

One Dimensional Motion (Part I and Part II)

Purpose: To understand the relationship between displacement (position), motion (velocity), and change in motion (acceleration).

Topics of PART I and PART II:

- To learn to interpret displacement, velocity, and acceleration versus time graphs.
- To measure the acceleration of gravity and demonstrate that it is constant.
- To solve problems with a diagrammatic method.

Apparatus: Computer, motion sensor, LabPro lab interface, Logger Pro software, golfball, meter stick.

PART I

Introduction

The terms displacement, velocity, and acceleration are in common usage, yet students often are not clear about these concepts or their relationship. The intent of the first part of this lab is to clarify your understanding of these concepts using your own body as the object in motion. You will use a “sonic ranger” that measures how far away you are standing from the ranger -- your “displacement”. The sonic ranger measures your displacement as a function of time as you move toward or away from it. The software then calculates your velocity and acceleration. These three quantities are plotted as a function of time.

The sonic ranger uses ultra-high frequency sound to locate an object, similar in principle to radar. The computer measures the round-trip time for a sound pulse it emits to reflect off an object and return. Using the speed of sound, the computer converts this measured time into displacement. It also calculates the change in displacement to get the velocity and the change in velocity to get the acceleration. When using the sonic ranger, remember its limitations:

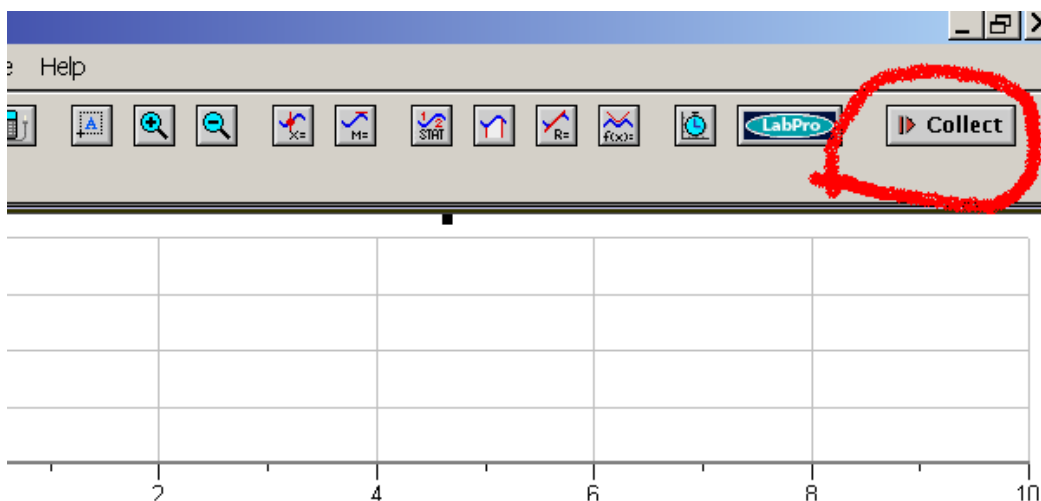
- The sonic ranger does **not** work properly for objects closer than 0.5 m and farther than 4 m.
- It detects the closest object; watch for swinging arms, other people, sides of tables and chairs.
- The software program treats the ranger as the origin when graphing the results. Distance, d , is from the ranger to the object. The ranger itself is at distance $d = 0$.

In this experiment, you will be the object in motion. You will try to duplicate, by moving back and forth in front of a motion sensor, various plots of Distance or Velocity versus time. These graphs will be automatically plotted in the data-acquisition software, Logger Pro(version 3).

Activity 1. Relating displacement, velocity and acceleration

1. Open “motion practice.xml”, which is a Logger Pro file in the same folder as this write-up (Hard Disk C:→Desktop-->Course Folders-->161-->1D motion). **If you get a message warning you that there is data stored in the LabPro interface, choose the option to Ignore/Eraser the data.** You should see three blank graph windows (Distance, Velocity, Acceleration) on the right and a data Table Window on the left. Once you start collecting data, the table on the left will fill with numbers – raw motion sensor data for the Distance, as well as calculated values (using the formulas for v and a) for Velocity and Acceleration. The plots on the right will also be drawn. Note that the time scale for each of the three graphs range from 0 to 10 seconds – the software is set to take data every 0.05 seconds for a total period of 10 seconds each run.

