LABORATORY I: Description of One Dimensional Motion (Free Fall)

Introduction

In this laboratory you will measure and analyze one-dimensional motion; that is, motion along a straight line. With digital videos, you will measure the positions of moving objects at regular time intervals. You will investigate relationships among quantities useful for describing the motion of objects.

There are many possibilities for one-dimensional motion of an object. It might move at a constant speed, speed up, slow down, or exhibit some combination of these. In this particular lab you will be studying the motion of an object in free fall. That is to say that the object is only subject to acceleration due to gravity.

If your ideas are wrong, this is your chance to correct them by discussing the inconsistencies with your partners, rereading your text, or talking with your instructor. Remember, one of the reasons for doing physics in a laboratory setting is to help you confront and overcome your incorrect ideas about physics, measurements, calculations, and technical communications. Pinpointing and working on your own difficulties will help you in other parts of this physics course, and perhaps in other courses. Because people are faster at recognizing patterns in pictures than in numbers, graphing your data is an important part of this lab activity.

Objectives:

After you successfully complete this laboratory, you should be able to:

- Describe completely the motion of a falling object in one dimension using position, time, velocity, and acceleration.
- Distinguish between average quantities and instantaneous quantities for the motion of an object.
- Write the mathematical relationships among position, time, velocity, average velocity, acceleration, and average acceleration for different situations.
- Graphically analyze the motion of an object.
- Begin using technical communication skills such as keeping a laboratory journal and writing a laboratory report.

Preparation:

- Define and recognize the differences among these concepts:
    - Position, displacement, and distance.
    - Instantaneous velocity and average velocity.
    - Instantaneous acceleration and average acceleration.
- Find the slope and intercept of a straight-line graph.
- Determine the slope of a curve at any point on that curve.

Problem:

Before the end of summer arrives, you and some friends drive to Six Flags New England to ride Scream which shoots you 20-stories high only to drop you from that height. During the busy afternoon, this thrill ride is always full of people. But as the day comes to an end and the park is less crowded, you want to go on this once more. However, your friends say that the fall downwards from the top won't be as fast as it was earlier, because there is less mass in the carriage, so they don't want to go. What do you think? To determine how the acceleration of a free falling object depends on its mass, you decide to model the situation using various weights.

Equipment

You will have a set of weights, meter stick, whiteboard, and video camara. To analyze the results you will have access to computers and the Tracker software.

Warm-up & Prediction

Using attached sheet:

1. Do you think the acceleration of the free falling carriage **increases**, **decreases**, or **stays the same** as the mass of the cart increases? Explain your reasoning.
2. Sketch a graph of how you would expect an *instantaneous acceleration vs. time graph* to look for a cart released from rest on an inclined track. Next to this graph, sketch a new graph of the acceleration vs. time for a cart with a much larger mass. Explain your reasoning. Write down the equation that best represent each of these graphs. If there are constants in your equation, what kinematic quantities (position, time, velocity, and accleration) do they represent? How would you determine these constants from your graph?
3. Sketch a graph of *instantaneous velocity vs. time* for each case. Use the same scale for the time axes as the acceleration graphs. Write down the equation for each graph. If there are constants in your equation, what kinematic quantities do they represent? How would you determine these constants from your graph? Can any of the constants be determined from the equation representing the *acceleration vs. time graphs*?
4. Now do the same for *position vs. time*. Can any of the constants in your functions be determined from the equations representing the *acceleration vs. time* or *velocity vs. time graphs*?

Procedure

Exploration

Observe the motion of several different free falling masses when released from rest. **BE SURE TO CATCH THE WEIGHT BEFORE IT HITS A HARD SURFACE!** From your estimate of the size of the effect, determine the range of mass that will give the best results in this problem. Determine the first two masses you should use for the measurement.

How do you determine how many different masses do you need to use to get a conclusive answer? Explain.

When placing the camera, consider which part of the motion you wish to capture. Try different camera positions until you get the best possible video. Make sure that the 25 cm line is visible on screen. *Hint: Your video may be easier to analyze if the motion on the video screen is purely horizontal. Why? It could be useful to rotate the camera!*

Make sure everyone in your group gets the chance to operate the camera and the computer.

Measurement/ Video Analysis

Using the measurement plan you devised in the Exploration section, make a video of the free falling weight Make sure you get enough points for each part of the motion to determine the behavior of the acceleration.

Choose your coordinate system

Why is it important to click on the same point on the car's image to record its position? Estimate your accuracy in doing so.

Make sure you set the scale for the axes of your graph so that you can see the data points as you take them.

Use Excel to produce *position vs. time*, *velocity vs. time*, and *acceleration vs. time* graphs along with the equation that best describes that graph. *Remember to set the axes so that they are appropriate for the graph.*

Determine the acceleration as the cart goes down the track for different masses. Make a graph of the *acceleration vs. mass*. Is the average acceleration of the cart equal to its instantaneous acceleration in this case?

Do you have enough data to convince others of your conclusion about how the acceleration of the cart depends on its mass? If the acceleration does indeed depend on the mass of the cart, what might be causing this difference?

Conclusion

How will you respond to your friend? Does the *acceleration* of a free falling carriage depend on the mass of the people in the coaster?   Does the *velocity* of the carriage depend on its mass? (Will the carriage drop be just as fast with fewer people?) State your result in the most general terms supported by your analysis.

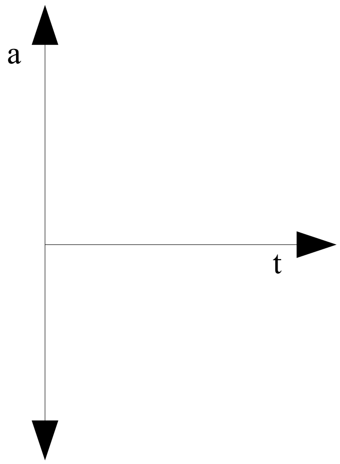
Did your measurements agree with your initial predictions? Why or why not?

Read "Improving measurements of space and time" and include a discussion of this article in your discussion as to the accuracy of your measurement of acceleration.

Honors: Acceleration due to gravity is not the same over the surface of the planet. Why does this change and what formulas have been proposed to determine the acceleration due to gravity? Mathematically determine the acceleration due to gravity in Mr. Gorman's classroom which is 330 ft above sea level and at a latitude of 42.102.

Predications

Empty Carriage



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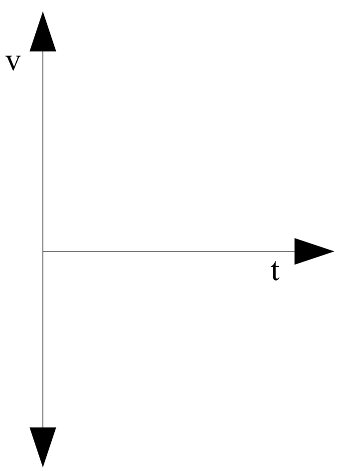

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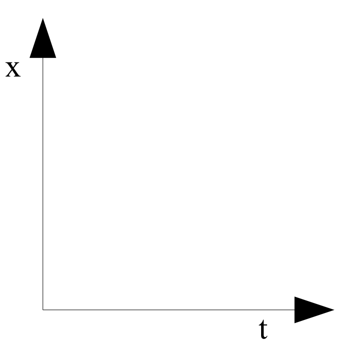

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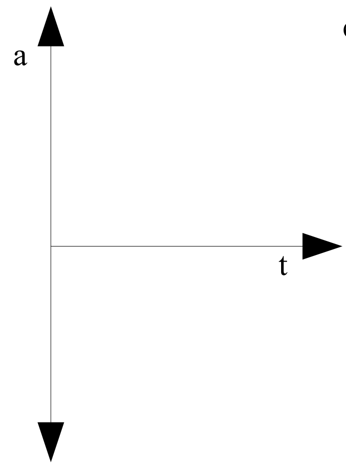
Full Carriage



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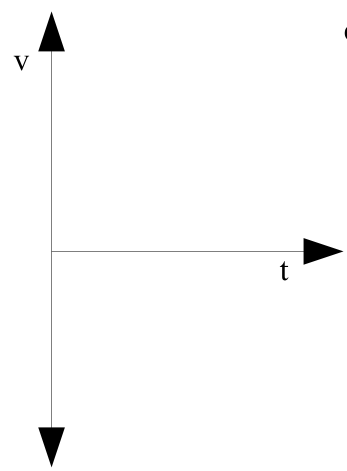

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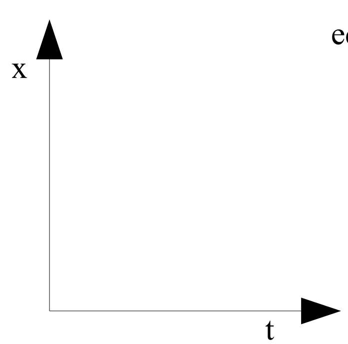

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