



Getting Started with TI-Nspire™ Connecting Science and Mathematics

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Materials for Institute Participant*

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Day One	Page #
1. Overview, Logistics, and Introductions <u>Reflective Questions:</u> How much experience have you had with handheld technologies? 84? TI-Nspire™? How much experience have you had with data collection? What do you hope to learn and use from this institute?	7
2. Calculator Scavenger Hunt <u>Reflective Questions:</u> How difficult is it to learn a new system (and new concepts, procedures and knowledge)? What are some other strategies for helping learners with a large amount of detail?	13
3. Graphing Functions <u>Reflective Questions:</u> How are language and vocabulary different in science and mathematics teaching, even when talking about the same concepts? How can Math and Science Teachers help students transfer skills and understanding between classes?	15
4. How Much Does It Weigh? <u>Reflective Questions:</u> What are the advantages of a pre-made Nspire document?	17
5. Match Me <u>Reflective Questions:</u> Can kinesthetic learning (or incorporation of other “intelligences”) help in understanding concepts?	19
6. Discussing Stations <u>Reflective Questions:</u> What are some of the benefits and challenges of running a class with stations? How can stations be incorporated in a class without active use of equipment or manipulatives?	31
7. Walk a Line <u>Reflective Questions:</u> Why is it important to have students make a prediction about what the graph will look like prior to collecting the data? What is the value of real-time data collection?	33
8. River of Life <u>Reflective Questions:</u> Can relationships in one context be transferred to other contexts?	43
9. Nailing Density <u>Reflective Questions:</u> What role does student ownership of data play in motivation and engagement?	53
10. NASA Shuttle Ascent (Alg) <u>Reflective Questions:</u> Does a “big name” context add value to an activity?	63



11. Day 1 Summary of Learning & Reflections <u>Reflective Questions:</u> How do you know what students have learned in your class? More importantly, how do they know what they have learned?	
Day Two	
1. Navigator: Feedback <u>Reflective Questions:</u> What are some useful strategies for getting students to reflect and provide feedback?	
2. Using the Temperature Sensor <u>Reflective Questions:</u> What are the benefits of asking learners to make predictions? How does attempting to explain data in conceptual ideas help understanding?	105
3. Roller Coaster Energy <u>Reflective Questions:</u> Can a simulation do an adequate job of illustrating or proving a concept?	113
4. Reflection & Absorption <u>Reflective Questions:</u> How could this activity be done if you did not have the capability to run two different sensors simultaneously?	119
5. Rolling Rates <u>Reflective Questions:</u> How valid is the data collected in student experiments? How important is this? How does this affect learning?	123
6. Teacher Software Explorations <u>Reflective Questions:</u> Can the Teacher Software be useful if students do not have it for their own use?	133
7. Summary of Learning & Reflections <u>Reflective Questions:</u> How many different types of learning have taken place?	
Day Three	
1. Alcohol Evaporation <u>Reflective Questions:</u> What are the roles of molecular size and molecular interactions on the rate of evaporation? Does doing an activity like this help get the concept across to students?	141
2. Beer's Law <u>Reflective Questions:</u> Can an unknown value be determined even though the value of the unknown does not match the values of any of any knowns?	149



3. Sound Waves & Beats <u>Reflective Questions:</u> How can different models of a concept help understanding and learning?	161
4. Carousel <u>Reflective Questions:</u> What is the value to learning of learner choice in what they do?	171
5. Ball Toss <u>Reflective Questions:</u> What variations or inquiry possibilities could be done by adapting this activity?	173
6. Boyle's Law <u>Reflective Questions:</u> How can the unseen be understood?	181
7. Dew Point <u>Reflective Questions:</u> How can an understanding of a scientific concept be transferred into everyday life?	191
8. Freeze - Melt <u>Reflective Questions:</u> Simple concepts often have some surprising special cases. What is the value of having students discover some of these situations?	197
9. Friction: A Sticky Subject <u>Reflective Questions:</u> How could expanding an activity like this into an open-ended, student-directed project enhance learning in both science and mathematics, and enhance student growth? Just because a topic is not in the curriculum (e.g. friction is not in a mathematics curriculum) does not mean that it should not be introduced in the classroom. Do you agree or disagree? Why?	203
10. Carousel Reports <u>Reflective Questions:</u> What are the benefits of peer teaching for those doing the teaching and for the peer learners?	
11. Next Steps: Closure & Adieu <u>Reflective Questions:</u> What is the real value of technology to teaching and learning? What do you need as now to implement what you have learned at this workshop?	

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Welcome to Connecting Science and Mathematics

This three-day workshop is intended for beginning users of the TI-Nspire™ technology. During our time together, you will have many opportunities to work through activities with your peers. And, of course, you have the help and guidance of an experienced TI-Nspire user—your T³ Instructor.

In the course of these few days together, you will learn many of the features of the TI-Nspire™ handheld and software in the context of classroom-ready activities and other explorations. The Instructor will lead you through several activities, demonstrating suitable pedagogical techniques with the technology, and will facilitate discussions about classroom and educational issues as well as address any concerns you might have. You will also be given time to explore some activities of your choice and share your thoughts and challenges with the whole group.

The foci of this workshop are for you to:

- Observe, learn, and practice sound pedagogy for using technology in the classroom.
- Learn about and practice with the TI-Nspire™ document model and its features.
- Experience the use of TI-Nspire™ handhelds by setting up experiments and collecting data.
- Make contextual and pedagogical connections between science and mathematics.

The materials you will receive include three types of documents:

- Teacher Notes (in this format)
- Student Activity Worksheets (activity/instruction sheets)
- TI-Nspire documents

You will be asked to take on several different roles during the workshop:

- You might take on the role of a student as you learn specific science and mathematics content.
- You will think like the classroom teacher considering the impacts on classroom management.
- You will think like an educator using sound pedagogy to enhance student learning.
- You will rely on one another as content specialists, helping to apply or adapt activities to particular lessons and to make the connections between science and math.

You are a full learning partner here and will be immersed in this technology experience. Practice is the best way to become comfortable with the technology, including setting up activities, cleaning up, contributing to discussions, and asking questions. Your sincere contributions to your roles in the team will make this workshop successful.



Science Objectives

- Student activities will include science content or skill objectives that can be expected to be achieved by completion of the activity. They will be written as:
 - Students will . . .

Math Objectives

- Math objectives that connect with the activity will also be listed as:
 - Students will . . .

Materials & Advance Preparation

- A list of materials and equipment, along with any advance preparation needed, will be listed where needed.

About the Lesson

- A short overview of the lesson will be given here.

TI-Nspire™ Navigator™ System

- TI-Nspire Navigator will be available throughout the workshop, and used by the instructor to facilitate your learning (and as a demonstration of how it can benefit classroom teaching). Many of the activities will have TI-Nspire Navigator suggestions, but the activities can still be completed without TI-Nspire Navigator in your classroom.
- For those with TI-Navigator access in the classroom, TI-Navigator suggestions are given at appropriate points in the activities.

TI-Nspire™ Technology Skills:

- New or significant skills for each activity will be listed here. This is a good chance for you to review them for your students, or for yourself.

Tech Tips:

- Some common technical issue resolutions or shortcuts are given here and throughout the notes.

Lesson Materials:

- Print or electronic files are listed here.



Discussion Points and Possible Answers

Suggestions for introducing the activity are given. Throughout the activity, specific suggestions or answers to questions from the Student activity are provided for each step.

This parallels, but does not repeat, the Student Activity. You will need to read through (and work through) the Student Activity and TI-Nspire document.

Wrap Up

A short summary of the expected outcomes of the activity along with some suggestions for discussion, connections, or extensions are provided.

Assessment

Ideas on how and where assessment can be linked to the activity are provided. The assessment may be formative and informal, or summative and much more formal, including actual testing on the TI-Nspire.

TI-Nspire Navigator

Note 1

Specific notes for Navigator use are provided where suitable.

References will be made where appropriate to point out how activities address:

Common Core State Standards Mathematical Practices

Constructivist 5-E's Processes

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Interactive Math and Science Classrooms...

I.C.E.R

Interaction
Communication
Engagement
Reasoning & Sense-Making

5 E's Learning Cycle for Science

Engagement
Exploration
Explanation
Elaboration
Evaluation

CCSS

Mathematical Practices

Make sense of problems & persevere in
solving them

Reason abstractly & quantitatively

Construct viable arguments & critique
others' reasoning

Model with mathematics

Use appropriate tools strategically

Attend to precision

Look for & make use of structure

Look for & express regularity in
repeated reasoning

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Scavenger Hunt – TI-Nspire CX™ CAS

GETTING TO KNOW THE CALCULATOR PAGE










Activity Overview

- In this activity, you will create and investigate the features of a calculator page.






