

Introduction

In this lab you will study the motion of an object that travels with a constant acceleration. You will do experiments with an object in “free flight” and measure the acceleration of gravity. You will then investigate the relationship between the force applied to a cart by a fan and the cart’s acceleration, and what happens if you use two fans, back to back.

Pre-lab Questions:

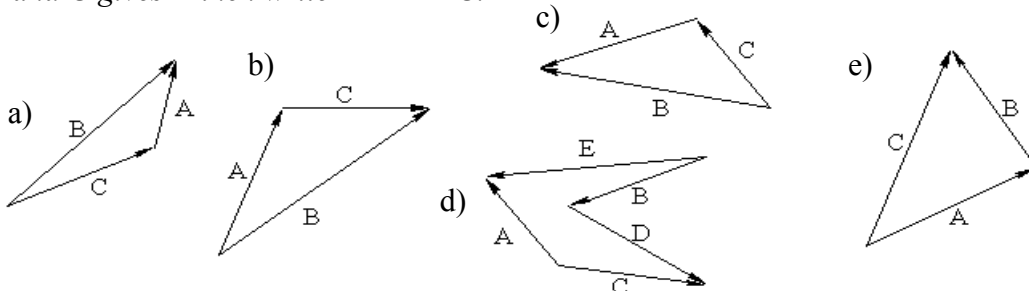
1. Vector A has a magnitude of 4.5 m and is directed due north. Vector B has a magnitude of 9.4 m and is directed 45° north of due east.

What are the (a) magnitude and (b) direction (angle relative to east) of $A + B$?

Also, what are the (c) magnitude and (d) direction (angle relative to east) of $A - B$?

Finally, what are the (e) magnitude and (f) direction (angle relative to east) of $5A - 2B$?


2. Write a vector equation for A for each arrangement of vectors. For example, if adding B and C gives A then write $A = B + C$.

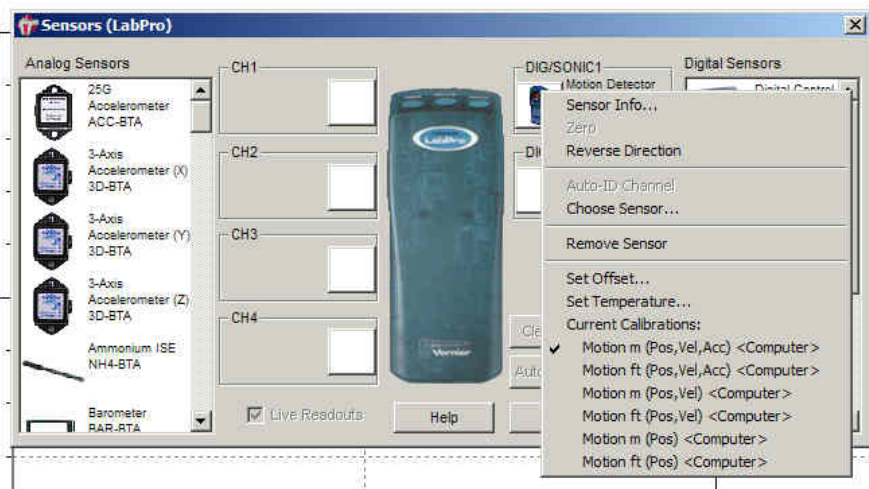


3. A ball is thrown up from the top of the tower. At each of the following instants is the ball’s acceleration larger than g , equal to g , zero, or $-g$ (assume up is positive and that $g = 9.80 \text{ m/s}^2$)
- Just after leaving your hand and you are no longer touching it?
 - When the ball is at the top of its path?
 - Just before hitting the ground?
 - Draw graphs of position vs. time, velocity vs. time, and acceleration vs. time for the ball from the instant it leaves your hand until the instant before it hits the ground.

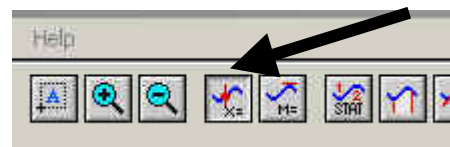
A. Motion under gravity – the Ball Drop:

Procedure

- A1.** Please place the echo sensor on the floor so that it is not near any chairs or the table. You may need to fold down the front so it is facing vertically. Open Logger Pro.
- A2.** Zero the sensor by holding a piece of paper in front of it, like in previous labs.
- A3.** Hold the ball steady as high above the sensor as you can. Click  to begin data collection. Drop the ball one second after the motion detector starts clicking. Move your hands out of the way after you release the ball. You will need a second person to catch the ball to keep it from hitting the sensor.



- A4.** Examine the distance vs. time graph. Repeat the process if your distance vs. time graph does not show a smoothly changing distance with time.
- A5.** Copy all 3 graphs into your notebook (position, velocity, and acceleration vs. time). Draw them vertically displaced from each other (like LoggerPro) so a vertical line passes through the same time instant on each graph. For each graph explain in words what is happening and how the graph corresponds to the motion of the ball.
- A6.** Repeat the ball drop a few times more. Each time examine the acceleration graph with the cursor (select with button shown on the figure to the right). Note in your record an average value of the ball's acceleration for each drop. Are they all exactly the same? Why might the accelerations differ?



B. Motion under gravity – the Ball Toss:

Procedure

Use the same setup as for the ball drop, but now throw the ball upwards.

- B1.** Start with the ball about 50 cm above the sensor, and toss the ball hard enough to reach about 2 meters above the sensor at its highest point. Toss the ball into the air one second after the motion detector starts clicking. Move your hands (and head) out of the way after you release the ball.
- B2.** Examine the distance vs. time graph. Repeat the process if your distance vs. time graph does not show a smoothly changing curve for both the up and the down

motion.

- B3.** Copy all 3 graphs into your notebook (position, velocity and acceleration vs. time). Explain in words what is happening and how the graph corresponds to the action. In particular draw vertical lines through all graphs to show these features:
- Draw a line at the time when the ball was at the top of its trajectory. Label this on the graph.
 - Note the values of position, velocity and acceleration at this point.
 - Check your answer to pre-lab question 2, especially the graph you made for part 2d. What is the acceleration at the top of the ball's motion?
 - From the acceleration graph can you tell when the ball was in free fall (the only force acting on the ball is gravity)?
 - Label the region on each graph where the ball was in free fall and moving upward.
 - Label the region on each graph where the ball was in free fall and moving downward.
 - Identify the region when the ball was being tossed but still in your hands:
 - Examine the velocity vs. time graph and identify this region. Label this on the graph.
 - Examine the acceleration vs. time graph and identify the same region. Label the graph.
- B4.** From your data can you measure the acceleration of the ball when it is in flight?
- Is the ball's acceleration constant?
 - Are your measurements of the ball's acceleration for the ball toss consistent with those you made for the ball drop experiment?

C. Motion of a Fan Powered Cart – Single Fan:

Procedure

In this experiment you will use the battery powered fans which attach to the carts you used in weeks 1 and 2. The fans clip onto the back of the carts, your TA will show you how to attach them. The fan units can run with 4, 3 or 2 batteries. The fan turns more and more slowly as batteries are removed. The purpose of the first part of this activity is to examine how the acceleration of the cart is related to the number of batteries in the fan.

- Load week3 fans.xml and use page 3 of the program.
- Move the position sensor back to the end of the track. Make sure it is oriented so that it sees the cart with a fan the whole length of the track.
- Check that the track is level.
- Start with all batteries in the fan's battery holder and the 2 "blanks" stored on top of the fan unit. Measure the cart's acceleration as it moves away from the sensor, then repeat the measurement as the cart moves towards the sensor. (Turn off the fan when not in use, this extends the battery life and makes the lab a quieter environment.) Note these values in your lab book (make a table).

- C5.** Would you expect the same acceleration each way? Explain why, or why not.
- C6.** Repeat the acceleration measurements for 3 and 2 batteries. To change the number of batteries you must remove the fan from the cart, and replace batteries in the holder under the fan with blanks from the holders above the fan housing. Always replace the batteries you removed into the space left by the blanks so that the mass of the cart remains the same.
- C7.** Measure the mass of the cart with the scales in the front of the lab.
- C8.** Calculate the product of the *mass* of the cart and the cart's *acceleration* for each battery configuration. Does this value increase, decrease or stay the same as more batteries are used? Does it correspond with the amount of "push" you feel from the fan?

D. Motion of a Fan Powered Cart — Two Opposing Fans:

Procedure

In this experiment you will use attach two fans to the cart (one "pushing forward" and one "pushing backward") and measure the acceleration of the cart.

There are only 2 extra fans for the class, not enough for each lab group to simultaneously do this part of the lab. If your group is the first to reach this section go ahead and use one of the extra fan units. When you are finished, return the fan to the back bench where you found it. If there are NO extra fan units available when your group is ready you should team up with a neighboring group for this activity.

- D1.** Set both fan units to 4 batteries and mount them back to back on the cart (they only just fit; one fan will hang over the end a little).
- D2.** Push the cart with its fans turned off along the track and note if it tends to accelerate in either direction (use the motion detector to measure). If so re-level the track.
- D3.** Discuss within your group what will happen if both fans run at the same time in opposite directions. Make your predictions in your notebook.
- D4.** Turn both fans on. Hold the cart at rest and gently let go. Does the cart now tend to move one way or the other? Measure the acceleration. Compare this with your acceleration for 4 batteries measured in **C3** above. Which is larger? Explain.
- D5.** If the acceleration you measured above was significantly different from zero can you explain what causes this?
- D6.** Now give your cart (with both fans turned on) a gentle push towards the sensor. Measure the acceleration. Repeat with a small initial push away from the sensor. Are these accelerations the same as in **D4** above? Are they the same as each other? Why do you think that is?

Conclusion:

1. Write a conclusion for the section that your TA assigns.