Bell Ringer: Graphical Determination of Velocity – ID: 13361

Time required
15 minutes

Topic: Kinematics

- *Interpret graphs of position and velocity versus time.*

Activity Overview

In this activity, students will use precompiled data to determine the velocity of a falling object from a graph of its position vs. time. They will use a graph of velocity vs. time to confirm their calculations.

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

Data & Statistics, Notes

Teacher Preparation

Before carrying out this activity, review with students the relationship between displacement (position) and velocity.

- *The screenshots on pages 2–5 demonstrate expected student results. Refer to the screenshots on page 6 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 "13361" in the search box.***
- *For a more extensive exploration of this content, use activity 8739: Air Resistance. Activity 8739, 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 8739 at education.ti.com/exchange.*

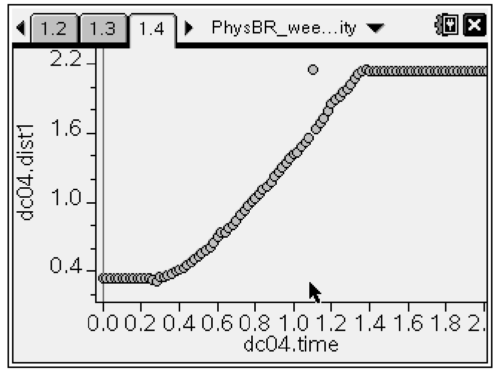
Classroom Management

- *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 following questions will guide student exploration in this activity:

- How can a graph of position vs. time be used to determine velocity?
- How can a graph of velocity vs. time be used to determine acceleration?

Students will use a precompiled set of position vs. time data for an object falling to the ground. They will determine the slope of the best-fit line through the constant-velocity region of the graph. They will then use a graph of velocity vs. time to test their best-fit velocity.



Step 1: Students should open the file **PhysBR_week05_det_velocity.tns** and read the first two pages. (Students can press ctrl ▶ and ctrl ◀ to move between pages in the .tns file.) Page 1.4 contains a *Data & Statistics* application showing a graph of position (displacement) vs. time for a falling basket-style coffee filter. The filter was dropped from a great enough height that it fell at terminal velocity for most of its fall. Students should study the graph and then move back to pages 1.2 and 1.3 to answer questions 1 and 2. Students can type their answers into the *Notes* application on page 1.2, or they can write their answers on a sheet of blank paper.

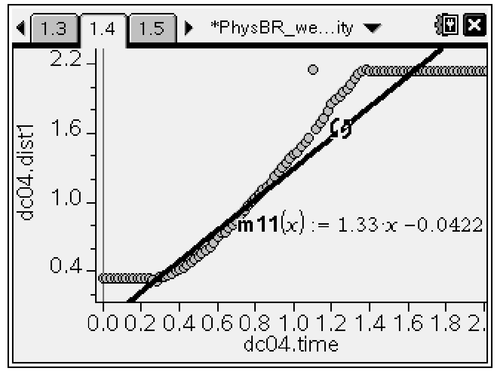
Q1. The graph on page 1.4 shows position vs. time data for a falling object. Describe how the speed of the object changed over time.

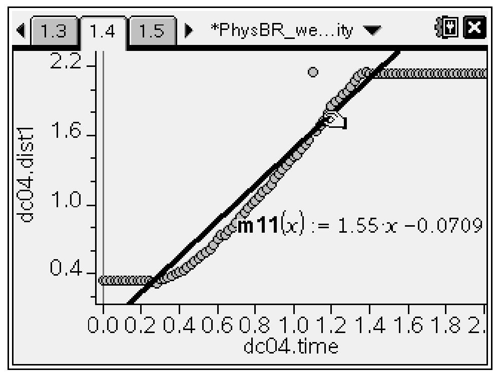
A. *The graph begins with a horizontal region, indicating that the object's position was not changing (i.e., it was at rest). A short, slightly curved section occurs after the initial resting region, indicating that the object was accelerating. A long, straight, upward-sloping region follows, indicating a period when the object was traveling at a constant velocity. The graph abruptly changes to another horizontal section, indicating a sudden and abrupt stop.*