Materials

- TI-Nspire CX™ CAS

Getting to Know the TI-Nspire™ CX

- Where are the letters? What do you notice about them? _____
- Which key is located under the  key? _____
The TI-Nspire is menu driven. You can explore the menu options in an application to figure out how to do most everything.
- On the TI-Nspire CX which key do you think you push to access the **blue** functions that appear above many of the keys? _____
- The Touchpad is used to navigate the cursor around the screen. Gently slide your finger across the Touchpad. What body part appears above the CLICK in the middle of the Touchpad? _____
Notice that it is closed.
- Where are the buttons for add, subtract, multiply, and divide? _____
- Press  to turn on the handheld. To adjust the contrast, hold down the  and press  or  keys repeatedly to lighten or darken the screen.
- The handheld is designed to mimic the operation of computers and computer software. Many of the traditional shortcut keys used with computer software are available on a TI-Nspire handheld. The handiest ones,   and  , are used to “undo” and “redo” actions.

Starting to Navigate the Handheld

- Press  to enter the Home Screen. Use the arrows to move and explore.
 - How many options are there to select from on the screen? _____
 - Which options might you select to graph a line? _____
 - Which options remind you of some computer functions? _____
- Press   to create a new document. If prompted to save the current document,  to [NO]. Press  to start the new document with a **Calculator**. A blank page appears on the screen and a tab labeled 1.1 appears in the top-left corner of the screen. What appears in the lower-right corner of the screen? _____

TI-Nspire Scavenger Hunt - Touchpad

10. Perform the following calculations.

- Type $1/2+1/3$ and press **enter**. What do you notice? _____
- Type $1./2+1/3$ and press **enter**. What do you notice? _____
- Type $2/5 + 3/8$ and press **ctrl** **enter**. What do you notice? _____
- Type $(4-3(2-4)3-7)2$ Do you notice the *faded* images of the close parentheses that appear immediately after you press **(**? Press **enter**. What was the result? _____

11. What do you think the 4/99 in the bottom-right corner of the screen means? _____

12. An object that is dropped near the surface of the earth initially accelerates down at 9.8m/s/s.

Distance $d = \frac{1}{2} a t^2$, where a is the acceleration and t is the time. If a rock is dropped 1.75 meters above the ground. How long will it take to hit the ground? What if the distance was doubled?

Use **ctrl** **^** and **ctrl** **÷** to perform the following calculations.

a. $\sqrt{\frac{2(1.75)}{9.8}} =$

b. $\sqrt{\frac{2(1.75)2}{9.8}} =$

c. $\frac{-5 + \sqrt{5^2 - 4(6)(-4)}}{2(6)} =$

d. $\frac{-5 - \sqrt{5^2 - 4(6)(-4)}}{2(6)} =$

After doing 12a there is any easy way to modify it to make it like 12b. Ask your instructor to demonstrate this tip if you cannot discover it yourself. Hint: Up arrow and notice what is selected. Press **enter.

One of the most important TI-Nspire key combinations to be aware of is **ctrl** **enter**.

After doing 12d, press **ctrl enter**. What does this do? _____

13. Perform the following actions. Use **ctrl** **=**, **?!>**, **π>** and **trig** to access the necessary symbols.

- Type $-4 < -5$. What did you get? _____
- Type $15\% \cdot 25$ to find 15% of 25 milliliter solution. Give decimal and fractional answer. _____
- Type $2x+3|x=\{-3, 0, 1, 4, 5\}$. What did you get? _____
What does the result from the previous calculation mean? _____
- Type $\cos(30^\circ)$. Where did you find the degree symbol? _____ What is the solution? _____

With the TI-Nspire CX CAS do the following.

- Press **menu** **Algebra** **Solve** **enter** $\sin(\theta)=1/2$ **(** **θ** **)** $-\pi < \theta < \pi$ What did you get? _____
- Type $v = \frac{d}{t}$ **enter**. Then press **x** **T** **enter**. What did you get? _____
- Now press **÷** **V** **enter** to solve for d. What did you get? _____

This is CAS = Computer Algebra System. It is a great tool for exploring mathematics, checking your work, identifying patterns, remediation, and climbing the tree of mathematics. The CAS even has the built in capability of units. Type 55_mph. What do you get? _____

(Hint: You should have found the underscore _ by pressing the punctuation button **?!>**. A common shortcut is the **ctrl** space, or **ctrl** **_**.) To explore more of what you can do with units on the TI-Nspire CX CAS, press the catalog button and then 3, **(** **3** **)**. For example try 1_mi>_ft. How many feet are in a mile? _____
The conversion operator **>** is can also be found in the top line of the symbols, **ctrl** **(** **>** **)**.



This activity provides an introduction to the basics of graphing functions.

Part One – Graphing Functions

Step 1: Press and select **New Doc** to open a new document.

Step 2: Choose **Add Graphs**.

Note: To add a new *Graphs* page to an existing document, press and choose **Add Graphs**. Alternatively, you can press , and make selections using the Touchpad.

Step 3: The cursor will be in the entry line at the bottom of the screen to the right of $f1(x) =$. To graph, type the function and press . For example, to graph $f1(x)=x^2$, type .

Note: To graph multiple functions without closing the entry line, press after entering a function definition. After entering the last function definition, press .

Step 4: Press the **menu** key to see the selections available in the *Graphs* application. Note that **Analyze Graph** includes the same options as the Calculate menu of the TI-84. Press until you are no longer exploring the menu options.

Note: Menu options change depending upon the application.

Part Two – Transforming Functions

Step 5: As the cursor moves toward certain regions of the graph of the basic functions, two different tools—the **Dilation** tool or the **Translation** tool—will display. When the symbol for the **Dilation** tool, is displayed, the graph of the quadratic function can be dilated.

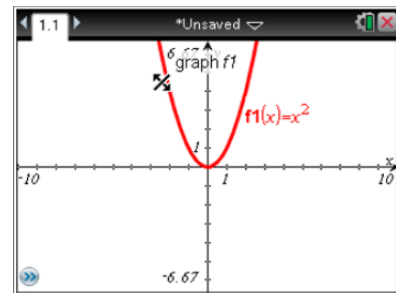
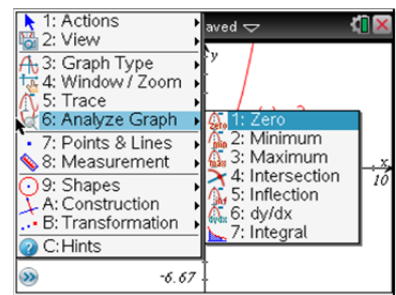
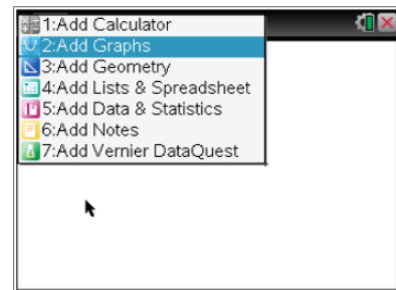
Step 6: Move the cursor toward the edges of the function to see the dilation tool appears as shown. Press or hold the key down until the hand closes to grab the graph, and use the Touchpad to dilate the graph of the function. Notice how the equation changes as the graph changes. Be sure to change the graph so that it opens upward and downward. When finished, press or .

TI-Nspire™ Technology Skills:



- Creating a document
- Adding a Graphs Page
- Transforming the Graph
- Using Scratchpad
- Calculator Settings

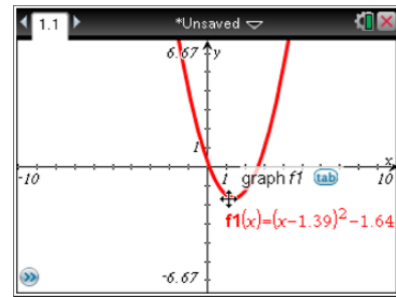
Lesson Files:

Created by the Teachers and Students





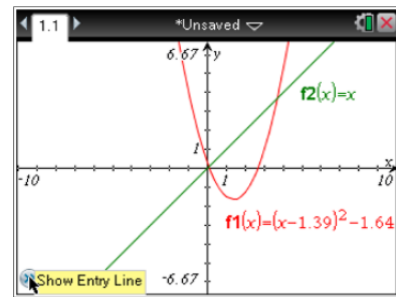
Step 7: To translate the graph of a quadratic function, move the cursor near the vertex of the parabola. When the **Translation** tool (a small set of axes \leftrightarrow) is displayed, press **ctrl**  or hold the  key down until the hand closes to grab the graph, and use the Touchpad to translate the graph of the function. Notice how the equation changes as you translate the graph.