2. Position the motion sensor on the table – as close as possible to the edge, but far enough such that it still remains on the table in the event it tips over. Point it in such a direction that you (the object it will be tracking), have a 4 meter “corridor” of space in which you will neither bump into adjacent tables or people, nor encroach onto other lab groups’ “corridors”. You will need diplomacy to discuss your planned “corridor” with adjacent groups.



3. *Play around with the apparatus and software.* Still in practice.xml, click on the “Collect” symbol in Logger Pro to collect data. You will hear rapid clicking, which is the sound of the pulses emitted by the motion sensor. Have your partner move back and forth in front of the motion sensor in a random fashion.

4. After the 10 second collection period, examine your graphs. In the menu bar, go to “Analyze-->Examine”. You can activate an analysis of any of the three graphs by just clicking on it, then moving the cursor around to trace the plot – you should see the coordinates displayed on the bottom left hand corner of the graph, and they will change as you move around the plot. **If you are not getting any data, make sure your motion sensor is plugged into the DIG/SONIC1 input on the LabPro (translucent-blue flat box).**

5. Turn off the “Analyze→Examine” feature, and now try out the “Analyze-->Tangent” feature. Move your cursor around one of the plots again – this time it will draw a line tangent to whatever point on the plot your cursor is on, and display the slope. Turn off the “Analyze→Tangent” feature.

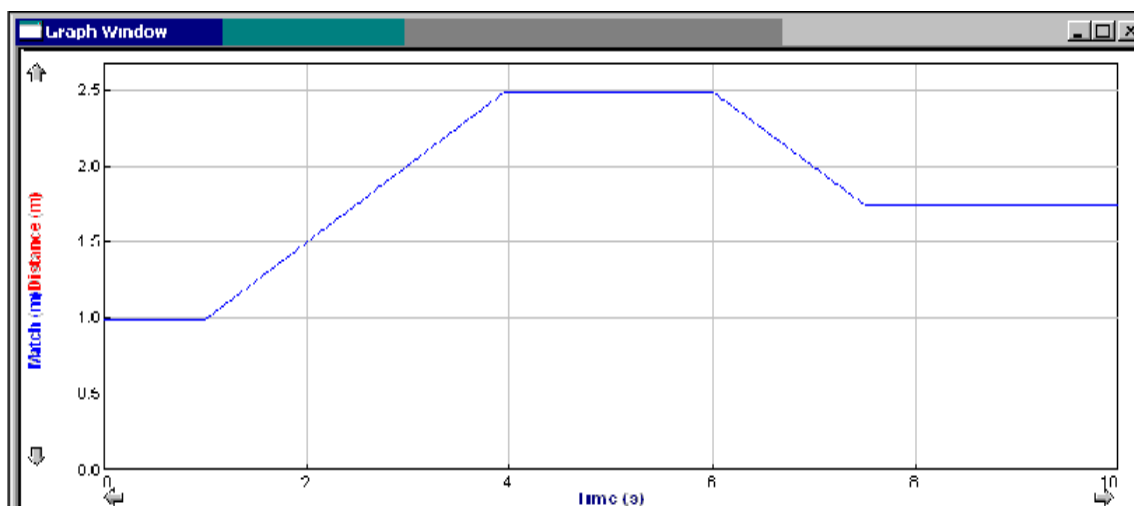
- Use the meter stick and a piece of chalk to mark off two points on the floor one meter apart. Make sure they lie in a straight line along your motion sensor beam line, within your “corridor”. Click on “Collect” again, and have your partner move from one marked point to another, spending a few seconds in each location. Confirm from your graphs that the points are indeed one meter apart. If they are not, notify your instructor. **If your motion sensor has a wide/narrow beam adjustment, you can switch to the narrow beam if you are getting too much interference or back to the wide beam if the sensor is not tracking you; experiment with what works best.**

You should now be ready to try the distance and velocity matches. When printing your results: Identify each graph with a meaningful title that also includes information to identify your group (each person’s initials, for example). Other students will be sharing the printer and the graphs may look similar. Titles should always clearly convey the meaning of the graph.

CASE 1. Displacement Match (Separate Graphs for Each Partner).

