

Bell Ringer: Determining the Angle of a Ramp – ID: 13275

Time required
15 minutes

Topic: Kinematics

- *Construct and interpret graphs of position versus time.*

Activity Overview

In this activity, students will use precompiled data to calculate the angle of a ramp from the displacement of a ball rolling on the ramp.

Materials

To complete this activity, each student or student group will require the following:

- *TI-Nspire™ technology*
- *pen or pencil*
- *blank paper*

TI-Nspire Applications




Graphs & Geometry, Notes, Lists & Spreadsheet

Teacher Preparation

Before carrying out this activity, review with students the kinematic equation for displacement as a function of time and the resolution of vectors into perpendicular components.

- *The screenshots on pages 2–6 demonstrate expected student results. Refer to the screenshots on page 7 for a preview of the student TI-Nspire document (.tns file). The solution .tns file contains data analysis and answers to the questions.*
- ***To download the student .tns file and solution .tns file, go to education.ti.com/exchange and enter “13275” in the search box.***
- *For a more extensive exploration of this content, use activity 8550: Rolling a Ball on an Inclined Plane. Activity 8550, which is longer than this bell ringer and involves data collection and analysis by the students, was designed for a full class period. You can download the files for activity 8550 at education.ti.com/exchange.*



Classroom Management

- *This activity is designed to be **student-centered**, with the students working cooperatively. However, you will need to guide students through the steps of the activity.*
- *If you wish, you may modify this document for use as a student worksheet. You may also wish to use an overhead projector and TI-Nspire computer software to demonstrate the use of the TI-Nspire to students.*
- *If students do not have sufficient time to complete the questions, they may also be completed as homework.*
- *In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.*
- *The Graphs & Geometry applications on students' devices will need to be set to Degree mode instead of Radian or Gradian mode for the calculations to work properly. To change these settings, press  and select System Info > Graphs & Geometry Settings. Press  to move between settings, and press  to select a setting.*

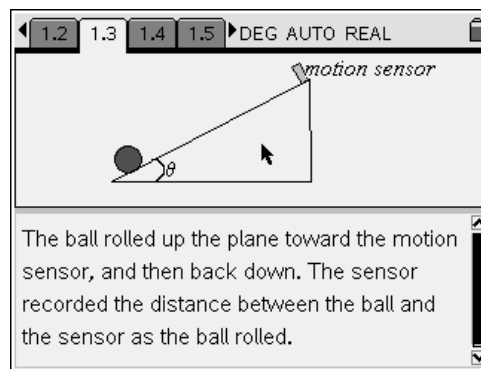
The following question will guide student exploration in this activity:

- How can displacement data for a ball rolling on a ramp be used to determine the angle of the ramp?

Students will use a precompiled set of distance vs. time data for a ball rolling up and down an inclined plane. They will determine the equation describing the ball's position as a function of time, plot the data, and use the equation for the best-fit curve to the data to infer the angle of the ramp used to produce the data set. Note: For the purposes of this investigation, students should ignore the rotational motion of the ball as it rolls on the ramp.

Step 1: Students should open the file **PhysBR_week01_ramp_angle.tns** and read the first three pages. (Students can press  and  to move between pages in the .tns file.)

Step 2: Students should move to page 1.4 and answer question 1. Students can type their answers into the *Notes* application on page 1.4, or they can write their answers on a sheet of blank paper.



- Q1.** What is the equation for the displacement (position) of the ball along the ramp as a function of time? Assume that there is no friction between the ball and the ramp, and that the only acceleration is due to gravity. Use s for displacement, v for velocity, g for acceleration due to gravity, and t for time. (Hint: What component of g is acting parallel to the ramp?)

- A.** *For motion in one dimension, the following general equation applies:*

$$s(t) = s_0 + v_i t + \frac{1}{2} a t^2$$

The only acceleration is due to gravity, which acts at an angle θ to the ramp. In this case, θ is equal to the angle between the ramp and the floor. The component of g that is parallel to the ramp is therefore $g \cdot \sin \theta$. Making this substitution into the equation above yields the following:

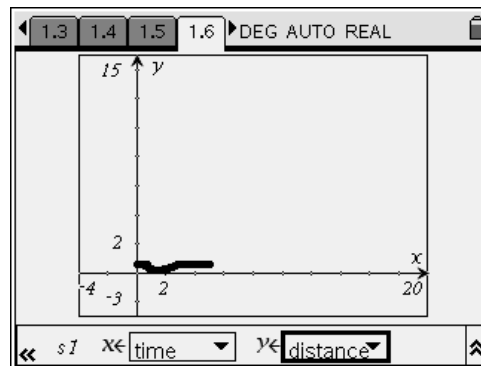
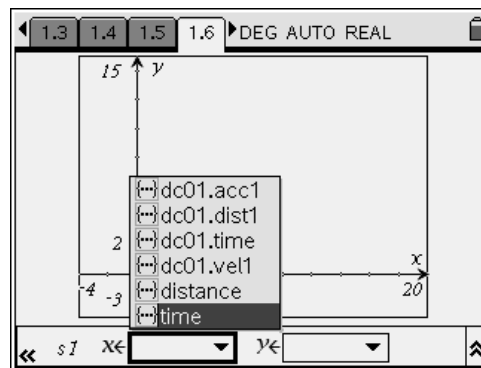
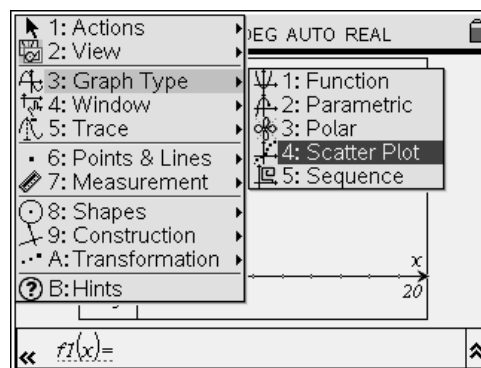
$$s(t) = s_0 + v_i t + \frac{1}{2} g t^2 (\sin \theta)$$

Step 3: Next, students should move to page 1.5, which shows the data that the motion sensor collected. The distance data are in meters, and the time data are in seconds.

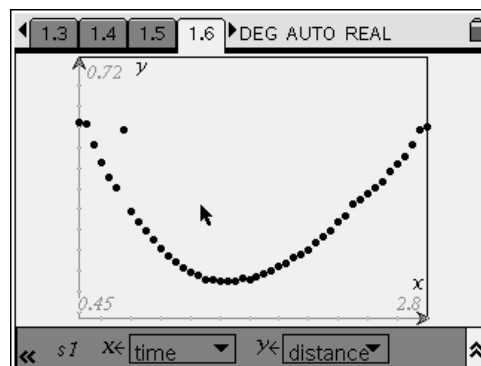
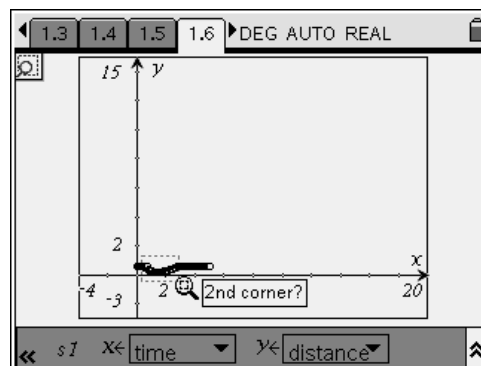
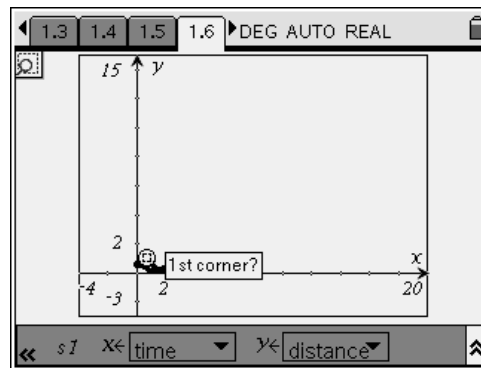
A	time	B	distance	C
=dc01.time	=dc01.time	=dc01.dist1		
1	0.	0.564292		
2	0.05	0.564378		
3	0.1	0.564378		
4	0.15	0.564309		
5	0.2	0.564154		

The data shown here are the distance and time data recorded by the sensor.

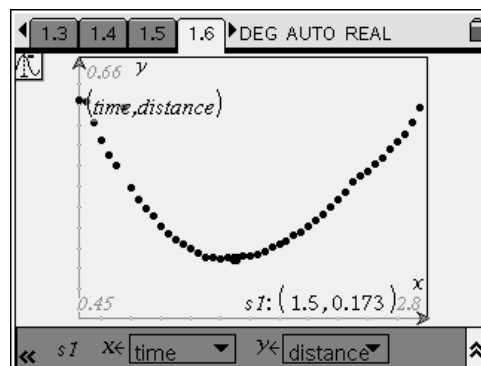
Step 4: Next, students should move to page 1.6, which contains an empty *Graphs & Geometry* application. Students should use this application to make a graph of the distance-time data set. To make the graph, students first need to change the graph to a scatter plot (**Menu > Graph Type > Scatter Plot**). When they change the plot to a scatter plot, the function bar at the bottom of the screen should change to show x and y series, as shown to the right. Students should select **time** as the x series and **distance** as the y series. (When students change the plot type, the x series box should automatically be highlighted. To select the x series, students should click [press] on the x series box. A list of available data sets should pop up. Students should use the NavPad to select the series **time** and press . To choose the y series, students should press until the y series box is highlighted, and then click and use the NavPad again to select the series **distance** and press .



Step 5: Next, students should use the **Zoom-Box** tool (**Menu > Window > Zoom-Box**) to resize the graph so it shows only the parabolic part of the data. When students select the **Zoom-Box** tool, the cursor should change to a small magnifying glass, and students should be prompted to select the first corner. They should use the NavPad to move the cursor to the top-left corner of the area they want to zoom in on and then click to select the point. The cursor should then prompt them for the second corner; they should use the NavPad to move to the lower-right corner of the zoom area and click to select it. The plot should zoom to the area they selected. Students should use the **Zoom-Box** tool to resize the plot until only the parabolic section of the data is showing. They can press (esc) to exit the **Zoom-Box** tool.



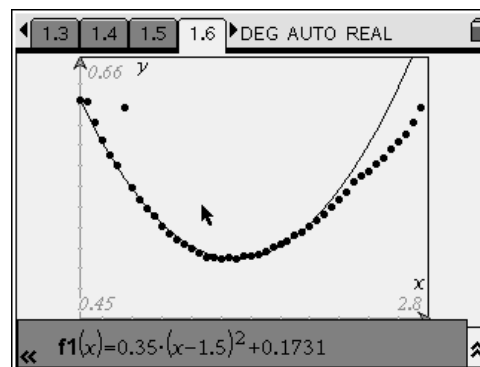
Step 6: Next, students should use the **Graph Trace** tool (**Menu > Trace > Graph Trace**) to locate the vertex of the parabola. After students have selected the **Graph Trace** tool, they should use the NavPad to move through the data points until they have reached the vertex of the data. Note: The data flatten out at the bottom of the curve, as shown. Students should identify the center of the lowest region of the curve. Once they have identified the vertex, they should record its coordinates.



Step 7: Next, students should attempt to fit a quadratic curve of the form $y = m(x - n)^2 + q$ to their data. Help students understand how to use the coordinates of the vertex to determine the values of n and q (the variable n should be approximately equal to the x -coordinate of the vertex; the variable q should be approximately equal to the y -coordinate). Students should make their own predictions for the value of m .

Step 8: Once students have made a prediction about the best-fit equation, they should change the graph to a **Function** graph (**Menu > Graph Type > Function**) and enter their predicted formula into the formula bar. They should then adjust the values of m , n , and q until the parabola matches the data as closely as possible. The values of n and q should not change significantly, provided students accurately determined the coordinates of the vertex in step 6. (To show or hide the formula bar, students should press $\text{ctrl} \text{ G}$.)

Another approach to determining a “best” value for m is to grab the graph of the function **f1** and manipulate the graph until the graph fits the data. Notice how the equation for **f1** changes with the curvature of the graph.



Step 9: Finally, students should answer questions 2–5 on pages 1.7–1.10. (To switch between question 3 and the *Calculator* application, students should press $\text{ctrl} \text{ tab}$.) Students may type their answers into the question pages or write their answers on a separate sheet of paper.

- Q2.** What is the acceleration coefficient in the best-fit equation? (Hint: Expand the equation for the best-fit parabola to write it in the form $ax^2 + bx + c$).
- A.** *Students' exact answers will vary, but the approximate value of the acceleration coefficient should be 0.35.*
- Q3.** Use the *Calculator* application above to calculate the angle of the inclined plane.
- A.** *Students should use the value of the acceleration coefficient from question 2 to calculate the angle of the plane; if necessary, remind them that the acceleration coefficient is equal to $\frac{1}{2}g \cdot \sin \theta$. Using an acceleration coefficient of 0.35 yields an approximate ramp angle of 4° .*
- Q4.** How would the acceleration coefficient change if the angle of the ramp were increased? Explain your answer.
- A.** *A greater angle would increase the component of gravity acting on the ball. Therefore, the acceleration coefficient would be larger.*

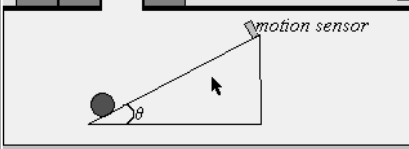
Q5. If the ramp were infinitely steep (i.e., vertical), what would the acceleration coefficient in the equations be? Explain your answer.

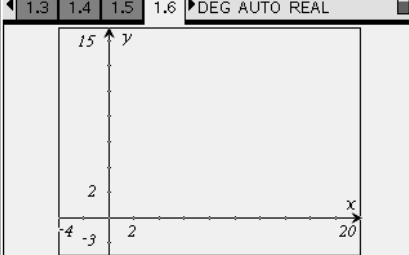
A. *The component of gravity acting along the ramp is equal to $g \cdot \sin \theta$. If the ramp were vertical, θ would equal 90° , and $\sin(90^\circ) = 1$. The acceleration component would therefore simply be acceleration due to gravity, 9.8 m/s^2 . That is, the ball would be moving straight up and down.*

Suggestions for Extension Activities: If you wish, you may have students use a Vernier CBR 2™ or Go!™ Motion sensor and EasyLink™ or Go!® Link interface to collect their own displacement data to analyze. You may also have students investigate the velocity and acceleration data sets included in the file. (Velocity is stored in the series **dc01.vel1**, and acceleration is stored in the series **dc01.acc1**.)

Bell Ringer: Determining the Angle of a Ramp – ID: 13275

(Student) TI-Nspire File: *PhysBR_week01_ramp_angle.tns*

<p>1.1 1.2 1.3 1.4 ▸ DEG AUTO REAL</p> <p>DETERMINING THE ANGLE OF A RAMP</p> <p style="text-align: center;">Physics</p> <p style="text-align: center;">Motion in One Dimension</p>	<p>1.1 1.2 1.3 1.4 ▸ DEG AUTO REAL</p> <p>In this activity, you will use data on the position of a rolling ball over time to calculate the angle of the inclined plane on which the ball was rolling.</p> <p>The data were collected for a ball rolling up and then back down an inclined plane. A motion sensor was placed at the top of the plane, as shown on the next page.</p>	<p>1.1 1.2 1.3 1.4 ▸ DEG AUTO REAL</p>  <p>The ball rolled up the plane toward the motion sensor, and then back down. The sensor recorded the distance between the ball and the sensor as the ball rolled.</p>
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<p>1.1 1.2 1.3 1.4 ▸ DEG AUTO REAL</p> <p>1. What is the equation for the displacement (position) of the ball as a function of time? Assume that there is no friction between the ball and the ramp, and that the only acceleration is due to gravity. Use s for displacement, v for velocity, g for acceleration due to gravity, and t for time. (Hint: What component of g is acting parallel to the ramp?)</p>	<p>1.2 1.3 1.4 1.5 ▸ DEG AUTO REAL</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>A</th> <th>time</th> <th>B</th> <th>distance</th> <th>C</th> </tr> </thead> <tbody> <tr> <td colspan="5">= dc01.time = dc01.dist1</td> </tr> <tr> <td>1</td> <td>0.</td> <td></td> <td>0.564292</td> <td></td> </tr> <tr> <td>2</td> <td>0.05</td> <td></td> <td>0.564378</td> <td></td> </tr> <tr> <td>3</td> <td>0.1</td> <td></td> <td>0.564378</td> <td></td> </tr> <tr> <td>4</td> <td>0.15</td> <td></td> <td>0.564309</td> <td></td> </tr> <tr> <td>5</td> <td>0.2</td> <td></td> <td>0.564154</td> <td></td> </tr> </tbody> </table> <p>The data shown here are the distance and time data recorded by the sensor.</p> <p>A1 = 0.</p>	A	time	B	distance	C	= dc01.time = dc01.dist1					1	0.		0.564292		2	0.05		0.564378		3	0.1		0.564378		4	0.15		0.564309		5	0.2		0.564154		<p>1.3 1.4 1.5 1.6 ▸ DEG AUTO REAL</p>  <p>$f(x) =$</p>
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<p>1.4 1.5 1.6 1.7 ▸ DEG AUTO REAL</p> <p>2. What is the acceleration coefficient in the best-fit equation? (Hint: Expand the equation for the best-fit parabola to write it in the form ax^2+bx+c.)</p>	<p>1.5 1.6 1.7 1.8 ▸ DEG AUTO REAL</p> <p>3. Use the <i>Calculator</i> application above to calculate the angle of the inclined plane.</p>	<p>1.6 1.7 1.8 1.9 ▸ DEG AUTO REAL</p> <p>4. How would the acceleration coefficient change if the angle of the ramp were increased? Explain your answer.</p>
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1.7 1.8 1.9 1.10 ▸ DEG AUTO REAL

5. If the ramp were infinitely steep (i.e., vertical), what would the acceleration coefficient in the equations be? Explain your answer.