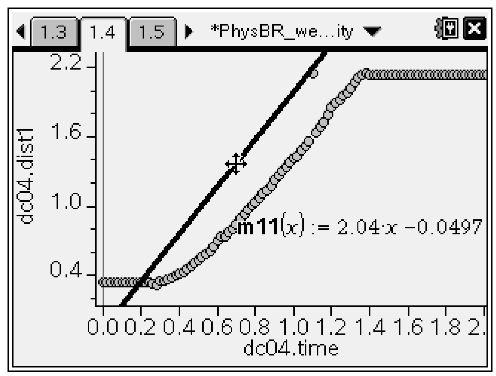
Q2. Explain how a falling object could reach a constant velocity if gravity is always acting on it.

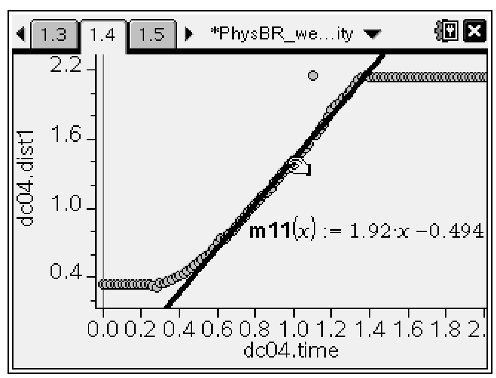
A. *As the object falls through the air, air resistance acts on it. The faster it falls, the more air resistance it experiences. When the upward force of air resistance equals the downward force of gravity, the object stops accelerating and falls at a constant velocity.*

Step 2: Students should move to page 1.5 and read the text there. They should then move back to page 1.4 and use the **Movable Line** tool (**Menu > Analyze > Add Movable Line**) to determine the slope of the best-fit line through the constant-velocity portion of the graph. To use the **Movable Line** tool, students should use the NavPad to move the cursor to a location on the movable line. The cursor will turn into either a four-corner arrow or a circular arrow. To grab the line, students should press and hold until the cursor changes to a closed hand. They can then use the NavPad to drag the line. They can press esc to release the line. To change the angle of the line, they should grab the line from a point at which the circular arrow is visible. To change the position of the line, they should grab the line from a point at which the four-corner arrow is visible. The equation for the line will be displayed on the screen. (Note: Because this is a "real" data set, rather than a calculated one, there is some noise in the data. Students should ignore outlying data points as they study the data.) After students have moved the line to its best-fit position, they should answer questions 3 and 4 on pages 1.5 and 1.6.









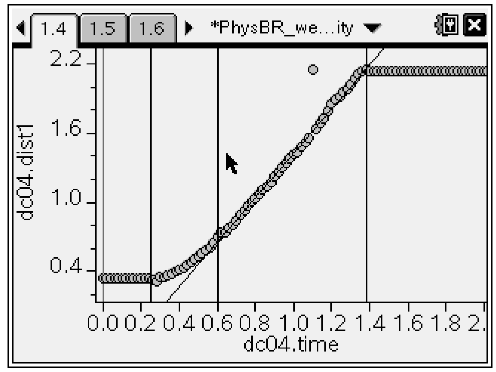
Q3. Use the **Movable Line** tool to determine the slope of the portion of the graph in which the object was falling at a constant velocity. What was the object's velocity during this portion of the graph?

A. *The slope of the straight, non-horizontal section of the graph is equal to the object's constant velocity. The exact slopes of the best-fit lines students identify may vary, but they should be approximately 1.9 m/s.*

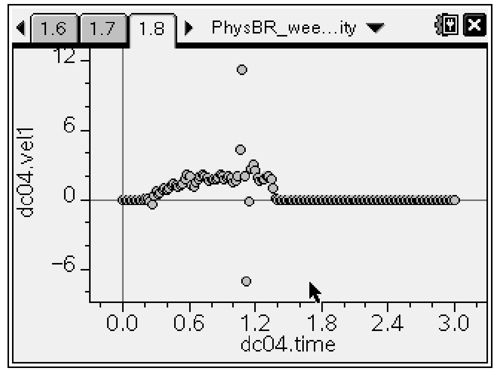
Q4. At what time is the object released? At what time does the object stop accelerating? At what time does the object experience a sudden and abrupt stop?