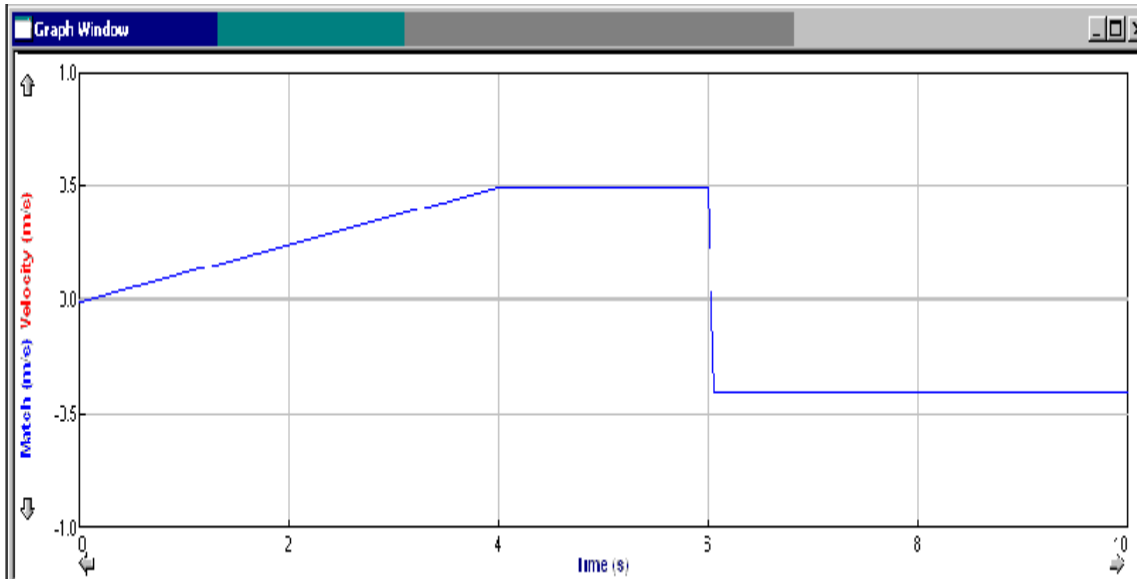
Open up the displacement(d) vs. time(t) match file (distance matching.xmlbl). Examine the blue trace with your partner and note the starting values. Discuss your walking plan to duplicate the blue trace, keeping in mind the relationships between Distance and Velocity. **Remember that the beam may bounce off any object along its “detection cone”, so keep track of the objects it may be recording. You may also find that holding a flat, rigid object (folder or binder, for example) in front of you may improve the beam's “tracking” of your position.** Practice a few times, and print out one good graph for the match. Attach the graph to hand-in lab report and submit at the end of the lab period.

The plot you will be trying to match is shown below. Note that one of them will ask you to match Distances; the next one will have you match Velocities:



CASE 2. Velocity Match (Separate Graphs for Each Partner)

Open velocity match file (velocity matching.xml). Practice a few times to match. Hand in your best match with the lab report.



PART II.

Activity 2. Measuring the acceleration of gravity.

Using the same motion detector as in Activity 1, measure the motion of a falling (and bouncing) golf ball. Place the detector near the edge of lab table and face the detector side towards the floor. Open the file gravity.xml. Measure the motion of the golf ball after you release it underneath the detector towards the floor. Recall that the closest distance that the detector can measure is 0.4 m, therefore you will have to choose carefully to make a sensible measurement of the bouncing path. Record at least four subsequent bounces of the ball.

Activity 3. Describing motion in multiple ways

One of the most frequent mistakes that students make when solving problems is to immediately start writing equations -- “plug and chug”. Although this technique often works fairly well for simple problems, it leads to confusion and errors in more complicated cases. For the balance of this laboratory you will solve several one-dimensional motion problems using a diagramming technique that is a substantial improvement over plug and chug. The basic idea is to represent the problem in a series of diagrams that lead to a numerical solution.

- The first diagram is a pictorial representation of the problem that includes all the given information. In order to understand a problem you need to read it, form a mental picture of the problem, and then write down this pictorial representation.
- The next step is to draw a motion diagram that identifies the relevant variables -- time, distance, velocity, and acceleration, in this case -- and pictorially shows their relationship.
- Next, you draw qualitative graphs -- d versus t, v versus t and a versus t -- showing how you expect the variables to vary.
- Finally you write the equations and solve them to get a numerical answer.

An example of a completed set of diagrams (the method is called ActivPhysics™) for the balloonist problem is shown below. Study it and discuss with your partner any steps you do not understand. If doubt persists, ask for a hint from your TA.

