Physics 2010 – Spring 2006
Laboratory 1: Motion and Gravity

NAME ______________________________
Section Day (circle): M Tu W Th F
Section Time: 8a 10a 12p 2p 4p

In this lab you will be working with air tracks and playing around (in a scientific way) to discover some properties of motion, acceleration, and effects of gravity. Have fun and learn some good physics!

Instructions

- **Your first priority in any lab is safety.** The good news is that there are relatively few ways to hurt yourself or others in this lab. Still, pay attention at all times to what you and your lab mates are doing.
- Your next priority is to treat the equipment safely and respectfully. They are cool instruments, but they are sensitive and easily broken. The air tracks and gliders can be destroyed if their surfaces are gouged or bent. Do not elevate the air tracks past approximately 10 degrees.
- **DO NOT BRING FOOD OR DRINK TO THE LAB.**
- Work the prelab problems *before* the lab. Failure to turn in the prelab before the lab will result in a 2-point penalty for the lab. You are encouraged to make a copy of your prelab responses, so you can refer to them in the lab.
- In the lab, use the space provided for short answers, and attach your own paper for extended analysis and commentary.
- All plots should have axes drawn neatly with a straightedge, with scales and units clearly labeled.
- A measurement is *wrong* if it has units and they are not specified.
- Measurements made with real equipment are not infinitely precise. It is important to report enough figures of a result so that all the real information from the measurement is conveyed. However, it's equally wrong – and more misleading – to report more digits than are significant!

Prelab Questions

1. Describe the difference between average velocity and instantaneous velocity.
2. If you take the average velocity over some period of time (say 1 hour on a car trip), is it possible that the instantaneous velocity at any moment during that period is larger than the average velocity?
3. What are some real world conditions where you measure instantaneous velocity? What about average velocity?

4. The equation of motion for constant acceleration is:

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$

   Assume you start from rest, so $v_0 = 0$. Solve for the displacement $x - x_0$. Then solve for acceleration, a, in terms of $(x - x_0)$ and t.

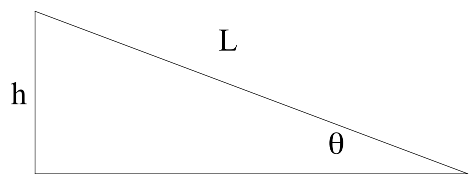
5. Given a plot of distance versus $(\text{time})^2$, which feature of the curve represents acceleration?

6. Assume the photogate timers read the time to 0.001 s precision and you measure distances using a ruler with 0.1 cm precision.

   a) If you set two photogates 88.3 cm apart and the glider travels between them in 0.379 s, how would you report the average velocity? Use the correct number of significant figures.

   b) Repeat, with the gates 8.8 cm apart and the glider traveling in 0.038 s.

7. In the following triangle, what is θ in terms of h and L? Use trigonometric functions in your answer.



8. Let the acceleration due to gravity be g. What is the acceleration (call it a) *along the track* of a glider whose track is tilted at an angle θ to the ground, as in the previous question? Make sure your answer makes sense in the "limiting cases" where $\theta \to 0$ and $\theta \to 90°$.

1 Setting Up (15 min.)

In this lab we work with gliders moving along the air track. The speed of a glider on the track will be measured with *photogate timers.* A card 10.0 cm long, placed on top of the glider, interrupts a light beam in the photogate and triggers a timer (See Fig. 1). The photogate timer can be used to measure either the time for the glider to travel between two gates (when the timer control is set to PULSE mode), or the time for the card to pass through one gate (when set to GATE mode). The timer can be set to read either milliseconds (ms or msec) or 0.1 ms. With 0.1 ms resolution, the timer will count up to a maximum of 2 s before overflow.

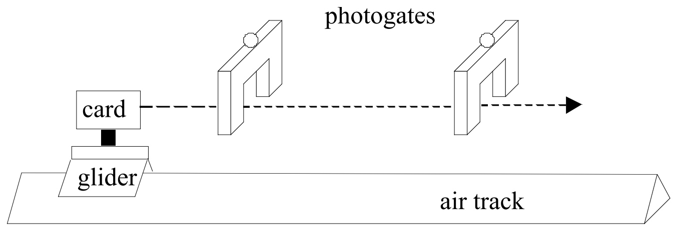


Figure 1: Air track, glider with card attached, and two photogates.