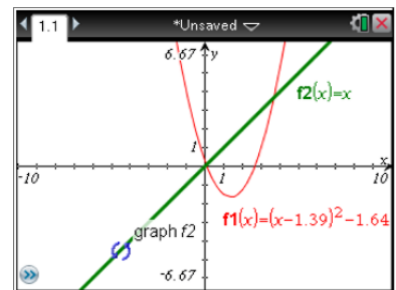
Note: Not all functions can be translated and dilated by grabbing it. Linear, quadratic, exponential, logarithmic, and sinusoidal are the types of functions that can be manipulated this way.


Tech Tip: If you move the cursor near a point on the graph and there are two different objects that can be selected, you might see the **tab** show up on the screen. Press the **tab** key to select the item that you want.

Step 8: Add the linear equation. To graph the linear function, first press **ctrl** **G** to view the entry line or click on the chevron as shown in the image to the right. The cursor will now be to the right of $f2(x) =$. Graph a linear equation like $f2(x)=x$.



Step 9: As you move the cursor toward certain regions of the graph of a linear function, two different tools—the **Rotation** tool or the **Translation** tool—may be displayed. To rotate the graph of the line, move the cursor to the graph of a line near the edge of the graph screen. When the rotation symbol \curvearrowright appears, grab and rotate the line. When finished, press  or **esc**.



Step 10: To translate the graph of a linear function, move the cursor near the center of the graph displayed on the screen. The symbol for the **Translation** tool for a linear function is the same as that for a quadratic function. When the **Translation** tool is displayed, press **ctrl**  to grab the graph, and use the Touchpad to translate the graph of the function.

Step 11: Go to the **menu** and patiently look for how you can find the **intersection** of the linear and quadratic functions. See how easy it is even without formal instructions.

Note: Notice the icon that appears in the upper left corner of the screen when a menu option is activated. Hover over this for tips and instructions. To get out of the operation press **esc**.



In this activity, you will navigate through a TI-Nspire™ document, answer questions, manipulate a graphic, and input values into a spreadsheet.

Part One – Opening the Document

Step 1: Press and select **My Documents**.

Step 2: Locate the file *How_Much_Does_It_Weigh*, and press to open it. Choose 'No' to saving the open document (unless you want to save it).

Step 3: Once the document opens, press to move to Page 1.2.

Part Two – Selecting an Answer

Step 4: To answer the question, press the down arrow on the bottom of the Touchpad to move to the desired response.

Step 5: Press to select a response. On questions with multiple responses allowed, you deselect the answer by pressing a second time or select **MENU > Clear Answers**.

- Another option for selecting an answer is to swipe your finger across the Touchpad to move the cursor, and click to make a selection.

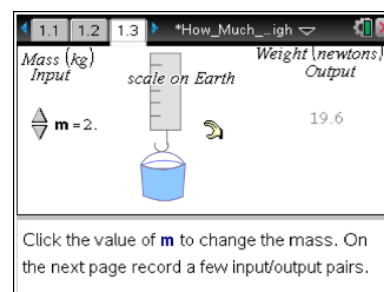
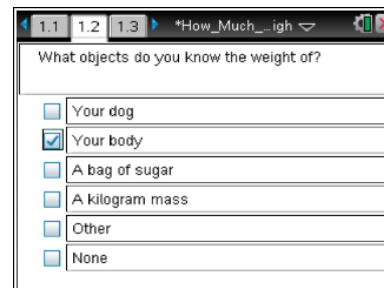
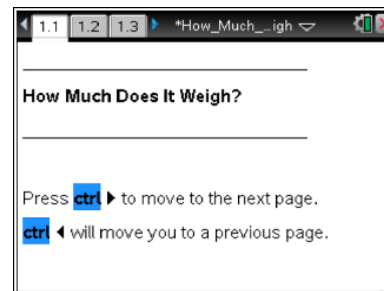
Step 6: After choosing all desired responses, press to move to page 1.3.

Part Three – Changing the Input for the Mass

Step 7: Move the cursor to the up/down arrows under the text Mass (kg) Input. Click , and use the up and down arrows on the Touchpad to change the values.

Step 8: Also try clicking the number next to **m=** and manually change the value. Use the arrows to get to the end, press to backspace over the previous value, and enter a new value.

Step 9: Press to evaluate this value.





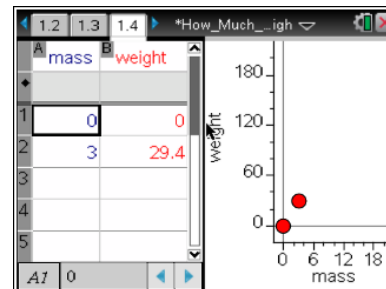
Step 10: Press **ctrl** ► to move to the next page.

- A scatter plot of force/weight versus mass has been set up.

Part Four – Editing the Spreadsheet

Step 11: Record the input and output values in the spreadsheet on Page 1.4, but using the arrows to move to the desired cell.

Step 12: Press the number on the keypad, and press **enter**.



1. What science concepts can be explored with this activity?
2. What questions can we ask to highlight the math concepts?

Step 13: Press **ctrl** ► to move to page 1.5 and 1.6 to answer the open response and multiple choice questions (multiple responses not allowed this time).

Overview

In this activity you will match your motion to a given graph of position versus time. You will apply the mathematical concepts of slope and y -intercept to a real-world situation.

Materials

- TI-Nspire™ handheld or software with *Vernier DataQuest™* application
- CBR 2™ with USB cable

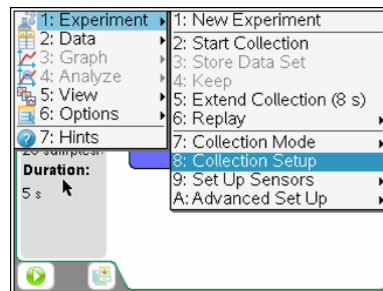
Part 1—Easy, step-by-step setup

To utilize the built-in, easy-to-use **Motion Match** activity, first turn on the TI-Nspire™ and choose **New Document**. Then plug in the CBR 2™ and the screen to the right will automatically launch.

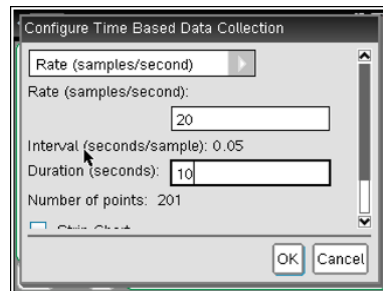


Hold the CBR 2™ so that it points toward a smooth surface like the wall or door. Move forward and backward to observe the reading changes on the meter.

1. How far are you from the wall? _____
Record all the digits that are given, as well as the units.



You will set up an experiment for 10 seconds. Press **Menu > Experiment > Collection Setup**. Change the duration to 10 seconds.





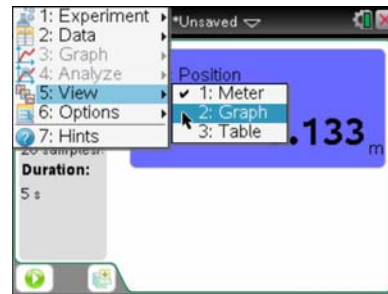
Match Me Student Activity

Name _____

Class _____

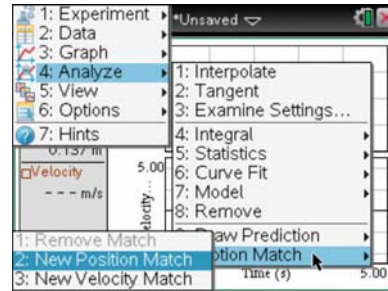
Now, set up the graph. Press **Menu > View**. There are three views. The first view you had was **Meter**. Choose the **Graph** view for additional menu options.

Press **Menu > Analyze > Motion Match > New Position Match**. These menu selections are shown in the screen shot on the right.



2. What physical quantity is the dependent variable? _____
 - A. velocity in meters/second
 - B. position in meters
 - C. time in seconds

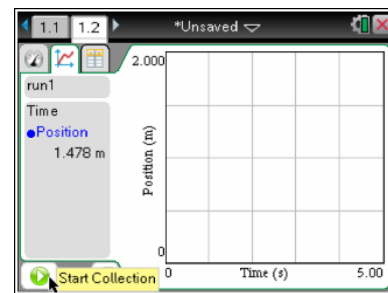
3. What variable is plotted on the x-axis? _____




Draw your Position Match on the graph to the right.

