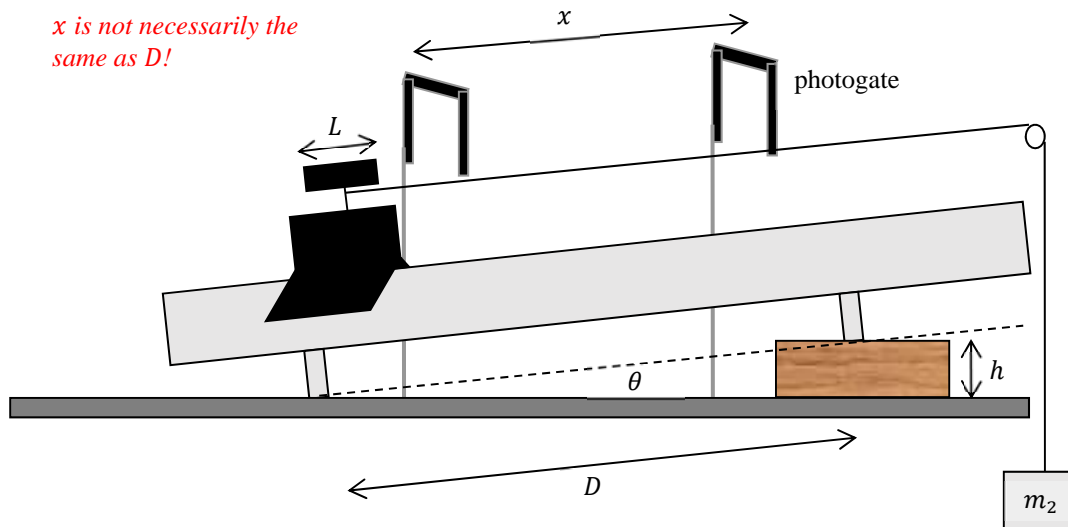


Newton's Second Law Part II

Apparatus: Air track glider (1 per track), air tracks, air supplies, air supply hoses & power cords, air track accessories kit, wood blocks, scissors, photogate heads, photogate interface cables, photogate stands, pulley cord, meter sticks, calipers, PASCO Science Workshop 750 Interface & Power Supplies

Purpose: To gain additional practice drawing force diagrams and solving force problems using Newton's 2nd Law. To predict and measure the acceleration of a cart up an inclined track pulled by a hanging mass.

Procedure:



- Before raising one end of the air track, verify it is level. To be sure it is level place a cart on the leveled air track at rest. If the cart starts moving it is not quite level.
- Place one of the black flags on the glider. Measure the length L of the black flag by placing up to the air track (which has a ruler built into it).
- Record the mass of the glider as m_1 .
- Raise one end of the air track by placing a wooden block under the single leg of the air track.
- Measure the distance between the legs D and the height of the block h . Use calipers for h .
- It turns out that in your equations today, only $\sin \theta$ appears. Rather than determining the angle θ used, we can use D and h to determine $\sin \theta$ directly! Draw a triangle labeling the sides (one should be D and one should be h). Determine if $\sin \theta$ is given by h/D or D/h .
- Prepare the track with a pulley at the raised end. The string that runs over the pulley should connect to both a mass hanger and to the glider.
- Open the Data Studio program on the computer.
- Once you get to the interface set-up window add two photogates to the interface box. You will want to measure the time in each gate and the velocity in each gate. The instructions for doing this are in the appendices.
- Set-up two photogates above the air track. The photogates should be set up to have the black metal flag on the glider pass through the photogate. You can verify this if the little red light on the photogate turns on as the black flag crosses through the photogate.
- ALSO, the photogates should be set up in such a way that the glider passes through both photogates prior to the mass hanger reaching the ground. Place them as far apart as possible while still allowing this to occur. Try to pick a convenient distance like 0.500 m.

