Lab #3 Newton's Second Law-Part One

Purpose: To investigate the dynamics of one-dimensional motion.

Equipment: Air track with glider, Smart pulley, Scales, Weights, string, & paper clips, Computer and Science Workshop Interface

Discussion:
Newton's 2nd law states that the acceleration of an object is directly proportional to the force impressed upon it and inversely proportional to the object's mass ($a = F / m$). Part One of this lab deals with the relation between FORCE and ACCELERATION while total system mass is held constant. Next week, Part Two will focus on the relation between MASS and ACCELERATION while force is held constant.

The object that will undergo CONSTANT acceleration in this lab is an aluminum glider, which will move on a horizontal air track. The air track provides nearly frictionless movement of the glider, so the force can be controlled without complications due to the presence of unknown frictional forces. The forces on the glider during each trial will be provided by the weight of various masses, which are hung vertically from a string attached to the glider and running over the pulley. The masses will be hung from a paper clip (mass = 0.5 grams) attached to the end of the string. The total weight of the mass suspended (including the paper clip) equals the driving force, F_d, on the glider, assuming the string's mass is negligible, that it doesn't stretch, and that friction between the pulley and its axle can be ignored. (To calculate the weight of a mass, you multiply the mass by the acceleration due to gravity, g.)

The motion of the glider is monitored by the photogate attached to the smart pulley, which uses the computer's clock to lead us to glider acceleration values. The pulley is free to rotate between the two arms of the photogate. As it rotates, the spokes of the pulley interrupt the light beam, and the computer times the corresponding digital pulses. According to the manufacturer of the pulley, the distance the glider moves horizontally during successive interruptions of the photogate beam (one tenth of a revolution), which is the same as the distance through which the suspended mass falls vertically (since the string doesn't stretch), is 1.50 cm, or 0.0150 meters.

The operative kinematic equation we will use is:

$$V = a\,t + V_o \qquad (1)$$

Note that this equation is in y= mx + b form. The computer will provide us with a graph of velocity vs. time, and slope of the trendline of this graph should be the value for the CONSTANT acceleration during each trial.

The only FORCE on the moving system (glider, sting, 2 paper clips, hanging mass) that is in the direction of motion is the WEIGHT of the suspended mass and the one paper clip to which it is attached. (We're neglecting the mass of the string.) Let us call the "driving mass" for each trial m_d. It is the mass of the suspended paper clip plus whatever is attached to it. Its weight, as noted above, is m_d times g, where $g = 9.8 m/s^2$. So the NET force on the entire moving system, F_d is (m_d g). Applying Newton's 2nd Law (net force = total system mass times system acceleration) to this situation, we have:

$$F_{net} = m_d \, g = (M + m_d) \, a \qquad (2)$$

where M represents the mass of the horizontally-moving glider with its taped-on masses and its paper clip, and m_d represents the mass of the vertically-moving hanging mass plus its paper clip.

Once we get the acceleration for each trial with the help of the computer, we can then plot them (acceleration values for each trial) versus the different driving forces, and the slope of this linear graph should equal the <u>total system mass</u> that is responding to each trial's net force. Notice that equation (2) is in y = m x + b form. We will plot driving force on the vertical axis and acceleration on the horizontal axis, so the slope's units will be newtons divided my m/s^2, which are kilograms (mass). For the drawing of the linear function, F_{net} = (tot. syst. Mass) times (a), we are going to use EXCEL.

Procedure:

Constant total system mass, variable force and thus variable acceleration.

1. Turn on the blower and level the air track as discussed by the instructor. With the glider pulled back away from the pulley, and with some mass on the end of the vertical paper clip, adjust the height of the pulley so the string between it and the glider is parallel to the top crest of the air track and therefore horizontal. Also, make sure the air track is positioned laterally so that the string aligns with the top crest as viewed from the end. Further, make sure the alignment of the pulley matches that of the string & air track.

2. Each run will utilize 45 grams of mass. Since the idea in this lab is for the total SYSTEM mass to be <u>constant</u>, you're going to begin on the first trial with 35 grams taped to the top of the glider and 10 grams hooked onto the dangling paper clip. On the next run, you'll take 5 grams off the glider and add it to the dangling paper clip, so you'll have 30 grams riding on top of the glider and 15 grams tugging (not incl. the paper clip). So you can see that the total mass of all the moving metal on each trial remains the same. You will continue to reduce the mass on the glider in 5 gram increments, while increasing the driving mass in 5 gram increments, until, on the last run, you have NO mass taped to the top of the glider, and all 45 grams hanging vertically. Eight runs total.

3. Begin with the computer by double clicking on the Data Studio icon, the select Lab02, then select Newton's Law(Smart pulley).ds. A blank graph will appear. For each trial, pull the glider away from the pulley until the hanging mass is next to the bracket holding the smart pulley. Hold the glider perfectly still using your finger or a pencil eraser touching the track face perpendicularly, and click the "start" icon, then release the

system, and observe the acceleration! The moment you click start icon, it turns into a “stop” icon, and YOU NEED TO CLICK THE STOP ICON BEFORE THE GLIDER BUMPS INTO THE SPRING AT THE END OF THE TRACK!!!!! Your instructor will amplify on this more.

4. Provided there was no operator error, a linear graph should appear. Click on the “Fit” icon, and then click “Linear fit” in the drop-down menu that appears. The slope of the $V = a\,t + V_o$ (that is, the acceleration) will appear in a box. Write it down. Then, in the upper left-hand corner of the screen, click on “Run#1” and delete it. Then click on “Linear Fit” and delete it also. Now you’re ready to hit the start button again for the next run.

5. Build a table in Excel similar to this:

Trial #	Acceleration	Driving Mass, M_d	Driving Force, F_d
1			
2			
3			
4			
5			
6			
7			
8			

6. Use Chart Wizard to plot a graph of driving force vs. acceleration. Add trendline and its equation. The slope of the graph should give you the total system mass as indicated in equation (2). Compare this experimental value with the actual total system mass, and compute percent error. (Neglecting the string, the total system mass is the mass of your glider, plus the mass of two paper clips, plus 45 grams.) Don’t forget to discuss error sources in your results section.