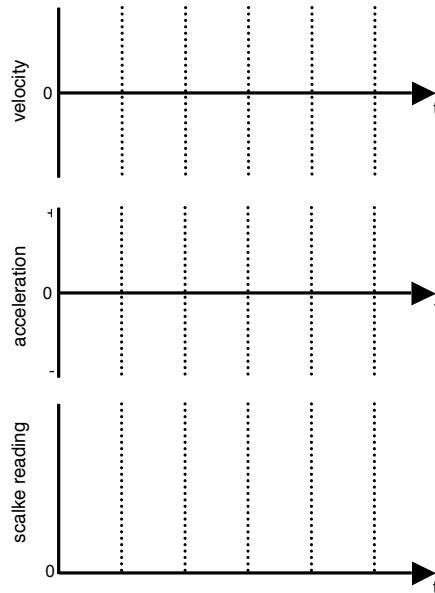


PRELAB: FORCES AND MOTION

1. Sketch Prediction 1-1 on the axes at the right.
Explain the reasoning behind your acceleration graph.

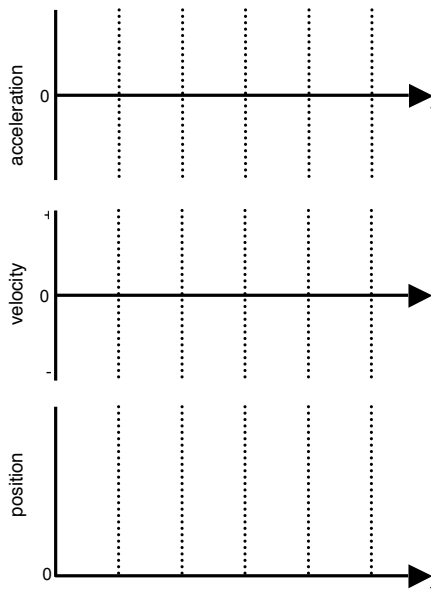
Prediction 1-1



2. Draw the free body diagrams deccribed in Step 1 of Investigation 2.

3. Sketch Prediction 3-2 on the axes at the right. Explain the reasoning behind your prediction.

Prediction 3-2



FORCES AND MOTION

Topic: Newton's 1st and 2nd laws

Overview:

You will be investigating the relationship between forces and motion in a series of three short investigations. The investigations can be performed and analyzed in any order.

Writing it up: Throughout this handout, you will be asked to answer questions, sketch graphs and diagrams, and do calculations. Write these things in your lab notebook *as you go through the experiment*. Label each answer/graph/calculation/diagram so that you (or your lab TA) can find things quickly. If you have any computer printouts (such as graphs), remember to affix them to your lab notebook. After lab, write a short (<300 words) conclusion of the experiment that summarizes what you did and the major findings of the experiment.

Investigation 1: The elevator

In this short experiment, you will place a mass on a scale and observe what happens to the scale's reading as you ride the elevator.

Prediction 1-1 (Going up): Sketch your prediction of velocity, acceleration and scale reading as a function of time for a ride from the 1st floor to the 2nd floor from the time the elevator starts moving until it is at rest on the second floor on the axes provided. Label important events (such as "elevator starts moving," "elevator stops speeding up") on your graph. Arrange the three sets of axes vertically, so that the time axes line up (as shown in the prelab). Explain the reasoning behind your predictions for acceleration and scale reading.

1. There is no way (using the equipment provided) to directly generate velocity and acceleration graphs for the motion. Instead, check your prediction concerning the velocity and acceleration graphs with your partner. Resolve any inconsistencies.
2. Test your prediction concerning the scale's reading. Record the scale's readings. Compare your data to your prediction. If your observations do not match your predictions, figure out why.

Q1-1: Is the scale's reading equal to the net force on the object at any point during the ride? If so, when? Explain your answer.

