Introduction  This is the second part of the lab that you started last week. If you happen to have missed that lab then you should go back and read it first since this lab will assume you already know about certain concepts and will not re-explain them. For example, you will need to already understand Free-Body Diagrams (F.B.D.s) and how to apply Newton’s 2nd Law to them.

Last week we discussed the normal force, weight, tension, and equilibrium. This week you will still be using these ideas but you will also be introduced to some new forces as well as discussing non-equilibrium situations.

Part 1 – Two Objects, Horizontal Surface  When you are dealing with a rotating pulley that is approximately massless and frictionless (like the ones you are using in lab) then you can approximate the tension on either side of the pulley to be the same.

A) Open the file called MOTION SENSOR on the computer.

B) Make a chart in your lab report like Chart 1 on the next page.

C) Go to one of the digital mass scales in the lab and measure the mass of the cart along with the fan attachment. Place the value in the chart.

D) Move the adjustable feet brackets so that one is about 15 cm from the end with the motion sensor. Next, get a level at the front of the lab room and level the track. There are adjustable feet that you can rotate to raise or lower the track. See Figure 4 below.

E) Attach a fan to the cart. Place the cart on the track about 50 cm from the motion sensor. This will always be the starting position of the cart. There should be a string attached to the cart via a paperclip. Have the string slung over the pulley with the other end attached to the mass hanger. See Figure 4. Also make sure that the string goes UNDER the stop bracket. Once you have done all this the cart will want to move but you should hold it in place.

F) Place the small cardboard box directly below the mass hanger. The box will “catch” the hanger when it falls.
G) Have one of the people in your lab group at the end of the track to catch the cart and prevent it from slamming into the stop bracket. Once you release the cart it will have a high acceleration so make sure you catch it. If you break a cart you will have to pay for it.

H) Place a combined mass of 250 g on this mass hanger. The combined mass should include the mass of the hanger which is always 50 g. Place this value in the chart.

<table>
<thead>
<tr>
<th>Chart 1</th>
<th>Part 1</th>
<th>Part 2</th>
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<tbody>
<tr>
<td>Cart Mass</td>
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<td>Hanging Mass</td>
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<td>“a” – Trial 1</td>
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<td>Average “a”</td>
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<td>“T” Hanging</td>
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<td>“T” Cart</td>
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I) Push COLLECT on the computer. Wait until you hear the motion sensor begin to click and then release the cart.

J) Highlight the mostly straight region of the graph with your mouse by holding and clicking. Push the “R=” button. This will give several pieces of information including the slope of the line. What does the slope of a v vs. t give you? If you don’t remember then go back and read the Acceleration lab. Record this value in the chart.

K) Repeat I) and J) two more times and place these values in the chart. Calculate an average value and place it in the chart. Place the mass hanger on the table so that it doesn’t pull on the cart anymore.

L) Draw appropriately labeled F.B.D.s for the cart and the hanging mass. NOTE: Make sure that, when you label your positive directions, they always point in the direction of motion for each object.
**M)** Apply Newton’s 2\textsuperscript{nd} Law to both objects for as many axes as possible.

**N)** Solve each applicable equation for the tension, $T$, \textit{algebraically}. Solve each applicable equation for the normal force, $F_n$, \textit{algebraically}.

**O)** Plug in the masses from your chart as well as any other constants you need and calculate the tension from each equation. Place these values in the chart.

**P)** Calculate a percent difference between the two tension values and place this in the chart. If your percent is greater than 15\% then you made a mistake. Go back and find your error.

**Question 1** The tension values should have come out exactly the same for either side of the pulley (as mentioned at the beginning of this section). Why do you think they didn’t? Is it just a systematic error, bad data taking, or is it something else?

**Part 2 – Two Objects, Angled Surface** You are now going to follow the same procedure as the last section but now you will be doing it with the track at an angle. See Figure 5 on the next page.

**Question 2** How do you think angling the track will affect your results? Which results will change?

**A)** Adjust the feet that support the track so that they are 100 cm apart. Make sure that neither support is closer than 50 cm from an end.

**B)** There is a wood block on your table with an arrow on the edge of it. Place it under the adjustable foot that is closest to the pulley so that the arrow is pointing \textit{up}.

**C)** Using the same masses, repeat the procedure you used to find your acceleration from Part 2. The only thing that has been changed is the angled track. Record your acceleration values in the chart and find your average.

**D)** Draw appropriately labeled F.B.D.s for the cart and the hanging mass. Make sure you take into account that the track is at an angle. Looking back at Part 1 might help.