A. *approximately 0.25 s, 0.6 s, and 1.38 s, respectively*

Step 3: Next, students should use the **Plot Value** (**Menu > Analyze > Plot Value**) tool to plot vertical lines representing the times they identified in question 4.

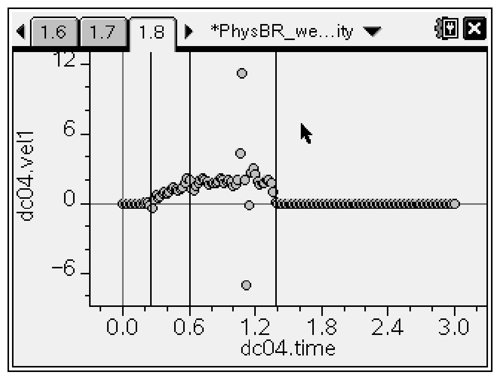


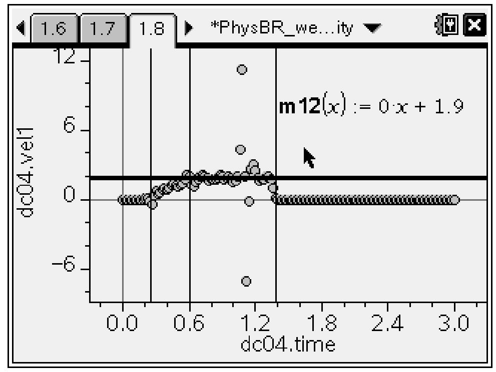
Step 4: Next, students should move to page 1.7 and read the text there. They should then examine page 1.8, which shows a plot of the object's velocity vs. time. After students examine the graph, they should answer question 5 on page 1.7.



Q5. The graph on the next page shows a graph of velocity vs. time for the object. Does this graph match the description you gave in question 1? If not, explain what errors you made in your answer to question 1.

A. *Students' answers will vary. Encourage students to use metacognitive thinking to identify errors in their reasoning. Students should again use the **Plot Value** tool to plot vertical lines corresponding to the three times they identified in question 4. These lines should help students identify the relevant regions of the graph.*

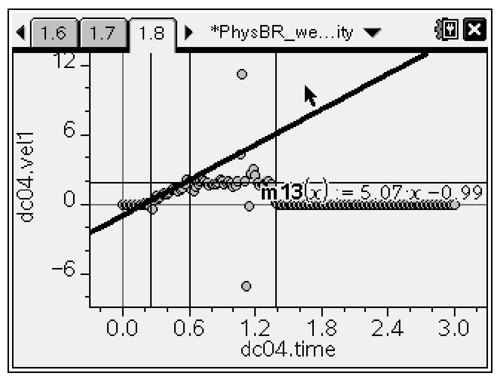




Step 5: Next, students should move to page 1.9, read the text there, and then move back to page 1.8. They should use the **Movable Line** tool to determine the *y*-intercept of the best-fit horizontal line through the region of the data that represent the constant-speed motion of the object. They should then answer question 6 on page 1.9.

Q6. Use the **Movable Line** tool to determine the object's speed during the time it was traveling at constant (non-zero) speed. Compare this value to the value you determined in question 3.

A. *The exact* y*-intercepts students determine will vary, but they should be approximately 1.9 m/s. If students' values are significantly different from those they determined in question 3, encourage them to examine their methods on both questions to identify possible sources of error.*



Step 6: Finally, students should move to page 1.10, read the text there, and then again move back to page 1.8. They should add a second movable line and adjust it to find the slope of the region of the graph in which the object was accelerating. They should then answer question 7 on page 1.10.

Q7. Use the **Movable Line** tool to determine the object's acceleration during the portion of the graph in which it was accelerating. What was the object's acceleration? How can you tell?

A. *The object's acceleration is equal to the rate of change of its velocity (i.e., the slope of the velocity vs. time graph). Students' exact values will vary, but they should be close to 5 m/s*^{2}.

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. The data used in this activity were collected for a basket-style coffee filter falling from a height of approximately 2 m. For best results, students should use a similar high-drag object that will reach terminal velocity relatively quickly.

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(Student)TI-Nspire File: *PhysBR_week05_det_velocity.tns*