4. What is the domain? Include units. _____

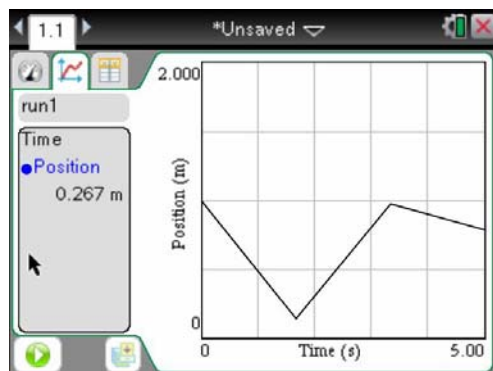
5. What is the range? Include units. _____



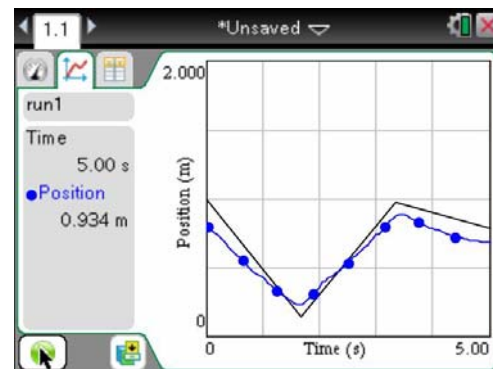
6. Record your observations about the graph by answering the following questions:
 - a. What is the y-intercept?
 - b. What does the y-intercept represent physically?
 - c. Approximately what distance from the wall will the motion detector need to be located to match the initial position in the motion graph?
 - d. The slope is the rate of change of position with respect to time. When does the graph depict the slowest motion?
7. Press the **Start Collection**  arrow on the bottom-left of the screen. Point the CBR 2™ at a wall and move yourself back and forth until your graph matches the Position Match graph as closely as possible. If you are not pleased with your first attempt, you can press **Start Collection** again to repeat. You may want to review the information that you wrote about the graph to assist you. When you are satisfied, sketch the graph you created on top of the given graph.

8. Describe the parts of your graph that were difficult to match and how you made adjustments, based on your graph of your walk, to make a better match in your next attempt..

Now, look at the graph shown to the right.



9. Describe how you would need to walk in order to match that graph with your motion. Be sure to include information about the y -intercept, position at various times, velocity, and direction. For what times does the graph depict the slowest motion and the fastest motion?



10. Describe the curve with round dots that was created when **Start Collection** was pressed. Contrast the motion graph that should have been created to what actually happened. Write at least two complete sentences. For example, *from 2 to 3.5 seconds the person is moving too slow to reach the maximum distance away.*

Part 2—Extend and Explore

Press **Menu > Analyze > Motion Match > New Position Match**. Press **Start Collection** and walk to match the graph. A trial can be saved by pressing the file cabinet icon next to **Start**.

11. Discuss your new match with a classmate. Use words like *positive and negative slope*.

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Math and Science Objectives

- Students will examine graphs of position versus time and match them with their motion to demonstrate their understanding of the graph.
- Students will explain how velocity and starting position relate to slope and y-intercept.
- Students will use appropriate tools strategically. (CCSS Mathematical Practice)

Vocabulary

- speed
- velocity
- initial position

About the Lesson

- In this lesson, students will examine a graph of position versus time and collect data by moving in front of a CBR 2™ to match their motion to the given graph.
- As a result, students will:
 - Develop a conceptual understanding of how their motion affects the slope and position values on the graph
 - Make a real-world connection between position, time, and velocity

Materials and Materials Notes

- CBR 2™ with USB CBR 2™-to-calculator cable.
- Using the CBR 2™ with a computer requires the use the mini-standard USB adaptor to plug the CBR 2™ into a computer with TI-Nspire™ Teacher or Student Software. This adapter will convert the CBR 2™ USB cable to a standard USB connection so that it can be connected to the computer.
- **New option:** Use the legacy CBR™ with the new TI-Nspire™ Lab Cradle. You will need the MDC-BTD cord to connect a motion detector to the TI-Nspire™ Lab Cradle. With the Lab Cradle, you can even connect multiple motion detectors to extend your exploration.



TI-Nspire™ Technology

Skills:

- Collect motion data with the *Vernier DataQuest™* app.

Tech and Troubleshooting

Tips:

1. Flip the motion detector open. Set the switch to normal.
2. Check that the four AA batteries in the motion detector are good.
3. Unplug and plug the CBR 2™ back in.
4. When using an older CBR™ or motion detector with the Lab Cradle, you may need to launch Vernier LabQuest™.

Then press **Menu >**

Experiment > Advanced Setup > Configure Sensor > TI-Nspire Lab Cradle: dig1 > Motion Detector.

Lesson Files:

- Student Activity*
- Match_Me_Student.pdf
- Match_Me_Student.doc

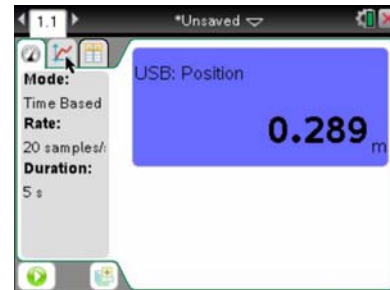


Discussion Points and Possible Answers

Part 1—Easy, step-by-step setup

To utilize the built-in, easy-to-use **Motion Match** activity, first turn on the TI-Nspire™ and choose **New Document**. Then plug in the CBR 2™ and the screen to the right will automatically launch.

Hold the CBR 2™ so that it points toward a smooth surface like a wall or door. Move forward and backward to observe the reading changes on the meter.



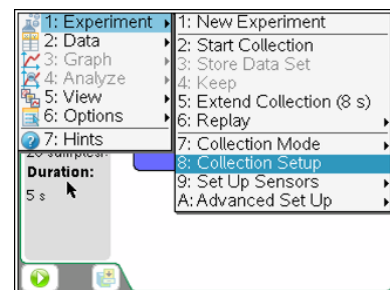
Tech Tip: The *Vernier DataQuest™* app is user friendly. It should launch when the CBR 2 is connected. To begin the data collection, click the green Play button in the lower left corner of the screen.

1. How far are you from the wall? Record all the digits that are given, as well as the units.

Sample answer: Answers will vary. The meter in the **Screen Capture** above shows 0.289 m from the wall or closest object.

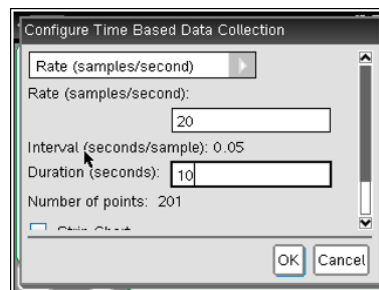
Teacher Tip: When the CBR 2™ is first connected it, begins clicking and recording measurements. Have the students move the CBR 2™ by pointing it at different objects. Ask them what the motion detector is doing. It should be measuring the distance from the CBR 2™ to the object directly in front of it. Be aware that it reads the distance to the closest item in its path, so students should keep an open area between the wall and the target object or person.

You will set up an experiment for 10 seconds. Press **Menu > Experiment > Collection Setup**.

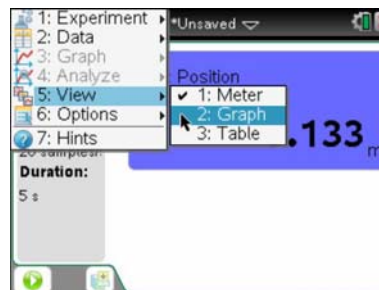




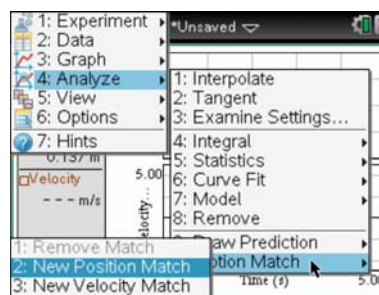
Change the duration to 10 seconds.



Now, set up the graph. Press **Menu > View**. There are three views. The first view displayed was **Meter**. Choose the **Graph** view for additional menu options.



Press **Menu > Analyze > Motion Match > New Position Match**.



2. What physical quantity is the dependent variable?
 - A. velocity in meters/second
 - B. position in meters
 - C. time in seconds

Answer: B. position in meters

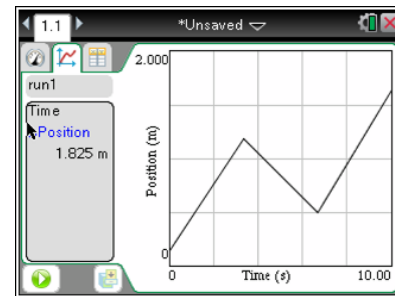
3. What variable is plotted on the x-axis?

Sample answer: The time in seconds, the independent variable, is graphed on the x-axis.



Draw your Position Match on the graph to the right.

Answer: Student graphs will vary because the *Vernier DataQuest™* application randomly generates new graphs.



4. What is the domain? Include units.

Sample answer: The domain is from 0 to 10 seconds.

5. What is the range? Include units.

Sample answer: The range is from 0 to 2 meters (This could vary).

6. Record your observations about the graph by answering the following questions.

a. What is the y -intercept?

Sample answer: Numerical values may vary but the answer should be in meters.

b. What does the y -intercept represent physically?