**Question 3** Explain in detail (not just “because we changed the angle”) why your acceleration value came out less than the one from Part 2. HINT: The answer is in your F.B.D. of the cart.

**E)** Apply Newton’s 2\textsuperscript{nd} Law to both objects for as many axes as possible.

**F)** Solve each applicable equation for the tension, $T$, \textit{algebraically}. Solve each applicable equation for the normal force, $F_n$, \textit{algebraically}. You will plug in numbers later.
G) In order to calculate the tension from these equations you need the angle, $\theta$, of the track. You are going to use a right triangle (in black in Figure 5 below) where the hypotenuse is the 100 cm between the feet and the height, $h$, is the height of the block. Remove the block from under the foot of the track and use the ruler on the track to measure its height. Using a trig function, calculate the angle, $\theta$.

![Diagram of a tilted track with a right triangle showing the hypotenuse, 100 cm, and the height, h, and angle, $\theta$.]

H) Plug in the masses from your chart, the angle you just calculated, as well as any other constants you need and calculate the tension from each equation. Place these values in the chart.

I) Calculate a percent difference between the two tension values and place this in the chart. If your percent is greater than 15% then you made a mistake. Go back and find your error.

**Question 4** How does the normal force on the cart from Part 2 and Part 3 differ? What caused them to be different?
Your results should also verify that the reading on the computer is not giving you a measurement of the weight on the platform. You saw this in Part 1 as well. The reading is always giving you the normal force.

F) Describe two physical situations in which $F_n \neq W$.

Part 3 – External Force, A Fan
On your cart there is a battery operated fan that is now going to act as an external force on the cart.

A) Make a chart in your lab report like Chart 2.

<table>
<thead>
<tr>
<th>m</th>
<th>a</th>
<th>$F_{ext}$</th>
</tr>
</thead>
</table>

B) Note the mass of the fan plus the cart in the chart.

C) Set up the fan cart such that the thrust of the fan accelerates the cart toward the sensor. If you are unsure set the cart down and turn it on! Which way does it move?

D) Close open MOTION SENSOR #2.cml

E) Remove the block from under the track so that it is now horizontal. Place the cart (without the string attached) on the track far from the motion sensor and with the arrow pointing towards the motion sensor. NOTE: The longer you leave the fan on the worse your results are going to be. As the battery drains the fan spins slower and you need to have it as constant as possible. So, shut the fan off as soon as you are done.

F) Make sure someone is ready catch the cart before you release it. Push COLLECT on the computer, turn on the fan, and release it.

G) Highlight the mostly straight region of the graph. Push the “R=” button. Omit the negative sign and record your acceleration in the chart.

H) Draw an F.B.D. of the cart and fan as one object. Label the force due to the fan as $F_{ext}$.

I) Apply Newton’s 2nd Law to your object and calculate the external force due to the fan. Record this value in the chart. This is the constant (hopefully) force due to the fan. *You will use it in the next part of the lab.*
Part 4 – External Force With Multiple Objects  You will now be doing Part 1 (earlier in the lab) over again but with an external force due to the fan acting on the cart.

Question 5  With everything set the same as in Part 1 except for the fan acting on the cart, in which direction will the cart move? How do you know this? Explain. (You should be able to tell just by comparing two numbers. Which ones?)

A) Move the adjustable feet brackets so that each one is about 15 cm from an end.

B) Set up your system the same as in Part 2 except now with the fan acting on the cart. The fan acceleration again should be towards the motion sensor.

C) Make sure you have a catcher ready. Hold the cart at starting position. Push COLLECT on the computer, turn on the fan, and release the cart.

D) Make a chart in your lab report like Chart 3.

E) Measure the acceleration from the graph and put it in the chart.

F) Draw an appropriately labeled Free-Body Diagrams for the cart/fan and the hanging mass.

G) Apply Newton’s 2nd Law to both objects. You don’t need to do one for the cart/fan on the y-axis.

H) Solve for the tension algebraically in both equations. Set the two equations equal to each other and then plug your numbers in to calculate the acceleration of the system. Put this value in the chart.

I) Calculate a percent difference between the two acceleration values and place this in the chart. If your percent is greater than 15% then you made a mistake. Go back and find your error.

J) Please remove the fan from the cart as well as the attached string. Thanks!

What You Need To Turn In:

Answer all the questions asked in the lab. Make sure you include all the charts as well. You must show your work for all of the Newton’s 2nd Law equations.