

## ACTIVITY 4

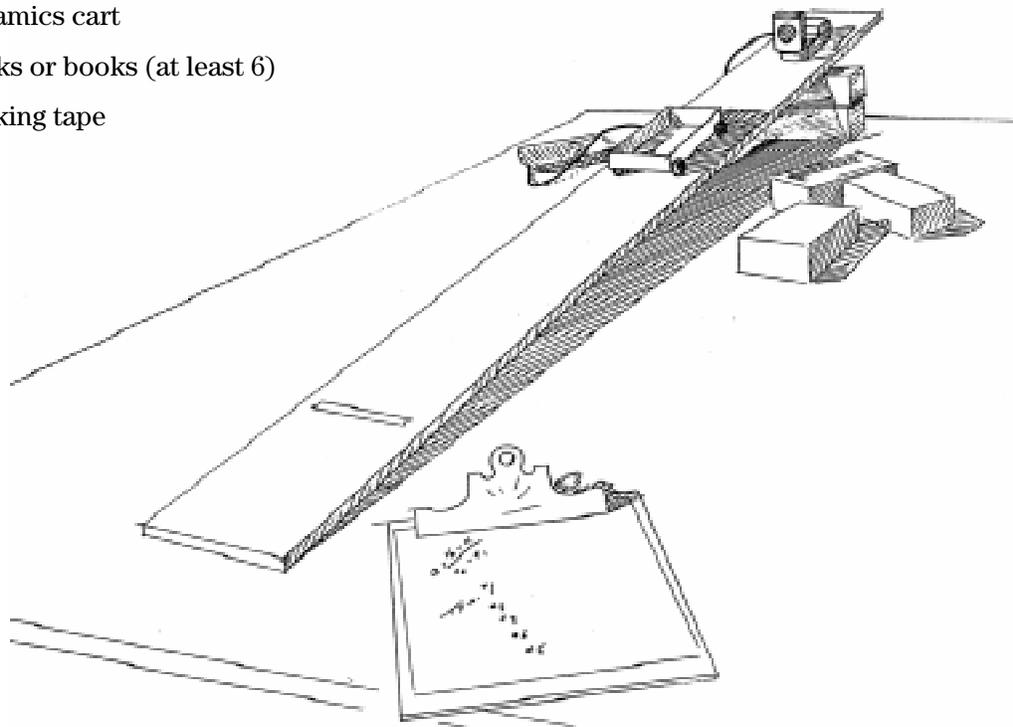
### What is Gravity?

When an object is tossed into the air, it rises a certain distance and slows down as it does so. When it reaches its highest point, it begins to fall back to earth increasing its velocity. What causes this phenomenon? The gravitational acceleration,  $g$ , causes the object to behave as it does.

In this lab, you will perform a series of experiments much as Galileo did with inclined planes. As the angle of inclination of the inclined plane is increased, the object's acceleration will also increase. As the angle of inclination approaches  $90^\circ$ , the value of the acceleration will become closer and closer to that of gravitational acceleration.

#### You'll Need

- ◆ 1 CBR unit
- ◆ 1 TI-83 or TI-82 Graphing Calculator
- ◆ Wooden board (about 2 meters long)
- ◆ Meter stick
- ◆ Dynamics cart
- ◆ Bricks or books (at least 6)
- ◆ Masking tape



## Instructions

1. Stack a few bricks or books underneath one end of the ramp.
2. Set the CBR on the ramp as shown. Measure 0.5 meter from the CBR and place a piece of masking tape on the ramp at that point. Your cart should start from this point so that it is no closer than 0.5 meter from the CBR for each trial.
3. Run the **RANGER** program on your calculator.
4. Enter the setup instructions.
  - a. From the **MAIN MENU** select **1:SETUP/SAMPLE** to access the setup menu.
  - b. Press **[ENTER]** until the **REALTIME** option reads **no**.
  - c. Press **[↓]** (the down arrow) to select the next line **TIME (S)** and press **[ENTER]** **[2]** **[ENTER]** to change the time to **2** seconds.
  - d. Press **[↓]** to select the next line. Correct or verify the settings and press **[ENTER]**. Repeat until the options for each line read as shown at right.

MAIN MENU	▶START NOW
REALTIME:	NO
TIME (S):	2
DISPLAY:	VEL
BEGIN ON:	[ENTER]
SMOOTHING:	LIGHT
UNITS:	METERS

- e. Press **[↓]** to move the cursor to the **START NOW** command. Do *not* press **[ENTER]**.