- Once you are certain that the photogates are properly set up, hang a mass on the mass hanger that is substantial enough to cause the glider to slowly accelerate up the plane. With a single block (or two blocks) you'll probably need to use all the little masses in the air track accessories kit. In general, a mass that is more than $m_1 \sin \theta$ (perhaps about 15 or 20 grams) will cause the block to slide up.
- The photogates record the time it takes for the black flag to cross through the first photogate t_0 and the second photogate t . Earlier you recorded the length of the black flag. You may assume the cart moves at an approximately constant speed during the time the photogate activated. Also, you know that during the time the photogate is activated the cart must travel the length of the flag. Use these numbers to calculate the velocity of the cart at the first photogate ($v_0 = L/t_0$) and at the second photogate ($v = L/t$). This should also be recorded in your data by the DataStudio program. Check a few to be sure it is working and then you can stop doing the calculation yourself.
- Now use the velocity of the first photogate (v_0), the velocity at the second photogate (v), and the distance between the photogates (x) to determine the **experimental acceleration** of the glider. Hint: Use the appropriate 1D kinematics equations. In your calculations section, first solve the appropriate equation for a . Then plug in the numbers and show one sample calculation.
- **Repeat this experiment 10 times; 5 times each for two angles with the same hanging mass m_2 .**

In your calculations section:

- Derive the expression which determines a_{exp} in terms of the velocities and $v_0, v, & x$.
- Draw a free body diagram (FBD) for both the glider and the mass hanger. Label the glider as m_1 and the mass hanger as m_2 . Assume the object will accelerate up the plane and that the air track is essentially frictionless.
- Use Newton's laws to derive a formula for the acceleration in terms of the masses, the angle, and the acceleration due to gravity. This is the **theoretical acceleration**. Check the units.
- Calculate the theoretical acceleration by plugging numbers into the formula you derived from Newton's laws earlier.
- Recall that $\sigma_{a_{exp}}$ is essentially δa_{exp} . Use this to estimate the %precision. Note: if the standard deviation is zero then you must use another method to determine the error.
- Determine the percent difference for this experiment.

Conclusions:

1. Were Newton's laws in good agreement with kinematics? Compare the %precision to the %difference. Comments to help you understand this appear on the next page of the handout.
2. Looking back on all the data you took, is there a single measurement that stands out as the largest contributor to error? Defend your answer.
3. Suppose $m_2 \gg m_1$. What *approximate* acceleration magnitude should the blocks have?
4. Suppose the angle was 0° . How does the equation for the theoretical acceleration simplify? Write down the simplified formula and compare it to the formula from last week's lab...
5. What if the angle was 90° ? Write down the formula for a_{th} in this case & compare your theoretical acceleration to the Atwood's Machine example in your textbook. Does it make sense at 90° if the masses are equal?

Going Further: Create a contour plot in MATLAB showing a for $m_2 = 0$ to 400g, $\theta = 0$ to 90° , & $m_1 = 200$ g.

Comments on % precision versus % difference

- Think of % precision as the number of sig figs on your final result. If you have a lot of sig figs on your final result it is very precise (lots of sig figs). This can be true even if your answer is “way off”.
- Think of % percent difference as quantifying how off you are from theory.
- If % difference is greater than % precision, the experiment is NOT in good agreement with theory. You have small bullet holes, closely grouped hitting far from the bull’s eye.
- If % difference is less than (or *approximately* equal to) % difference, the experiment is in good agreement with theory. Most of the bullets are hitting the bull’s eye. Note: in experiments with large % precision, (huge bullets) and you are very likely to agree with theory (to hit the target), but that doesn’t mean your results are very useful.
- We strive for experiments with small bullets (good precision) and hit the target (good agreement)

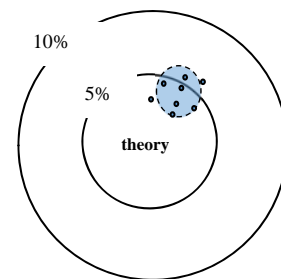
The *upper* figure at right shows one possible target diagram for this experiment. Several measurements were taken and each measurement had at least three sig figs. Because the individual measurements have several sig figs, each appears as a tiny dot.

Unfortunately, each measurement differs significantly from the others. Since we took several measurements the target looks like it was hit with a shotgun blast.

Distance from the bull’s-eye to the center of the shotgun blast represents % difference.

The spread in the dots (blue circle) represents % precision ($\frac{\sigma}{\text{average}} \times 100\%$).

Notice the % precision looks like it is about 4% based on the scale of the 5% ring.



The *lower* figure at right shows another possible target diagram for this experiment.

In this case, the measurements each have nearly identical values.

Unfortunately, each individual measurement might have only 1 or 2 sig figs.

Each bullet radius is larger than the blue circle defined by $\frac{\sigma}{\text{average}} \times 100\%$.

Distance from the bull’s-eye to the center of the shotgun blast represents % difference.

In this case we should use sig fig rules or propagation of error techniques to compute % precision. In this case the % precision looks like it is about 5% based on the scale of the 5% ring.