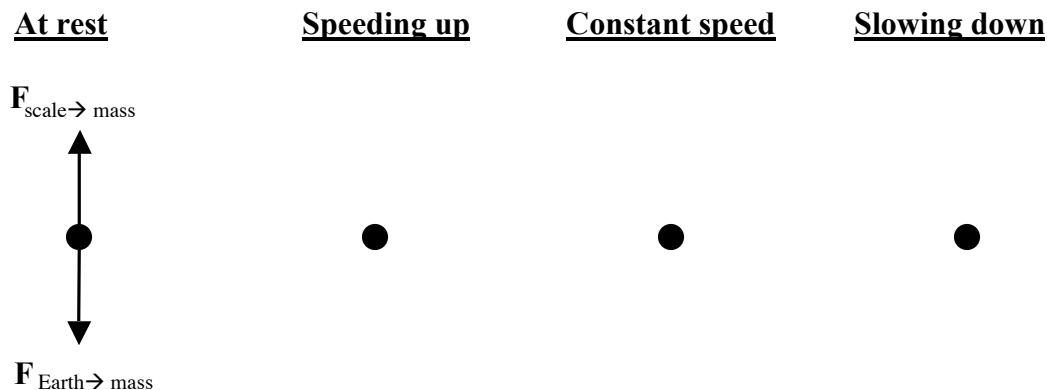
Q1-2: Is the scale's reading equal to the weight of the object at any point during the ride? If so, when? Explain your answers. (Note: The downward gravitational force the earth exerts on an object is referred to as weight).

Q1-3: What force does the scale reading equal?

Prediction 1-2 (Going down): Sketch prediction graphs of velocity, acceleration and scale reading for a downward ride from the 2nd floor to the 1st floor.

3. Check Prediction 1-2.

4. Sketch a free body diagram for the mass sitting on the scale during each phase of the upward ride. (There should be three diagrams). Label each force completely. Each force label should clearly indicate the object being pushed (or pulled) and the object doing the pushing (or pulling). For example, the gravitational force the earth exerts on the mass would be written as $F_{\text{earth} \rightarrow \text{mass}}$ (see example below). Each arrow should indicate the direction of the force. The length of the arrow should indicate the strength of the force. Keep the same scale for all three force diagrams; two forces of equal magnitude should be drawn the same length, even if the two arrows appear on different diagrams. Complete the force diagrams below.



5. Sketch free body diagrams for each phase of the downward ride.
6. Use your data to estimate the acceleration of the elevator during each phase of the two rides.
- Q1-4: Are the algebraic signs of the acceleration values consistent with your predictions? Are the values larger or smaller than you expected? If your observations do not match your predictions, figure out why.
- Q1-5: You just used the scale's readings to estimate the elevator's acceleration during various phases of the ride. Can you use the scale readings to estimate the cruising speed of the elevator? Explain.

Investigation 2: Falling coffee filter

In this short experiment, you will investigate the flight of a falling coffee filter.

1. Sketch a free body diagram for the single coffee falling through the air at three different instants:
 - immediately after release
 - after release, but before the filter stops speeding up, and
 - after the filter stops speeding up.

Clearly label each force by indicating the object being pushed/pulled and the object doing the pushing/pulling (e.g. $F_{\text{earth} \rightarrow \text{filter}}$). Make sure each vector has a length that corresponds to the strength of the force. Use the same scale for your vectors on all three diagrams.

Prediction 2-1: Sketch your prediction of net force, acceleration and velocity as a function of time for the filter, from the time it is released until the filter is at rest on the ground. Label important events on your graph. Explain the reasoning behind your prediction for acceleration.

2. To check your predictions, you will use an ultrasonic position detector connected to a computer. Double click on the file “coffee.ds” to set up the computer. Position the coffee filter under the detector and click the green start button. Release the coffee filter. Click on the stop button after the filter hits the ground. The computer will produce a position-time graph for the motion of the filter. Record the graph in your notes or attach a printout to your lab notebook. Identify important features on the graph.
3. To check the data against your prediction, you will need to use the position-time graph to infer the shape of velocity-time and acceleration-time graphs.
 - Q2-1: Compare your inferred acceleration-time and velocity-time graphs with your predictions. Resolve any discrepancies.
 - Q2-2: Does the acceleration increase or decrease with time? Is this result consistent with the free body diagrams you drew in Step 1? Explain.
 - Q2-3: Which direction does the acceleration vector point? Explain how you can deduce this from the changes in the velocity vector.

