

Introduction to Motion II

Objectives

In this lab you will learn how to

- find the slope at any point along your position graph and to understand its physical meaning.
- fit your velocity data to a straight line and to understand the physical meaning of its slope and vertical intercept.
- find the average of your acceleration data and to understand its physical meaning.

Equipment

Air track (with air supply), glider, Vernier Motion Detector (with clamp), Vernier LabPro™ system (includes computer and Logger Pro™), small stand, and a ruler.

Theory

The *position* $x(t)$, *velocity* $v(t)$, and *acceleration* $a(t)$ of a particle uniformly accelerating along the x axis are given by the equations:

$$x(t) = x_0 + v_0 t + \frac{1}{2} a t^2 \quad \text{Equation (1)}$$

$$v(t) = v_0 + a t \quad \text{Equation (2)}$$

$$a(t) = \text{const.} \quad \text{Equation (3)}$$

where x_0 and v_0 is its initial position and velocity, respectively, and a is its constant acceleration. Equation (1) is quadratic in t so its graph is a parabola. Equation (2) is linear in t , so its graph is a straight line of slope a and y-intercept v_0 . Equation (3) is a constant function, so its graph is a straight line of zero slope.

Procedure

Preliminary Set-Up (identical to Intro to Motion I lab)

- 1) Use the adjusting knob to lower the end of the air track that is connected to the air supply. The bottom of the track at the 15-cm mark (along the track measuring tape) should be 10 cm above the table top (Photo 1).
- 2) Turn on the air supply then place the glider on the air track. The glider should accelerate smoothly down the sloped track.
- 2) Make sure that LabPro is connected properly to the motion detector (at the DIG/SONIC1 port) and to the computer. Unfold the detector and clamp it horizontally to the ring stand. Move the entire assembly to the end of the track that is closest to the computer. The gold sensor must face the track. Position the center of the sensor between 2 to 6 cm above the air track and in line with its 0-cm mark (Photo 2). Tilt the motion

detector so that it is angled slightly away from the air track toward ceiling. Adjust until you get a good reading.

The motion detector emits ultrasound waves from the gold sensor in a 30° - 40° cone. Any object within this cone is detected when the waves “echo” back to the detector. The detector is tilted in order to avoid picking up any extraneous motions from you or your partners – a potential source of systematic error!

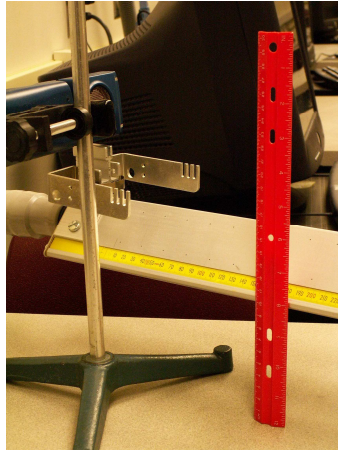


Photo 1

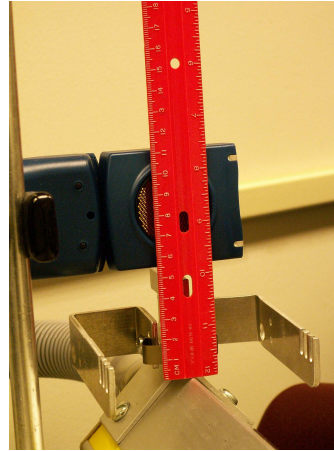


Photo 2

3) Click the Logger Pro icon on the desktop of your computer. Click the **Collect** button in the upper right corner of the screen. A clicking sound indicates that the motion detector is active. Wave your hand in front of it as you watch Logger Pro plot its position and velocity graphs. If you do not hear the clicking, check whether your LabPro is connected properly and try again. If this fails, ask your lab instructor for help.

4) Create a small “flag” to attach to the end of glider closest to the detector. Adjust the orientation of the detector so that the flag completely covers the gold sensor as you look through the groove at the end of the air track (Photo 3).

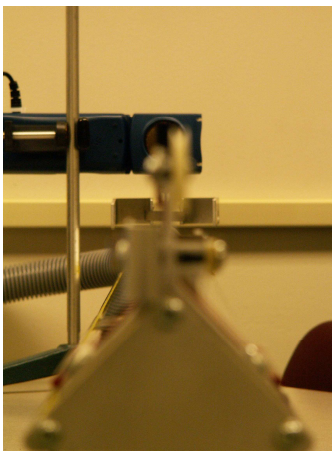


Photo 3

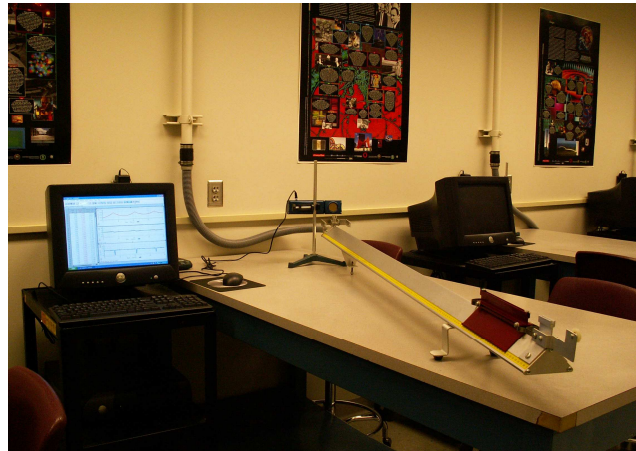


Photo 4

4) When you open Logger Pro, only two graphs (position and velocity) will be shown. Pull down the **Insert** menu and select **Graph**. A third graph (acceleration) will pop

out. Resize all three graphs so that your display resembles that of Figure 1. Click on the title of the y axis in each graph and change it to *position*, *velocity*, and *acceleration*. Change the title of all x axes to *time*. Click the **A** button to automatically rescale the axes.

5) Finally, click the clock ⌚ button (collection parameters) and enter 20 sec in the Length box. You are now ready to begin the experiment (Photo 4)!

Data Collection and Display

1) Hold the glider 40 cm from the detector and release it one second after clicking the Collect ▸ button. If your graphs are jittery, adjust the detector and/or the air track until your position graph shows at least 3 peaks and 3 valleys as in Figure 1. Make sure that that your velocity graph is positive (above the t axis) whenever the glider moves away from the detector, and that it is negative (below the t axis) whenever the glider moves toward the detector. Be sure to save your best graphs.

2) Use the $X=$ (get coordinate) and $M=$ (get slope) buttons (along the top toolbar) on your position graph. Set the $+$ cursor at various points along the graph. A text box will automatically display the time, position, and slope at each point. Similar text boxes will be shown at the corresponding points on the two other graphs (see Figure 1). Go to the File menu and select Print Graph to print only your position graph and its text box. Answer the questions in Part I of your data sheet.

3) Use the $X=$ and $M=$ buttons on your velocity graph. Set the $+$ cursor at various points along the graph. Notice that the slope is slightly different from point to point even though the graph is clearly linear. We need a use the $R =$ (linear regression) button to obtain an average slope. Click the $+$ cursor at the left end of a velocity segment and drag it to the right end. You should see the brackets $[]$ framing your data. Now click the $R =$ button to fit your data to a straight line. A best fit line appears along with a text box titled "Linear Fit." Now go to your acceleration graph and bracket the same time window. Use the STAT (statistics) button to compute the average acceleration over this interval (see Figure 2). Go to the File menu and select Print Graph to print your velocity graph with its Linear Fit box, and then print your acceleration graph with its Statistics box. Answer the questions in Part II of your data sheet.

4) Finally, use the $R =$ button along the same interval in your acceleration graph. Answer the questions in Part III of your data sheet.

Each student is required to submit a completed data sheet in order to receive full credit. Your lab group needs to submit only one set of motion graphs (one position, one velocity, one acceleration). These three graphs are to be stapled to the data sheet of one of your lab partners – each lab partner does not need to submit his/her own set of graphs.

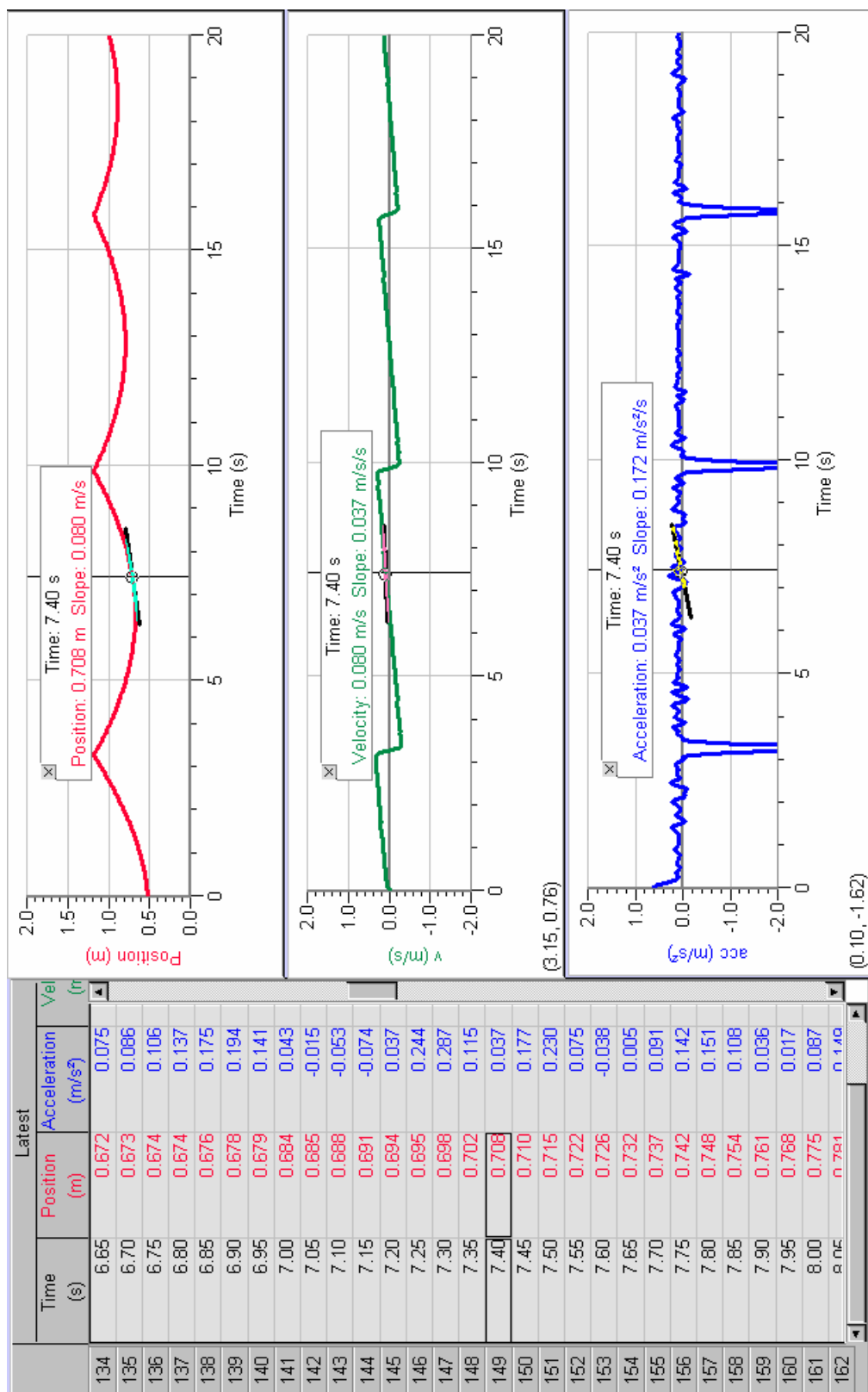


Figure 1 – Slope at a single point on a motion graph

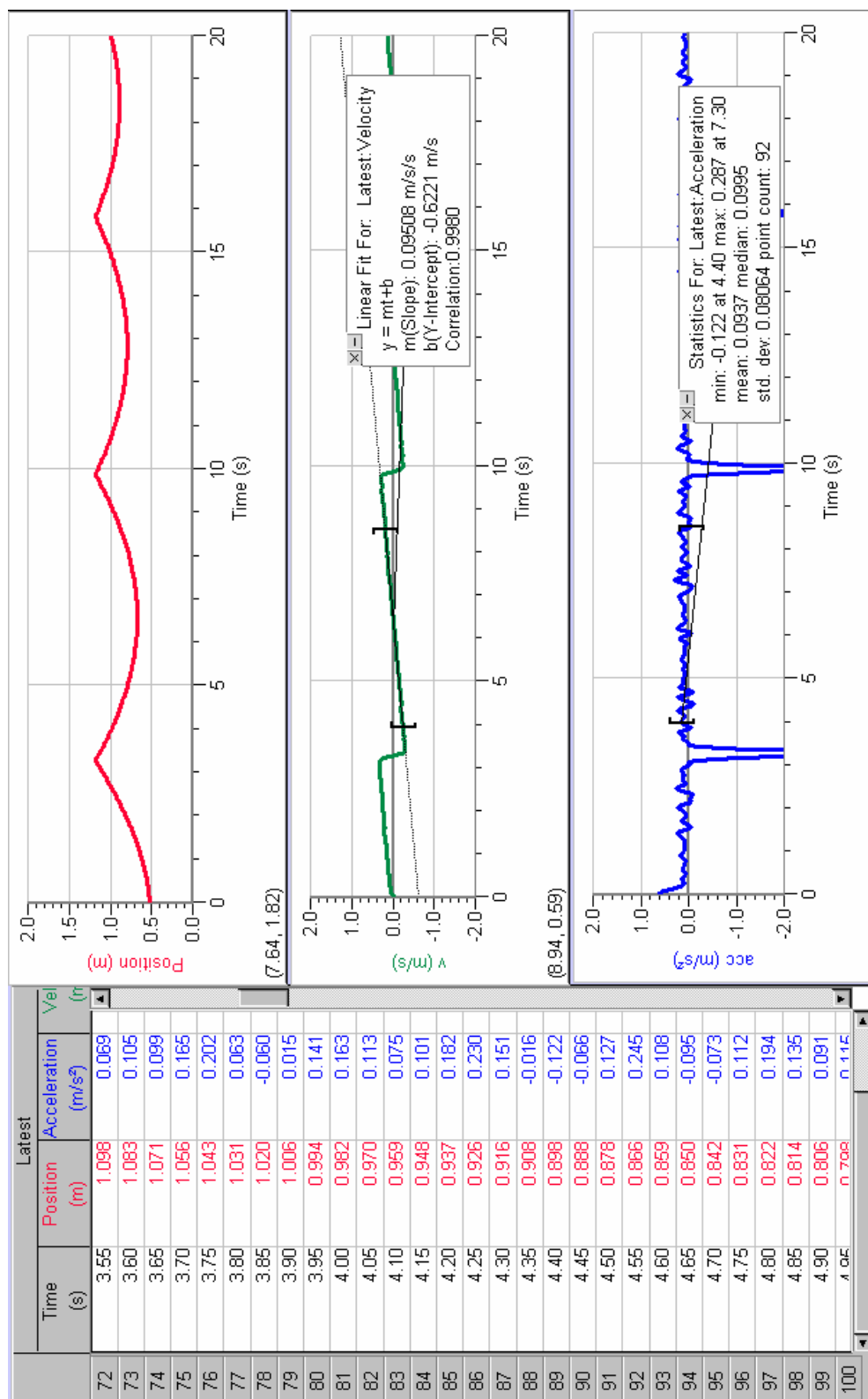


Figure 2 – Linear fit and average slope over an interval

Data Sheet - Introduction to Motion II

Name _____

Date _____

Partners' Names _____

Part I – Position and Velocity

Pick a single parabola in your position graph. Choose two points L1, L2 to the left of its vertex, two points R1, R2 to the right of its vertex, and the point exactly at the vertex.

Record the time, position, slope (from position graph), and velocity for each point.

Point	Time [sec]	Position [m]	Slope [m/s]	Velocity [m/s]
L1				
L2				
Vertex				
R1				
R2				

Answer the following questions.

1) Describe the glider's motion at points L1 and L2.

2) Describe the glider's motion at points R1 and R2.

3) What is the glider's velocity at the vertex?

5) What is the relationship between the slope at a single point along your position graph and the glider's velocity at that time? Why?

Part II – Velocity and Acceleration

Record the slope and y-intercept from your linear fit (velocity graph). Record the mean value from your statistics (acceleration graph).

Linear Fit: Slope = _____ Y-Intercept = _____

Statistics: Mean = _____

Answer the following questions.

- 1) What is the physical meaning of the y-intercept?

- 2) What is the purpose of a best-fit line and why was it used in your velocity graph?

- 3) What is the relationship between the slope of your velocity graph and the glider's mean (average) acceleration within that time interval? Why?

Part III – Acceleration Only

Record the slope from your linear fit (acceleration graph). Record the mean value from your statistics (acceleration graph, same value as in Part II).

Linear Fit: Slope = _____ Y-Intercept = _____

Statistics: Mean = _____

Answer the following questions.

- 1) What is the physical meaning of the y-intercept?

- 2) Calculate the percent discrepancy between the y-intercept and the mean. (Refer to the Measurement lab.)

- 3) What is the relationship between the y-intercept of your linear fit and the glider's mean (average) acceleration within that time interval? Does your percent discrepancy confirm this result?