1. Turn on the air tracks (get instructions from the TA).
2. Level your track: with the air on, place a glider on the track, and adjust the track's feet until the glider can remain stationary on the track, not sliding one way or the other.
3. Place *one* glider on the track, and play around in order to get a feel for how the cart moves, and determine how the timers work (see sample setup in Fig. 1). Ask the TA for help if you are stuck.

Describe or sketch the set-up and answer the following questions:

A. How are the air track / glider different from objects you normally encounter?

B. Why do we have them in the lab (instead of pushing a block on a table for instance)?

Make a couple of measurements of how long it takes for a glider to pass through a gate when you gently push it. Note the times in your lab books. In your groups discuss the following and answer:

C. Are the measurements always the same?

D. What is the best method to get the most accurate measure of the time it takes for a glider to pass through a gate: Take any one measurement? Average all measurements? Take the "middle-most" measurement?

2 Instantaneous vs. Average Velocity (10 min.)

Using the setups you have, play with the timers in the PULSE mode and the GATE mode. Note the differences in your worksheet or notebook. Answer the following questions in the space provided. (Hint: consider the definitions of instantaneous and average velocity. Which equations describe each?)

E. How can you measure average velocity?

F. How can you measure approximately the instantaneous velocity?

G. Convince your lab partners of your answers to Prelab problem 3. Collectively agree on good examples and write them down.

3 Measuring Gravity on an Incline (45 min)

Galileo figured out you could reduce the effects of gravity by placing an object on a slope – that is, by only having a portion of the earth's gravity pulling in the direction of motion along an inclined plane. (OK, a lot of people realized this before him, but he expressed it quantitatively!)

Play around with the air tracks by raising one end and placing a block under it. **NEVER INCLINE THE TRACK MORE THAN 10 DEGREES.** Convince yourself (make measurements) that an object accelerates faster when the track is steeper. Log your findings. Compare each of these results to an object (not the glider!) that you drop straight down from the same height. (You need not measure the time of free-fall, but note whether the glider or object falls faster in each case).

H. Describe these activities, including any data you collect, on a separate sheet of paper.

Now, let's get quantitative. Fix your angle of incline for the track. Make it somewhere between 5 and 9 degrees. Try to use a different angle from the groups around you. Record the following procedure on a separate sheet of paper.

I. Measure your angle. Use either a protractor or – better yet – measure distances and use trigonometry (see Prelab).

Take measurements of how long the glider takes to travel different distances. *It's very important that the glider starts at rest.* Don't give it a shove – even a slight nudge will throw off the measurement. Think creatively of ways to let the glider go with a minimal velocity. Describe your technique. A good test of how well you've succeeded is whether your measurement is reliably repeatable. Take several measurements for each distance, and calculate the average of the reasonable results.

J. Measure how long it takes the glider to travel from rest to 0.25m away.

K. Pick three other distances, each successively longer, and measure the time it takes to travel from rest to each of these distances. Do you need to make more than one measurement of each of these distances?

L. Make a table of the distance traveled $(x - x_0)$ versus time. Do you see a pattern? (No is an acceptable answer provided that you justify it.)

M. Add another column to your table: t^2 (time squared). Do you see a relation between $(x - x_0)$ and t^2? Try plotting one versus the other. Make sure to label your axes and use units.

N. Solve for acceleration using your data and/or graph. (Note: use Prelab work.) Is this more or less than the acceleration due to gravity? Does this make sense? Explain why or why not.

O. Compare your incline angle and your acceleration with the results from a couple of nearby groups. Describe how the acceleration depends on the angle. Do the results agree with the predictions of the Prelab?

4 The Angle Challenge (20 min)

Your TA will set up an air track at a fixed angle that only he or she knows. You are only allowed to measure distances along the air track (only L, not vertical or horizontal). Your team will be able to make one measurement of the glider running down an air track, and repeat the exact same measurement twice (no fair moving gates or changing the starting position between trials!). Based on the result of *your* measurement only, calculate the angle of inclination. Each group will only have a few minutes with the air track, so plan carefully.

Note that you have to think about a lot of experimental issues: where to place the gates; when, where, and how to let the glider go; etc. You only get one shot at this, so try your best to get it right.

In the last 10 min of lab, each team will present their measurement of the angle with reasoning and estimated uncertainty. The team with the most accurate answer (and best estimate of uncertainty) will be selected for a special reward.