Sample answer: The y -intercept represents the starting position of the target object or person, sometimes referred to as the initial position. It indicates how close the target should be to the wall before beginning to move.

c. Approximately what distance from the wall will the motion detector need to be located to match the initial position in the motion graph?

Sample answer: Answers will vary depending on the motion graph generated, but the answer should be in meters.


d. The slope is the rate of change of position with respect to time. When does the graph depict the slowest motion?

Sample answer: Answers will vary depending on the motion graph generated. The



slope is the velocity that describes how fast the target object or person is moving and in what direction. Some students may say that velocity is speed. This is a great opportunity to explain the difference between speed and velocity. Speed indicates how fast the target is moving, but it does not include direction. Since speed has magnitude only, it is referred to as a scalar quantity. Speed is always positive. Velocity is called a vector quantity. It includes both the speed and direction. Velocity can be positive or negative for a person moving back and forth along a line. Velocity is positive when the target moves away from the motion detector, increasing the distance, and negative when the target moves toward the motion detector, decreasing the distance between the detector and itself.

Teacher Tip: It is important for students to make a prediction before simply pressing the **Start** button. Making predictions and testing those predictions supports higher level thinking.

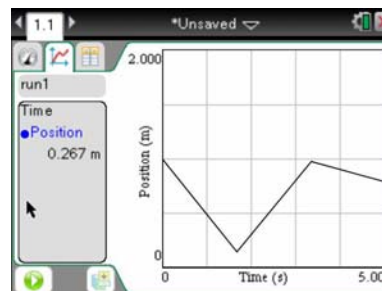
- Press the **Start Collection**  arrow on the bottom-left of the screen. Point the CBR 2™ at a wall and move yourself back and forth until your graph matches the Position Match graph as closely as possible. If you are not pleased with your first attempt, you can press Start Collection again to repeat. You may want to review the information that you wrote about the graph to assist you. When you are satisfied, sketch the graph you created on top of the given graph.

Tech Tip: If the students are not satisfied with their results, they can repeat the data collection by clicking the **Start** button again. This will overwrite the previous trial.

- Describe the parts of your graph that were difficult to match and how you made adjustments, based on your graph of your walk, to make a better match in your next attempt.

Sample answer: Answers will vary.

Now, look at the graph shown at the right.

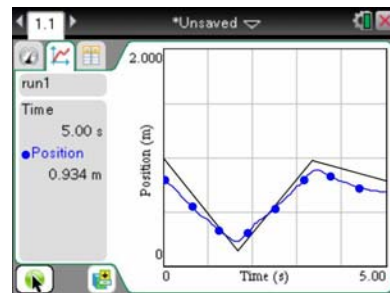




9. Describe how you would need to walk in order to match that graph with your motion. Be sure to include information about the y -intercept, position at various times, velocity, and direction. For what times does the graph depict the slowest motion and the fastest motion?

Sample answer: The walker begins one meter from the wall and moves toward the wall at a constant velocity for about 1.7 seconds. The walker gets about 0.3 meters from the wall and then begins walking away from the wall at about the same rate for another 1.7 seconds, arriving back at 1.0 meters from the wall. The walker then begins to slowly move toward the wall until a total of 5 seconds has elapsed. The slopes of the first two sections appear to indicate the same speed, but the first of these velocities is negative, while the second is positive. The walker moved slowest during the time period from 3.4 to 5 seconds.

10. Describe the graph with round dots at the right that was created when **Start Collection** was pressed. Contrast the graph of position versus time that should have been created with what actually happened. Write at least two complete sentences. For example, *from 2 to 3.5 seconds the person was moving too slow to reach the maximum distance.*



Sample answer: Answers will vary but may include the following information: The walker began a little too close to the wall, so the y -intercept is smaller than it should be. The walker was moving too slowly in the second section of the graph between 1.7 and 3.4 seconds. The walker was moving at about the right velocity for the third section of the graph, but the position was a little closer to the wall than it should have been.

Teacher Tip: If time permits, you should have each student match a graph without coaching. You may want to have them save the document and send it in via TI-Nspire™ Navigator™ as an individual evaluation. When students can match the graphs on their own, you are more assured that they understand the meaning of the y -intercept and slope as they relate to motion graphs.



Part 2—Extend and Explore

Press **Menu > Analyze > Motion Match > New Position Match**. Press **Start Collection** and walk to match the graph. A trial can be saved by pressing the file cabinet icon next to **Start**.

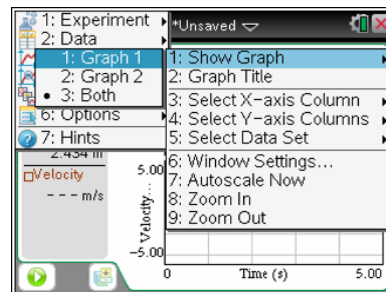
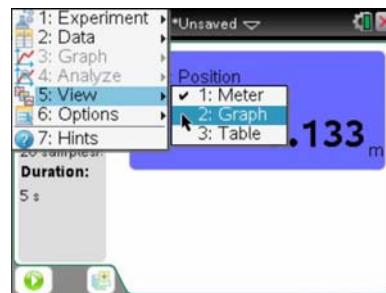
11. Discuss your new match with a classmate. Use words like *positive and negative slope*.

Sample answer: Answers will vary depending upon the graph generated.

Teacher Extension

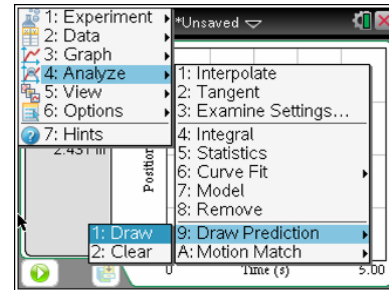
You can create your own matches for students if you want to be sure that they can match a graph with specific criteria. Follow these steps.

1. Open a new document and then connect the CBR 2™.
2. You will set up an experiment for 10 seconds. Press **Menu > Experiment > Collection Setup**. Change the duration to 10 seconds.
3. Now, set up the graph. Press **Menu > View**. Choose the **Graph** view. Then press **Menu > Graph > Show Graph > Graph 1**.

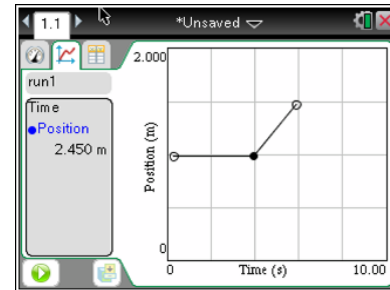




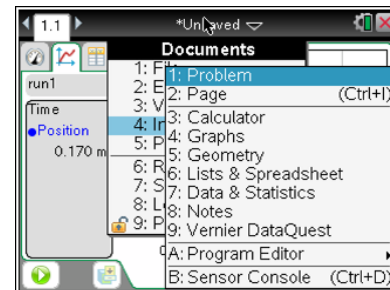
4. To draw your own match, press **Menu > Analyze > Draw Prediction > Draw**.



5. A pencil appears on the grid. Move the pencil to a point just off of the vertical axis on the left side of the grid, and click to set the initial value. Use the pencil to draw the path that you want students to match. Click at each point to set the end of a segment. Use the **[esc]** key to exit the draw mode when you have completed the match.



6. To create a document with multiple matches, insert a new problem for each match. To insert a new problem, press **[doc]** and select **Insert > Problem**. Follow the directions for creating a match. If you want to create a velocity match rather than a position match, choose to view **Graph 2** rather than **Graph 1** (**Menu > Graph > Show Graph > Graph 2**.)





The next three activities will be conducted using a station model. A set of stations might have a common theme, or a set of skills or content to be developed. In this case, each station will have a different activity exposing you to a different style of TI-Nspire use. The activities need not be done in any order. The station activities are:

- Walk a Line: uses a sensor (CBR 2™) to facilitate learning about motion.
- River of Life: uses a .tns document to work through and check understanding about numbers in the context of blood volume.
- Nailing Density: provides a .tns file with a format for students to collect and analyze measured information to discover the concept of density.

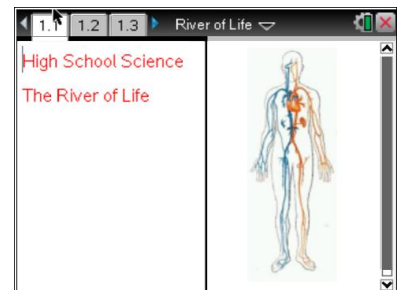
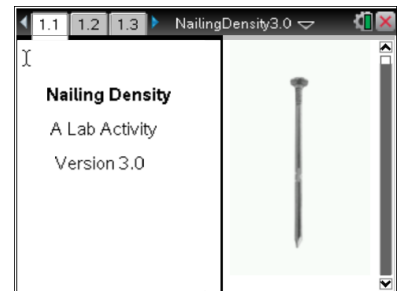
You are encouraged to work through the activities with an eye to the different TI-Nspire features and uses, as well as the application of the content topic in your classroom. Also, keep an ear open to what other groups are doing and share your discoveries.

What are some advantages of using stations?

What are some challenges in using stations?

TI-Nspire™ Technology Skills:

- Creating a document
- Setting up a sensor
- Building a spreadsheet
- Plotting graphs from data
- Analyzing graphs
- And many more. See individual activity Teacher Notes



Tech Tips:

- Numerous tips for specific situations are provided in individual activity Teacher Notes

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Activity Overview:

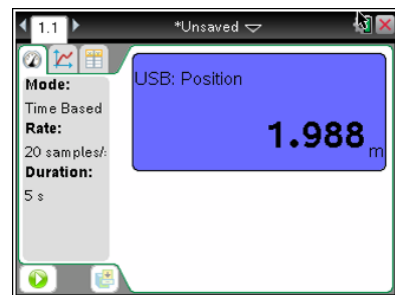
This activity will introduce the CBR2™ and the Vernier DataQuest™ Application. You will collect and analyze linear data.

Materials

- CBR 2™
- USB Connection Cable for CBR 2

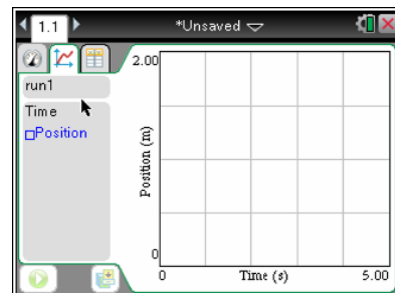
Activity Instructions:


Step 1: Connect the CBR 2 to the handheld with the USB cable. A Vernier DataQuest™ application page will automatically open and the CBR 2 will begin measuring the position of the closest object.



Step 2: Working in groups of two, one person will operate the TI-Nspire™ and point the CBR 2 towards the other person standing approximately two meters from the motion detector. The walker will walk slowly towards the motion detector at a constant velocity.

Step 3: Before collecting the data, make a prediction of what the graph of position versus time should look like. Sketch your prediction on the grid to the right.



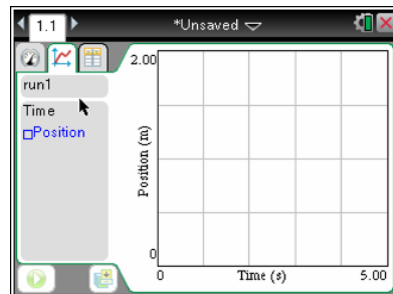
Step 4: The calculator operator should click the green Start button  in the lower left corner of the screen. The walker should walk **slowly** toward the CBR 2 with a constant velocity to close the gap in approximately five seconds. Don't go too fast or you will run out of room and need to try again. You must walk at the same velocity the entire time.

Step 5: Graphs for position versus time and velocity versus time are created and displayed on the same screen. Repeat as necessary until you generate a graph for position versus time that is roughly linear. How does the graph compare with your prediction?



Step 6: To display only the position versus time graph, press **Menu** > **Graph Settings** > **Show Graph** > **Graph 1**.

Sketch the actual graph of your position versus time graph on the grid shown to the right.



Step 7: Manual Analysis of Data:

- a. How can you estimate the average velocity of the walker?

- b. What was the position of the walker at time $t = 0$? At time $t = 5$?

- c. Show your work to calculate the slope of the graph.

- d. What does the slope of the graph represent physically?

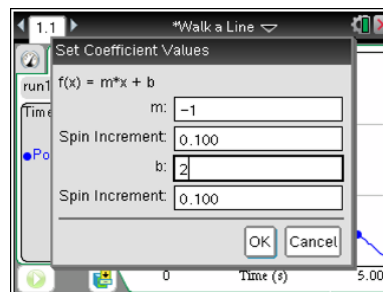
- e. Why is the velocity negative?

- f. Linear functions are usually written in the form $f(x) = mx + b$. Determine the y-intercept of your line and write an equation that you think will model the data.

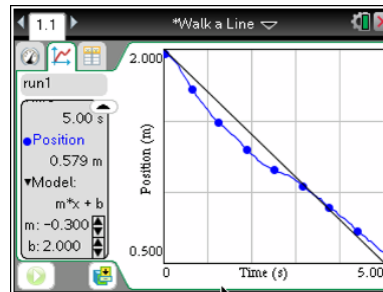
- g. What does the y-intercept represent?



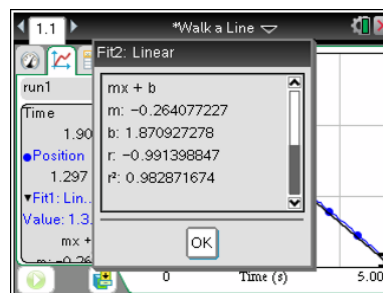
Step 8: Press **Menu > Analyze > Model**. Select $m \cdot x + b$ to create a linear model by clicking OK. Type your values calculated manually from above in the fields for m and b and click OK.



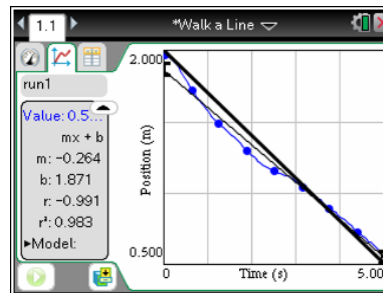
Step 9: The model can be adjusted by clicking the slider arrows on the left side of the screen or by changing the values of m and b manually. See the sample shown to the right. If you made adjustments, record the new values below.



Step 10: To analyze the data with a regression, a linear curve fit can be performed within the Vernier DataQuest Application. **Menu > Analyze > Curve Fit > Linear**. This will give the equation of the linear regression model. You will have to scroll down the dialog box to see the values of m and b for the linear model. Record the values for m and b below.



Step 11: Click OK to see the graphical results of the regression. How does your linear regression compare with the equation you found in Step 9? How do the values for m and b compare?



Discussions/Explorations

- As you may have gathered from your practice trials, the CBR 2 collects data measuring how far an object is from the sensor. By walking in front of the CBR 2, collect a set of data which appears linear and has a positive slope. Provide a detailed description of your “walk”. Be sure to discuss the “real-world” connections for the slope and y-intercept of the model.
- By walking in front of the CBR 2, collect a set of data which appears linear and has a slope which is approximately zero. Provide a detailed description of your “walk” including the connection between slope and y-intercept and the physical actions.



3. By walking in front of the CBR 2, collect a set of data which represents a piecewise function that has two parts – both of which are linear, one with a positive slope and one with a negative slope. Provide a detailed description of your “walk” including the connections between slope and y-intercept and the physical actions.



Math and Science Objectives

- Students will find the slope and y-intercept of a linear equation to model position versus time data.
- Students will explain the relationship between a position-time graph and the physical motion used to create it.
- Students will model with mathematics. (CCSS Mathematical Practice)

Vocabulary

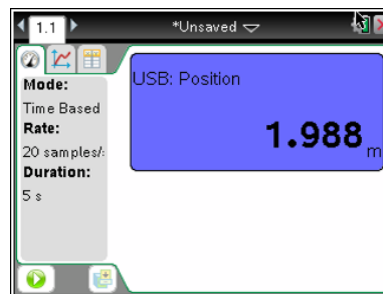
- linear equation
- position
- speed
- velocity
- average velocity

About the Lesson

- In this lesson, students collect data by moving at a constant velocity in front of a CBR 2™.
- As a result, students will...
 - Develop a linear model for a scatter plot of position versus time data.
 - Make a real-world connection between a linear equation used to model the data and the physical motion involved in the data collection process.

Materials Note

- CBR 2™ with USB CBR 2-to-calculator cable.
- Using the CBR 2 with a computer requires the use the mini-standard USB adaptor to plug the CBR 2 into a computer with TI-Nspire™ Teacher or Student Software. This adapter will convert the CBR 2 USB cable to a standard USB connection so that it can be connected to the computer.
- **NEW** option: Use the legacy CBR™ with the new TI-Nspire™ Lab Cradle. You will need the MDC-BTD cord to connect a motion detector to the TI-Nspire Lab Cradle. With the Lab Cradle, you can even connect multiple motion detectors to extend your exploration.



TI-Nspire™ Technology Skills:

- Collect motion data with the Vernier DataQuest™ app.
- Run a linear regression in the Vernier DataQuest app.

Tech Tips:

- (1) Flip the motion detector open. Set the switch to normal.
- (2) Check that the four AA batteries in the motion detector are good.
- (3) Unplug and plug the CBR 2 back in.
- (4) When using an older CBR or motion detector with the Lab Cradle, you may need to launch Vernier LabQuest™. Then press

Menu > Experiment > Advanced Setup > Configure Sensor > TI-Nspire Lab Cradle: dig1 > Motion Detector.

Lesson Files:

- Student Activity
- Walk_a_Line.pdf
- Walk_a_Line.doc



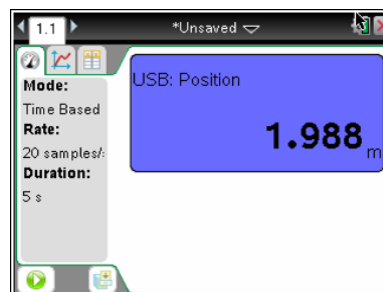
TI-Nspire™ Navigator™ System

- Use Screen Capture to monitor student progress and compare students' mathematical models.
- Use Live Presenter so that a student may demonstrate various steps in the modeling process.
- Share data via file transfer, if desired.

Discussion Points and Possible Answers

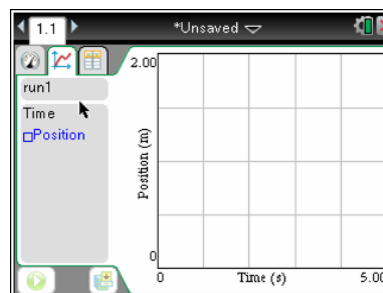
Tech Tip: The Vernier DataQuest™ app is user friendly. It should launch when the CBR 2™ is connected. To begin the data collection, click the green Play button in the lower left corner of the screen.

- Step 1:** Connect the CBR 2 to the handheld with the USB cable. A Vernier DataQuest™ application page will automatically open and the CBR 2 will begin measuring the position of the closest object.



Teacher Tip: When the CBR 2 is first connected it begins clicking and recording measurements. Have the students move the CBR 2 and point it at different objects. Ask them what the motion detector is doing. It should be measuring the distance from the CBR 2 to the object directly in front of it. We call this the position of the object with respect to the CBR 2. Be aware that it reads the position of the closest object in its path so students should have an open area between the walker and the CBR 2.


- Step 2:** Working in groups of two, one person will operate the TI-Nspire™ and point the CBR 2 towards the walker. The walker should be standing approximately two meters from the motion detector. The walker will walk slowly towards the motion detector at a constant velocity.



- Step 3:** Before collecting the data, make a prediction of what the graph of position versus time should look like. Sketch your prediction on the grid to the right.

Teacher Tip: It is important for students to make a prediction before simply pressing the Play button. Making predictions and testing those predictions supports higher level thinking.



Step 4: The calculator operator should click the green Start button  in the lower left corner of the screen. The walker should walk **slowly** toward the CBR 2 at a constant velocity to close the gap in approximately five seconds. Don't go too fast or you will run out of space and will need to try again. You must walk at the same velocity the entire time.

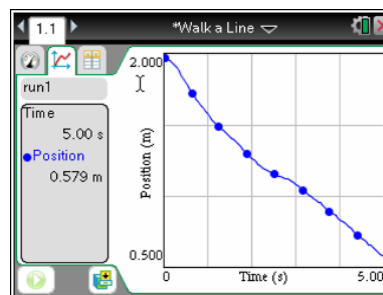
Teacher Tip: Students often cannot get the timing right at the beginning of this activity. You may want to suggest that the partner presses the enter key to begin data collection after the walker starts walking. This gives students a better opportunity to collect linear data for the entire collection time period. You may also want to remind students that they must walk slowly at a constant velocity.

Step 5: Graphs for position versus time and velocity versus time are created and displayed on the same screen. Repeat as necessary until you generate a graph for position versus time that is roughly linear. How does the graph compare with your prediction?

Tech Tip: If the students are not satisfied with their results, they can repeat the data collection by clicking the Play button again. This will overwrite the previous trial.

Step 6: To display only the position versus time graph, press **Menu > Graph Settings > Show Graph > Graph 1**. Sketch the actual graph of your position versus time graph on the grid shown to the right.

Sample Answer: A sample graph is shown to the right. Since students are all walking towards the CBR 2, all graphs should show a negative slope.



Step 7: Manual Analysis of Data:

a. How can you estimate the average velocity of the walker?

Sample Answer: Find the change in the position (final – initial) and divide that change in position by the elapsed time.

b. What was the position of the walker at time $t = 0$ sec? At time $t = 5$ sec?

Sample Answer: Answers will vary depending on the individual results. Students should give answers in meters.



- c. Show your work to calculate the approximate slope of your line using your positions at time $t = 0$ sec and $t = 5$ sec.

Sample Answer: Answers will vary but the results for the velocity should be negative.

- d. What does the slope of the graph represent physically?

Sample Answer: The slope represents the velocity of the walker. Some students may say speed. This is a great opportunity to explain the difference between speed and velocity. Speed indicates how fast the walker is moving, but does not include direction. Since speed has magnitude only it is referred to as a scalar quantity. Speed is always positive. Velocity is called a vector quantity. It includes both the speed and direction. Velocity can be positive or negative for a person moving back and forth along a line. Velocity is positive when the walker moves away from the motion detector, increasing the position, and negative when the walker moves toward the motion detector, decreasing the position.

- e. Why is the velocity negative?

Sample Answer: The velocity is negative since the position between the walker and the CBR 2 is decreasing.

- f. Linear functions are usually written in the form $f(x) = mx + b$. Determine the y-intercept of your line and write an equation that you think will model the data.

Sample Answer: Answers may vary, but the slope should be the same as above and the y-intercept the same as the position at time $t = 0$ seconds.

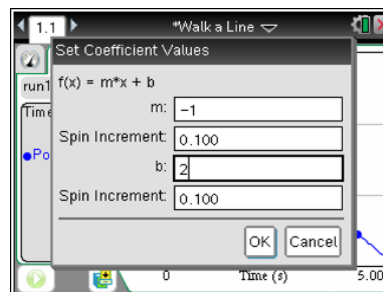
- g. What does the y-intercept represent?

Sample Answer: The y-intercept represents the initial or starting position – the position of the walker from the motion detector at time $t = 0$ seconds. The answer should be given in meters.

Teacher Tip: Students should determine an equation by hand first to practice finding slope and to help make the connections between the physical actions and the mathematical equation. Students will better understand the meaning and physical representations of the slope and y-intercept if they write their own model rather than simply run a linear regression.

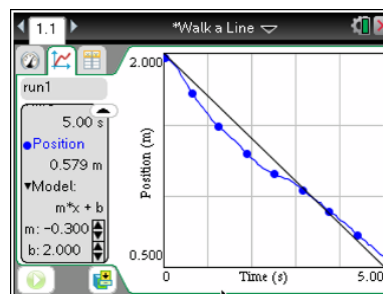


Step 8: Press **Menu > Analyze > Model**. Select $m \cdot x + b$ to create a linear model and click OK. Type your values calculated manually from above in the fields for m and b and click OK.

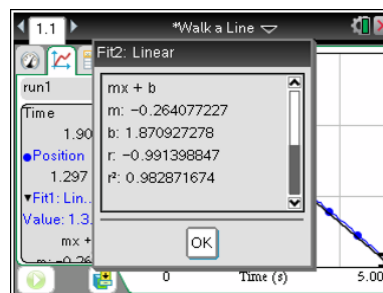


Tech Tip: Students can now decide how accurate their calculations were when compared to the actual data. You may wish to use Live Presenter here to have students share their results.

Step 9: The model can be adjusted by clicking the slider arrows on the left side of the screen or by changing the values of m and b manually. See the sample shown at the right. If you made adjustments, record the new values below.

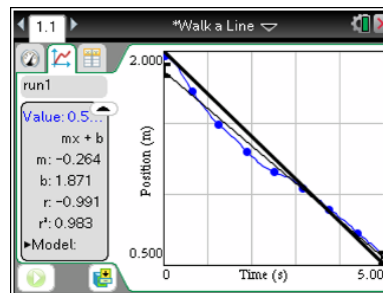


Step 10: To analyze the data with a regression, a linear curve fit can be performed within the Vernier DataQuest Application. Press **Menu > Analyze > Curve Fit > Linear**. This will give the equation of the linear regression model. You will have to scroll down the dialog box to see the values of m and b for the linear model. Record the values for m and b below.



Step 11: Click OK to see the graphical results of the regression. How does your linear regression compare with the equation you found in Step 9? How do the values for m and b compare?

Sample Answer: Answers will vary depending upon what the data looked like. The values for m and b should be similar, but will likely be a little different. It is important for students to understand that real data is not as neat as data we see in a textbook. People working with real world data often find that their mathematical models vary somewhat and they must make decisions about which model is best.



Teacher Tip: The regression equation should be similar to the students' equations. In some ways a student's equation may appear to be a better fit



because the regression equation may not go through the actual starting position.

Discussions/Explorations

1. As you may have gathered from your practice trials, the CBR 2 collects data measuring how far an object is located from the sensor. By walking in front of the CBR 2, collect a set of data which appears linear and has a positive slope. Provide a detailed description of your “walk”. Be sure to discuss the “real-world” connections for the slope and y-intercept of the model.