Notes about the ultrasonic detector: The detector works by emitting a sound and “listening” for the reflection. The “position” reported by the detector is simply the distance from the object to the detector. The detector is not reliable for distances less than about 15 cm or for distances beyond about 2 m.

Investigation 3: On the air track

In this investigation, you will investigate the motion of a glider that rides on an almost frictionless surface. You will observe how forces acting on the glider affect its motion.

Notes about using the air track:

- Do not slide the glider along the air track when the air source is off (to avoid damage to the air track).
- Avoid touching the air track surface or the underside of the glider (to avoid damage to the air track).
- Minimize the amount of time the air source is on (to minimize noise and heat).

Before you take data:

- Check to see if the air track is horizontal. Place the glider on the track and turn on the air source. If the track is not level, the cart will move in one direction or the other when the air is turned on. Try a few different spots. If the glider goes consistently one direction of the other, your air track is not level. If your air track is way out of level, consult your TA.
- Lay the spring scale on a horizontal surface. Make sure the scale reads zero when the hook is not being pulled. (You may need to adjust the spring scale to make this happen).

Activity 3-1: Pull and release

In this section, you will observe what happens you give the glider a brief pull to the right and then release it.



Prediction 3-1: Suppose you gave the glider a brief pull to the right and released it. Describe the velocity, applied force and acceleration of the glider in words.

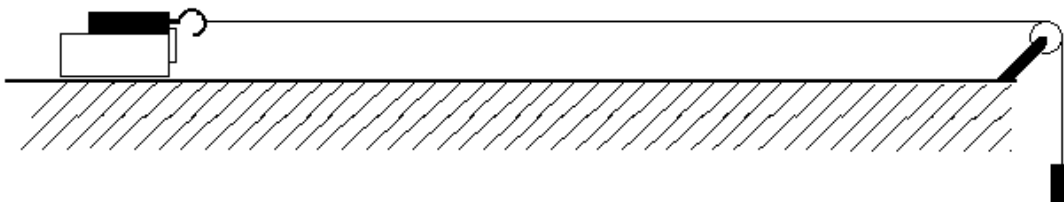
1. Set up the glider and spring scale as shown above. The body of the spring scale should rest against the metal plate attached to the front of the glider, as shown above. (This ensures that the glider gets pulled along by your hand).
2. Test Prediction 3-1 qualitatively. Turn on the air source while holding the hook of the spring scale. Give the glider a brief pull, release it and observe the motion of the glider and the reading on the scale. Stop the glider and turn off the air source. Sketch qualitative graphs for the observed velocity, scale reading and acceleration as functions of time.

Q3-1: Is the scale's reading equal to the net force on the glider during each phase of the motion? Explain.

Q3-2: Once the glider is moving, how much force is required to keep the glider moving at constant velocity?

Activity 3-2: A steady pull

In this section, you will observe what happens as the glider is pulled to the right by a constant force.



1. Set up the glider, spring scale, string and hanging mass as shown above. Select a hanging mass that is large enough that the scale can be easily read, but is small enough that the motion is slow enough to observe. The body of the spring scale should rest against the metal plate attached to the front of the glider. (This ensures that the glider gets pulled along by the string). Adjust the position of the pulley so that the string is horizontal.
2. Turn on the air source while holding the glider. Note the scale's reading. (If the force value recorded by the scale is too small to read easily, increase the hanging mass). Release the glider and observe what happens to the scale's reading. Stop the glider before the hanging mass can hit the floor. (You may need to practice this a few times to see when changes in the scale's reading occur). Shut off the air source. Sketch a graph of the scale's reading vs. time in your notes. Indicate the moment that you released the glider on your graph. Record the value of the hanging mass.

Q3-3: Is the scale's reading equal to the net force on the glider before you release the glider? Explain.

Q3-4: Is the scale's reading equal to the net force on the cart after you release the glider? Explain.

Q3-5: Use Newton's 2nd law to estimate the acceleration of the glider after it is released. (Hint: You will need to measure the mass of the stuff being pulled to the right by the string.)

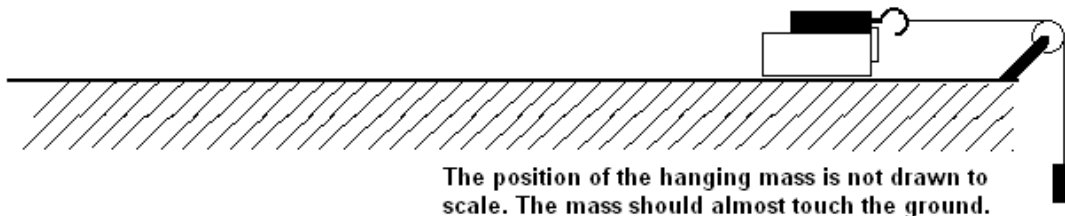
Prediction 3-2: Sketch prediction graphs for acceleration-time, velocity-time and position-time for the motion of the glider you just observed.

3. Use the spark timer to check Prediction 3-3. To save time, use Excel to calculate the velocity values and to plot the position and velocity graphs. Do not bother to construct an acceleration graph from the spark timer data. Use the velocity graph to determine the acceleration value (both magnitude and direction).
- Q3-6: Do the shapes of the position and velocity graphs match your predictions? If not, resolve the inconsistencies.
- Q3-7: Would you expect the magnitude of the acceleration that you measured using the spark timer to be *larger than*, *smaller than*, or *the same as* the acceleration the glider had when the spark tape was not attached to the glider? Explain.

Compare the acceleration value you just found from the spark data with the value you predicted using Newton's Law in Q3-5. Is this what you expect?

Activity 3-3: There and back again

Again the glider is pulled to the right by the string, but this time the glider starts at the right end of the track. You will give the glider a brief push up the ramp, so that the glider slows down, reverses direction and returns to your hand.



Prediction 3-3: Sketch prediction graphs for scale reading-time, acceleration-time and velocity-time for the motion of glider, from the moment you release the glider until just before you stop it.

1. Place the glider at the right end of the air track as shown above. (Use the same hanging mass as before. You should also be able to use the same string as before). Hold the glider and turn on the air source. Note the scale's reading. Turn on the air source. Give the glider a brief (but strong) push up the ramp and observe what happens to the scale's reading. The glider should slow down, reverse direction, and return to your hand. Stop the glider before the hanging mass can hit the floor. Shut off the air source. Sketch a graph of scale reading versus time. Indicate the moment you released the cart and the moment the cart reversed direction on your graph.
 - Q3-8: Is the scale's reading equal to the net force on the cart for each phase of the motion after you release the glider? Explain.
 - Q3-9: In which direction does the net force vector point before the glider reverses direction? In what direction does it point after the glider reverses direction? Explain your observations support your answers.
 - Q3-10: Based on your answer to the previous question, determine the direction of the acceleration vector during each phase of the motion.
 - Q3-11: Does the magnitude of the acceleration vector *increase*, *decrease* or *remain unchanged* during the motion? Explain how your answer is supported by your observations.
 - Q3-12: Based on your observations, determine the direction of the velocity vector during each phase of the motion.
 - Q3-13: Based on your observations, describe how the magnitude of the velocity vector changes during the motion.
 - Q3-14: Based on your analysis so far, draw velocity and acceleration graphs of the motion. Indicate the moment that the glider reverses direction on each graph. Make sure that the algebraic signs you use are consistent with the directions of the vectors.
 - Q3-15: Does the slope of your velocity graph change at any moment during the motion? Should it? Explain.