Working with your partner, complete a similar sequence of diagrams for the problem of the pole-vaulter. Finally solve the appropriate equations in the last panel.

Preliminary Questions: ONE DIMENSIONAL MOTION (Part I)

Name: _____

Section: _____

Date: _____

The equation for the location x of a moving automobile at any time t is $x = 3t + 10$. What is the slope of the equation (don't forget the units) and what is its physical meaning?

What is the x -intercept in the above equation? What is its physical meaning?

What is the car's acceleration?

Make sketches of :

1.) x versus t , and 2.) v versus t , for the automobile. Be sure to label the axes.

Would a second car with location $x = 4t + 2$ ever collide with the first car? At what time? Give a graphical solution by making a sketch showing x versus t for both cars, and look for any intersect.

Preliminary Questions: ONE DIMENSIONAL MOTION (Part II)

Name: _____

Section: _____

Date: _____

A stone is released from a 50 m high tower. (Use $g = 9.80 \text{ m/s}^2$)

a. How long does it take the stone to hit the ground?

b. Draw 3 graphs representing: a versus t , v versus t , height x versus t .

Use the convention: up is positive.

A stone is released at 50 m height from a rising balloon. The balloon rises at constant speed of 5 m/s.

c. How long does it take the stone to hit the ground?

d. Draw 3 graphs representing: a versus t , v versus t , height x versus t . (up is positive.)

Report: ONE DIMENSIONAL MOTION (PART I)

Name: _____ Section: _____

Partner: _____ Date: _____

Partner: _____

PART I

Activity 1: Sketch below your predicted graphs for 1.) v versus t , and 2.) a versus t , that will produce the d versus t graph in the distance match. Be sure to label your axes.

Use the computer function **Analyze Data B** to answer the following questions about the d versus t graph in **Distance Matching**:

What are the measured positions of the object at the times given in the table?

Time (s)	Displacement (m)	Time (s)	Displacement (m)
1			
2			
3			
4		8	
6		10	

Calculate the average velocity of the object between 2s and 3s? (Show work.)

Compare this with the velocity given by the Analyze function.

Calculate the average velocity of the object between 8s and 10s? (Show work)

Compare this with the velocity given by the Analyze function.

What is the average velocity of the object between 2s and 8s? (Show work)

Compare this with the velocity given by the Analyze function. Why is there a large mismatch between the two velocities? What velocity is the Analyze function calculating, average or instantaneous? When are those two types of velocity the same?

Sketch below your predicted graphs for :

1.) d versus t, and

2.) a versus t , that will produce the v versus t graph in **Velocity Matching**.

Do not forget to attach the graphs of your position and velocity matches to this lab report.

END OF REPORT ON PART I

Report: ONE DIMENSIONAL MOTION (PART II)

Name: _____

Section: _____

Partner: _____

Date: _____

Partner: _____

PART II

Activity 2: Falling and bouncing ball (Record at least four clean bounces). What is free fall?

Sketch the distance vs. time graph made by the Logger Pro program. Indicate the points in the graph where the golf ball hits the floor and also where it reaches the maximum height in each bounce.

Sketch the velocity vs. time graph made by the Logger Pro program. Indicate the points where the ball is in “free” flight. What is free flight? Where in this graph does the ball hit the floor? Where does it reach the maximum height in each bounce? Explain your reasoning.

The graph for acceleration vs. time looks quite complicated. Also in this graph, indicate where the ball is in “free” flight. What should be the magnitude of the acceleration during free flight?

What is the direction of the acceleration of gravity on the way up? What is the direction on the way down? What at the maximum height?

Activity 3: Study the worksheet that is completed below for the problem of the **balloonist and the falling cup**. Verify if the different stages make sense. Notice here $g = 10 \text{ m/s}^2$.

Complete the second worksheet for the **pole-vaulter** by following the same strategy.

Give a pictorial description, make a motion diagram, and finally solve the relevant equations.