Sample Answer: The walker stands close to the CBR 2 and slowly walks away at a steady rate. The y-intercept is how far from the CBR 2 the walker was located at time $t = 0$ sec. The slope is the walker’s average velocity.

2. By walking in front of the CBR 2, collect a set of data which appears linear and has a slope which is approximately zero. Provide a detailed description of your “walk” including the connection between slope and y-intercept and the physical actions.

Sample Answer: The walker stands still in front of the CBR 2 and does not move for the entire experiment. The y-intercept is how far the walker is standing from the CBR 2. Since there is no movement toward or away from the CBR 2, the slope is zero.

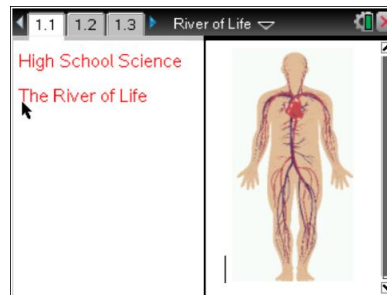
3. By walking in front of the CBR 2, collect a set of data which represents a piecewise function that has two parts – both of which are linear, one with a positive slope and one with a negative slope. Provide a detailed description of your “walk” including the connections between slope and y-intercept and the physical actions.

Sample Answer: The walker starts close to the CBR 2 and slowly walks away at a steady velocity for part of the time then changes direction and heads back toward the CBR 2 at a steady velocity. This could be reversed so that the walker start walking towards the CBR 2 then walks away. The y-intercept is how far the walker was from the CBR 2 at time $t = 0$ sec. The slopes are the walker’s average velocities, positive when walking away from the CBR 2 and negative when walking toward. During the change in direction, the graph will not be linear.

Teacher Tip: If time permits, you may wish to have students complete all of these explorations. You may even have them create their own graphs and have other students explain the motion necessary to “walk” the graph.



Blood is a body part that often gets overlooked because it is made, in large part, of liquid. This liquid portion of the blood is called the plasma, while the “solid” portion is made up of the blood cells. Later, you will have an opportunity to research what the different components of the blood do for you. For now, however, you will examine the relationship between the body weight and blood volume of a human. Look at the data table below and discuss with a partner what you observe about the relationship between body weight and blood volume.



Create a new TI-Nspire™ document.

1. Add a *Lists & Spreadsheets* page.
2. Name Column A ***weight***, and Column B ***pints***.
3. In cell A1, enter the number **60**, then continue to enter values in this column—adding 24 to the previous number—until you reach 300.
4. In cell B1, enter the number 5, and increase it by 2 in each succeeding cell until you have reached 25.
 - The weights are in pounds, and the pints are the number of pints of blood in the human body.
 - Double-check to make sure you have the same number of items in each column.

Press **ctrl** **▶** and **ctrl** **◀** to navigate through the lesson.

Weight	Pints
60	5
84	7
108	9
132	11
156	13
180	15
204	17
228	19
252	21
276	23
300	25

5. According to the data table, what is the relationship between body weight and blood volume?
6. a. What is the change in weight from data point to data point?
b. Is the ΔX the same between each two consecutive x -values?
7. a. What is the change in blood volume from data point to data point?
b. Is the ΔY the same between each two consecutive y -values?



8. Now, graph the data by inserting a *Data & Statistics* page.
9. Select **weight** as the x -value and **pint** as the y -value.
10. Use this graph to figure out approximately how much blood YOU have in your body.
 - There is more than one way to do this, so play around until you find a method that works for you.
 - Hint: It might be a good idea to have a "best-fit" line on your graph.
11. Next, insert a *Graphs* page, graph your data again, and figure out a way to determine your blood volume using this page.
 - After you have finished experimenting with weight and blood volume, move on to the questions that accompany this activity.
12. What is the significance of your answers to #10 and #11?

13. What is the formula for determining the volume of blood if you know your weight?

14. a. Using the regression model (best-fit line) you produced, estimate the volume of blood you have in your body.

b. How did you make your estimation?

15. How much blood would there be in a person who had a mass of 75 kg? Hint: there are about 2.2 pounds in one kilogram.

16. Estimate the weight in pounds of a person who has 11.5 pints of blood in his body.

17. How much blood would a 7-pound newborn baby have?

18. If this weight/blood volume relationship were true for other animals, too, how many gallons of blood would there be in a horse that had a mass of 500 kg?

19. Estimate the weight of a person who has two gallons of blood in his body.



20. If you decided to donate blood at the blood bank, you would donate one pint. Using your own weight, calculate the percentage of your blood you would be donating.
- 21 a. If 52% of your blood is water, what is the volume of water circulating in your blood vessels right now?
- b. Which of the two main blood components contains the water?
22. Sodium is an abundant ion in the bloodstream. Normally, there are about 2400 milligrams of sodium in one liter of blood. If one liter of blood is about the same volume as two pints of blood, approximately how much sodium do you have flowing through your blood vessels right now? Express your answer in both milligrams and grams.
23. One of the most important functions of the blood is to transport oxygen to all of your cells, and the cells that take care of this for you are called erythrocytes, or red blood cells. Red blood cells are by far the most numerous cells in the blood, averaging about 4.5×10^6 cells per microliter (1000 microliter = 1ml; 1000ml = 1L). How many microliters are there in one liter? Using this information, calculate the approximate number of red blood cells you have in your body right now.
24. Leukocytes, or white blood cells, are another type of blood cell in your body. Human blood contains about 7.0×10^3 WBC's per microliter. Calculate the approximate number of leukocytes you have in your body right now.
25. White blood cells function mainly in defending you against infections. Explain why the number of white blood cells in a person's body may tend to fluctuate a lot more than the number of red blood cells does.

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Science Objectives

- Students will calculate the volume of blood in their own bodies.
- Students will analyze and quantify some of the components of their blood.

Math Objectives

- Students will use tabular data to accurately generate a scatter plot.
- Students will generate a linear regression model, use the function to perform calculations, and interpolate a value on the regression model.

Materials Needed

- TI-Nspire™ or TI-Nspire™ CAS unit for each student

Vocabulary

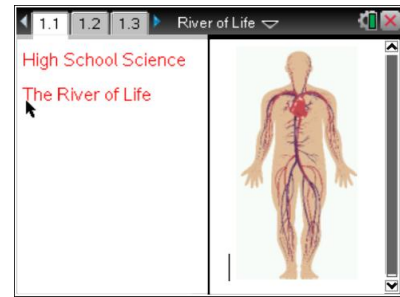
- plasma
- erythrocytes
- leukocytes
- milligram
- microliter

About the Lesson

- This lesson involves generating a linear regression model for human blood volume vs. body weight.
- As a result, students will:
 - Algebraically calculate their own blood volume.
 - Interpolate on the regression model to determine their blood volume.

TI-Nspire™ Navigator™ System

- Screen Capture to monitor student progress.
- Live presenter allows students to show their graphs to the class.



TI-Nspire™ Technology Skills:

- Download a TI-Nspire™ document
- Open a document
- Move between pages
- Entering and graphing data using multiple applications
- Tracing, interpolating, predicting

Tech Tips:

- Make sure the font size on your TI-Nspire handhelds is set to Medium.
- You can hide the function entry line by pressing **(ctrl) G**.

Lesson Materials:

Student Activity

- The River of Life.pdf
- The River of Life.doc

TI-Nspire document

- The River of Life.tns



Discussion Points and Possible Answers

Create a new TI-Nspire™ document.

1. Add a *Lists & Spreadsheets* page.
2. Name Column A ***weight***, and Column B ***pints***.
3. In cell A1, enter the number **60**, then continue to enter values in this column—adding 24 to the previous number—until you reach 300.
4. In cell B1, enter the number 5, and increase it by 2 in each succeeding cell until you have reached 25.
 - The weights are in pounds, and the pints are the number of pints of blood in the human body.
 - Double-check to make sure you have the same number of items in each column.
5. According to the data table, what is the relationship between body weight and blood volume?

Answer: As body weight increases, blood volume increases.

6. a. What is the change in weight from data point to data point?

Answer: 24 pounds

- b. Is the ΔX the same between each two consecutive x -values?

Answer: Yes

7. a. What is the change in blood volume from data point to data point?

Answer: 2 pints

- b. Is the ΔY the same between each two consecutive y -values?

Answer: Yes



8. Now, graph the data by inserting a *Data & Statistics* page.
9. Select **weight** as the *x*-value and **pint** as the *y*-value.
10. Use this graph to figure out approximately how much blood YOU have in your body.
 - There is more than one way to do this, so play around until you find a method that works for you.
 - Hint: It might be a good idea to have a "best-fit" line on your graph.
11. