PHYS101 Lab: The Inclined Plane

Equipment Needed:

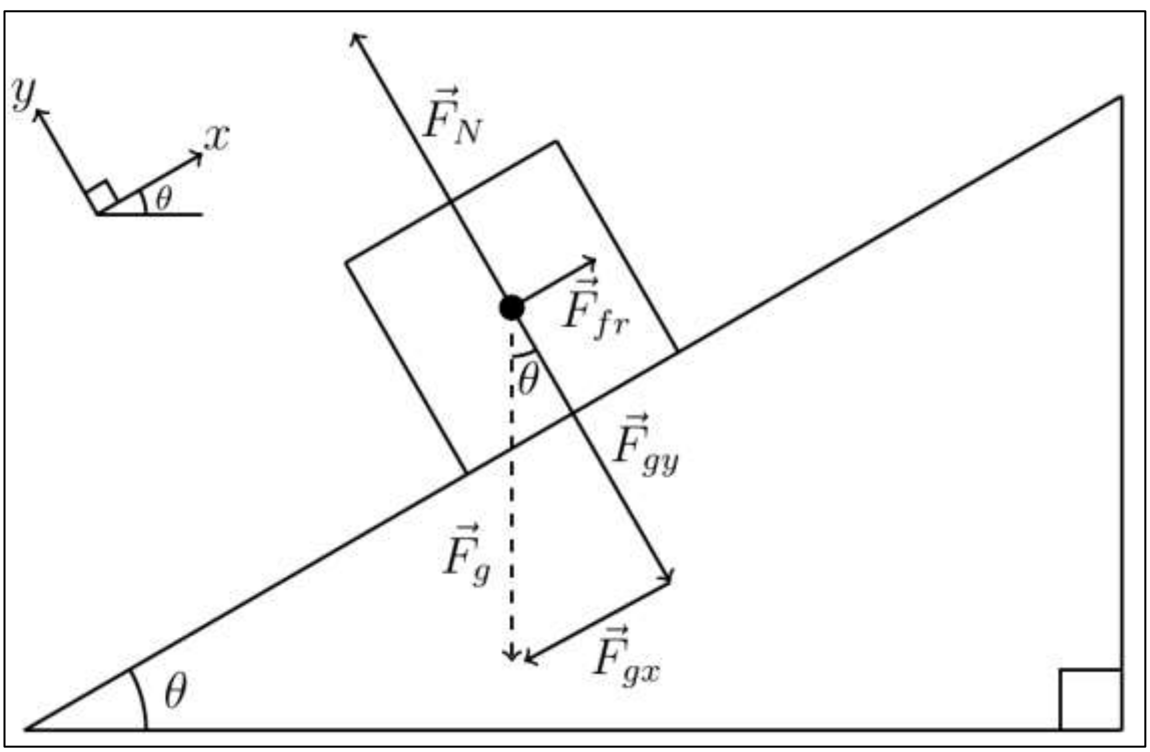
Computer	PASCO 850 Universal Interface
Aluminum Track (Not The Black Ones)	Aluminum Dynamics Cart
Blue Motion Sensor	Protractor
Digital Scale (By Sink or Equipment Desk)	Foam Pad
A couple of books (to prop the ramp up)	Spreadsheet in GDRIVE.
Dynamics Cart Masses (Either 2 long or 1 long and 2 short)	

Purpose:

In this lab you will practice using force equations and kinematics to analyze the motion of an object. You will be studying the motion of a cart moving down an inclined plane to see how it's mass, friction, etc. affect it.

Theory: If an object slides down an incline you can calculate the time that it should take for the object to travel, assuming you know how steep the incline is. In this lab you will calculate how long it takes for a dynamics cart to "fall" down a ramp. The dynamics cart is effectively frictionless, although your intuition should tell you that is not correct.

In the diagram below is the force diagram for an object on an inclined plane. Notice that the frictional force is present in the diagram. The reason: you will do the analysis for the system twice. The first time you will assume the system is frictionless, so that force goes to zero. The second time you will not assume that friction goes to zero. Notice that we are using a rotated coordinate system. This actually makes the math easier to handle.



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To analyze the system, one must do two things:

1) Solve a system of force equations to find the net acceleration of the system in the x-direction. We assume the object is not accelerating in the y-direction (the block won't magically fly off the ramp or sink into it).
2) Use the kinematic equations to calculate how long it will take the block to slide down the ramp some distance, x.

The system of force equations:

$$\sum \vec{F}_x = m\vec{a}_x = F_{fr,k} - F_{gx}$$

$$\sum \vec{F}_y = m\vec{a}_y = 0\ N = F_N - F_{gy}$$

The equation in the y-direction is the most straightforward to solve, and tells us the relationship between the normal force and the gravitational force, F=mg. This is useful, since we need to calculate a find a frictional force in the x-direction equation:

$$F_N = F_{gy} = F_g \cos\theta = mg\cos\theta$$

We now need to plug in the above relationship and the equation for friction, $F_{fr,k} = \mu_k F_N$, into the equation for the x-direction and solve for the acceleration:

$$\sum \vec{F}_x = m\vec{a}_x = F_{fr} - F_{gx}$$

$$\vec{a}_x = \frac{F_{fr} - F_{gx}}{m} = \frac{\mu_k F_N - F_{gx}}{m} = \frac{\mu_k F_{gy} - F_{gx}}{m} = \frac{\mu_k mg\cos\theta - mg\sin\theta}{m}$$

If you follow the algebra up to this point, you will notice an interesting conclusion. The mass of the object cancels out, so in theory that shouldn't matter! Note: $g = 9.81\ m/s^2$. We don't make it negative, because that would not mean anything in the rotated coordinate system.

$$\vec{a}_x = \mu_k g\cos\theta - g\sin\theta$$

This leads to a greatly simplified equation for the acceleration of the object:

$$\vec{a}_x = g[\mu_k \cos\theta - \sin\theta]$$

If the frictional force is assumed to be zero, then the equation for the acceleration simplifies even further:

$$\vec{a}_x = -g\sin\theta$$

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Once you have the net acceleration of the object, either with or without friction, you can calculate how long it should take the cart to slide down the ramp a pre-determined distance (this math should look familiar, since you already did a lab with it):

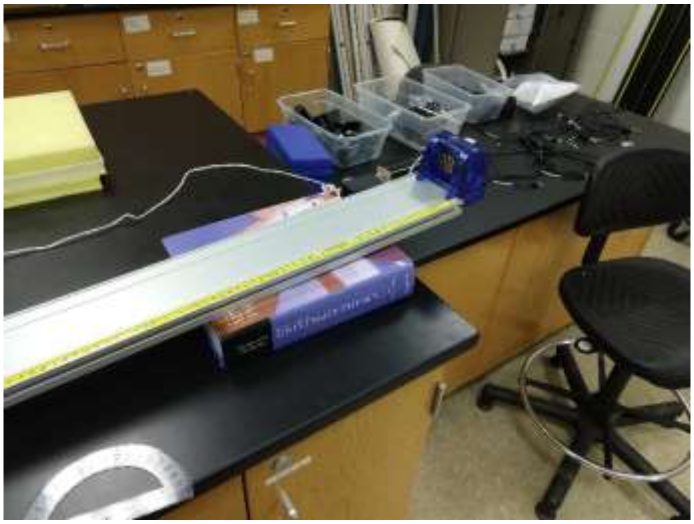
$$\vec{x} = \vec{x}_0 + \vec{v}_{0x}t + \frac{1}{2}\vec{a}_x t^2$$

If you release the cart from rest, then the second term goes to zero. The initial position will not be zero in this lab, because the physical limitations of the motion sensor do not allow for that.

$$\vec{x} = \vec{x}_0 + \frac{1}{2}\vec{a}_x t^2$$

Procedure:

1) Go to the GDRIVE and download the program "Motion Sensors Table.cap". You should download it onto your computer's desktop.
2) Measure the mass of your cart, and your large black masses.
3) Place the ramp on your books and foam pad, as shown in the diagram below. The angle of the ramp should not be more than 20°.
4) Connect your motion sensor to PasPort1 on the PASCO 850 UI. Clip your motion sensor to one end of the aluminum track.



5) Place the foam pad at the end of the track and prop it up a little, so that the cart doesn't fall off and hit the table or floor. You do not want the foam pad directly under the track: as the cart travels down the ramp the angle will change, if the pad is directly under the ramp.

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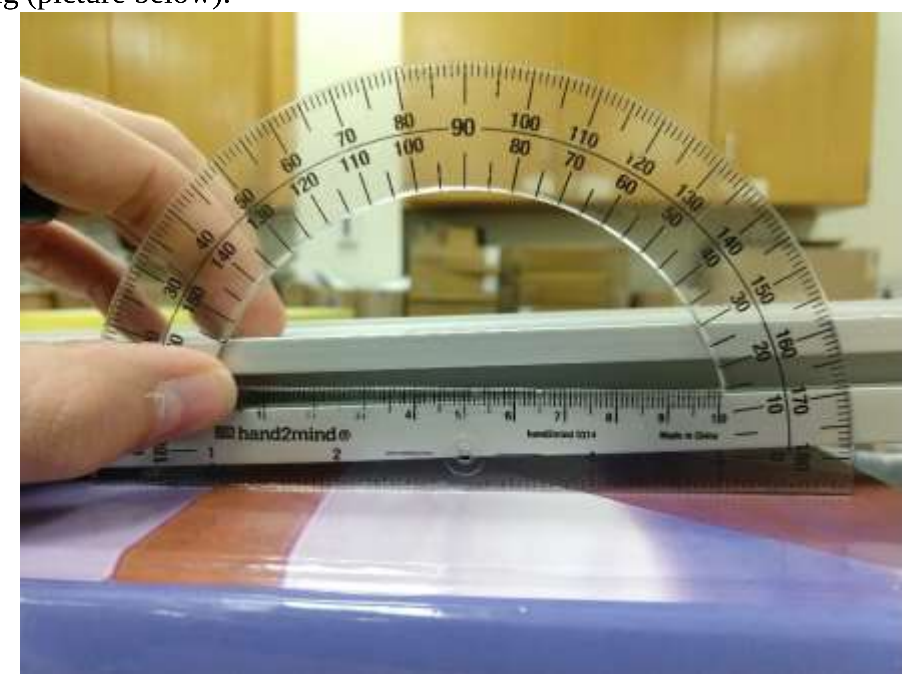
6) Use a protractor to measure the angle of the track. Make sure the center of the circle at the bottom of the protractor is level and centered on the edge of the track that you are measuring (picture below).



7) Make sure the motion sensor is level (set to 0°). There is a switch on top with two options: person or cart. Make sure the device is set to cart.
8) Open the motion sensor's program. Start the sensor (you will hear it click). Release the cart and let it fall to the bottom of the ramp.
9) The program will output a table of the cart's position vs. time. Go through the table and select 10 data points. You should choose data points that are equally spaced along the

track and that are representative of the entire motion of the cart. Make sure to take note of the initial data point in the table. That will give you your initial starting point, which you need for your calculations. Also, the time given in the table is a measure of how long the sensor has been running, not how long the cart has been rolling down the ramp. Make sure to account for that. You could even purposely hesitate before releasing the cart, so it is easy to tell in your table of data when the experiment actually starts.

10) Record your data in a spreadsheet. A spreadsheet has been provided in the GDRIVE. When you record the angle of your incline make sure to convert to radians: excel only computes things in radians. To convert degrees to radians type the following:

    =radians("angle in degrees")

11) In your spreadsheet you need to calculate the acceleration of the cart down the ramp with and without friction. Without friction is easy, since you set $\mu=0$. To include friction in the calculation set $\mu=0.008$.
12) Program your spreadsheet so that it calculates where the cart should be at each time step. This will be x_{calc} . When you include friction that should be $x_{calc\_friction}$. Note: the motion sensor only measures positive values.
13) Calculate the percent difference between $x_{measured}$ and x_{calc} . Do the same for $x_{measured}$ and $x_{calc\_friction}$.
14) If you carefully programmed your spreadsheet you should be able to repeat the entire experiment very quickly.
15) Place a large amount of weight in the cart (1 large black bar, or a couple of small ones). Repeat step 9. Make sure to take data at the same time stamps that you used in step 9. This will be the data in your second data sheet.
16) Place more weight in the cart, so that the little basket on top is totally full and repeat step 9 again. That data will comprise your third data sheet.
17) Create a fourth data sheet called "Questions". Use that to answer the questions at the end of the lab.

Questions:

1) Was the motion of the cart down the ramp reasonably independent of mass? According to the math it should be. Discuss.
2) How much of a role did friction play in this experiment? Are the dynamics carts "frictionless"?
3) What provides the frictional force in this experiment? Are there more sources than just 1?
4) At what angle will the frictional force be maximized, according to the math?