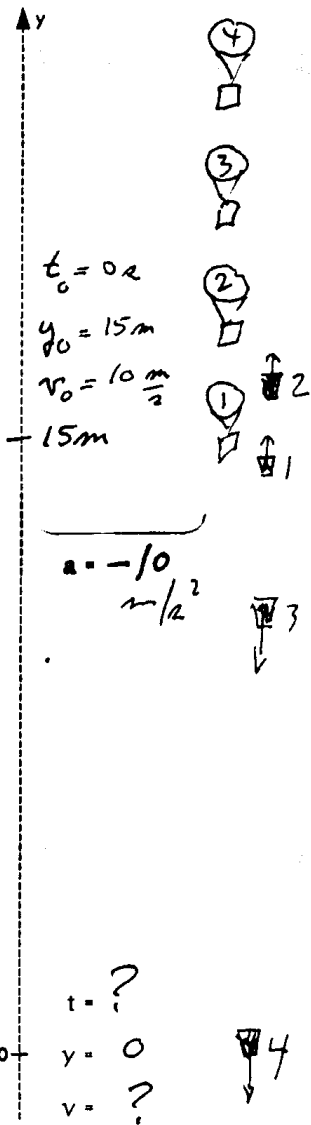
Consider stage 1 before the person hits the cushion as well as stage 2 when the person is sinking into the cushion.

Include graphs for : a versus t , v versus t , and y versus t .

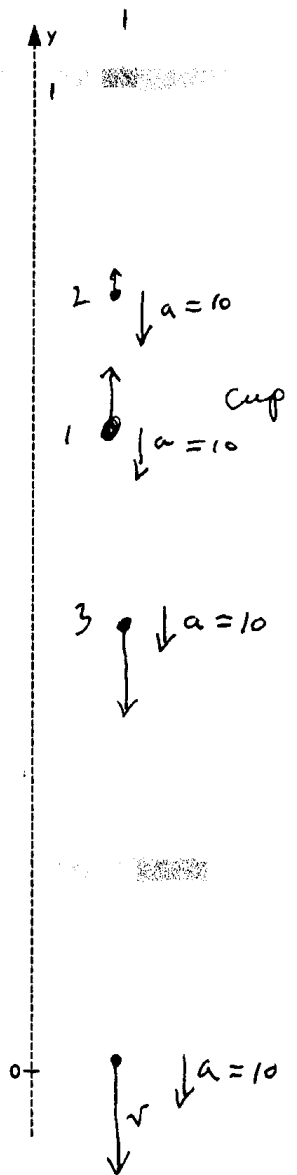


A balloonist ascending at a constant speed of 10 m/s accidentally releases a cup of lemonade when 15 m above the head of a crew person directly below the balloon. Determine the time interval that the crew person has to dodge the lemonade. Assume that the gravitational constant is 10 m/s².

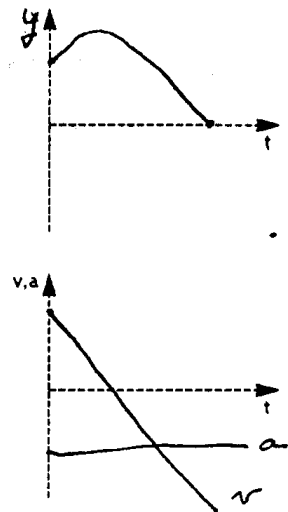
Question 1 - Pictorial Description:



Question 4 - Motion Diagram:



Question 5 - Graphs:



Question 6 - Equations and Solution

$$y = y_0 + v_0 t + \frac{1}{2} a t^2$$

$$0 = 15 + 10t - \frac{10}{2} t^2$$

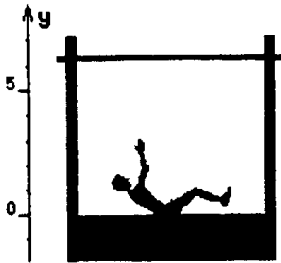
$$t^2 - 2t - 3 = 0$$

$$t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$t = \frac{2 \pm \sqrt{4 - 4(-3)}}{2}$$

$$= 1 \pm 2 = 3, -1$$

$t = 3 \text{ s}$



The problem starts with a pole-vaulter at the peak of his vault 6.1 m above the surface of a cushion. His fall stops after he sinks 0.40 m into the cushion. Determine the acceleration (assumed constant) that the vaulter experiences while he sinks into the cushion. Assume that the gravitational constant is 10 m/s^2 . (Complete the descriptions below to answer Questions 1-5.)

Pictorial Description:

y

$t_0 =$

$y_0 =$

$v_0 =$

$a_{01} =$

$t_1 =$

$y_1 =$

$v_1 =$

$a_{12} =$

$t_2 =$

$y_2 =$

$v_2 =$

0

Motion Diagram:

y

0

Equations and Solution: