to be exactly twice the weight of the chain that is already on the tray. Add that to the weight of the chain that is on the tray and they get their factor of three.

$$\sum\_{}^{}Force=Normal-(Weight of tray)=\frac{dp}{dt}$$

The surprising result is that at any instant of time: $\frac{dp}{dt}=2 (Weight on tray)$

Hence: $Normal=(Weight on tray)+\frac{dp}{dt}=3 (Weight on tray)$

This works very well as an interactive lecture demo. I am working on getting it to work as a lab.