4. Place the cart at the starting tape on the ramp. Release the cart and *simultaneously* press **[ENTER]** on the calculator.

## Data Collection

1. At least a portion of the Velocity-Time graph should resemble a straight line. It is only necessary to be able to find two distinct points on the line. If you are not satisfied with the results, press **[ENTER]** and select **5:REPEAT SAMPLE**.
2. Measure the distance from the tape to the bottom of the ramp along the surface of the ramp. Record the length as  $d$  in the table below.
3. Measure the distance from the surface on which the ramp is placed to the point on the ramp where the tape was placed. Record this value as  $h$  in the table below.
4. Trace along the graph of the Velocity-Time graph and choose two points that lie along the line. Record them in the table below.
5. Repeat the experiment 5 more times raising the end of the ramp each time. Record all of the results in the table below.

Trial	$d$	$h$	$(t_1, v_1)$	$(t_2, v_2)$	$\sin(\theta)$	acceleration
1						
2						
3						
4						
5						
6						

6. Press **[ENTER]** and select **7:QUIT**.
7. From trigonometry, it is known that the

$$\sin \theta = \frac{\text{opposite}}{\text{hypotenuse}}.$$

For each trial, the opposite side is  $h$  and the hypotenuse is  $d$ . Compute the  $\sin(\theta)$  for each trial and record it in the table on the previous page.

8. The slope of the Velocity-Time graph is the acceleration of the object. Using the standard formula

$$a = \frac{v_2 - v_1}{t_2 - t_1},$$

find the slope of the line for each trial and record in the table above as the acceleration.

9. Press **[STAT]** and select **4:ClrList**. Type **[2nd] [L5] [,] [2nd] [L6] [ENTER]** to clear the two lists.
10. Press **[STAT]**, select **1:Edit** and use the arrow keys until the first cell in **L5** is highlighted. Enter the first  $\sin(\theta)$  and press **[ENTER]**. Repeat for the remaining trials.

11. Press **[↓]** and move to the first cell of **L6**. Enter the first acceleration and press **[ENTER]**. Repeat for the remaining trials.

12. Press **[2nd] [STAT PLOT]** and select **Plot 1**. Highlight **On** and press **[ENTER]**. Change the **Type** to  $\square$ , enter **L5** as **Xlist**, **L6** as **Ylist** and use the **square** as the **Mark**.

13. Press **[ZOOM]** and select **9:ZoomStat**. Sketch a graph of acceleration versus  $\sin(\theta)$  in the space provided at right.



## Questions

1. What is the equation of the line that would best fit the data?

**For the TI-83:** Press **[STAT] [↓]** and select **4:LinReg (ax+b)**. Press **[2nd] [L5] [,] [2nd] [L6] [ENTER]**.

**For the TI-82:** Press **[STAT] [↓]** and select **5:LinReg (ax+b)**. Press **[2nd] [L5] [,] [2nd] [L6] [ENTER]**.

This line gives the value of the acceleration of an object as a function of the  $\sin(\theta)$ . Record the equation below.

$y =$  \_\_\_\_\_

2. Press **MODE**  $\square$   $\square$  to highlight **Degree**, and press **ENTER**. For each angle given below, compute the  $\sin(\theta)$ , then the acceleration of the cart on an incline with the given angle using the equation from question 1 with the  $\sin(\theta)$  as  $x$ .

angle	$\sin(\theta)$	acceleration
$30^\circ$		
$45^\circ$		
$60^\circ$		
$75^\circ$		
$85^\circ$		

3. As  $\theta$  approaches  $90^\circ$ , the  $\sin(\theta)$  approaches 1. Thus, for values close to  $90^\circ$ , the slope of the line is the acceleration. What is the slope of the line?

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4. As the angle approaches  $90^\circ$ , the object is nearly in free fall. Since the  $\sin(90^\circ)$  is 1, what would be the acceleration of an object that is in free fall?

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5. The acceleration of an object in free fall found in question 3 above is gravitational acceleration,  $g$ . Its given value is  $9.8 \text{ m/s}^2$  (or  $32 \text{ ft/s}^2$ ). How does your value compare to the true value?

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6. When an object is tossed into the air and is rising, what effect does  $g$  have on the velocity of the object?

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7. When an object is rising, it has positive velocity. Thus, would the object have positive or negative acceleration?

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8. When an object is tossed into the air and it is falling back to earth, what effect does  $g$  have on the velocity of the object?

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9. When an object is falling, it has negative velocity. Thus, would the object have positive or negative acceleration?

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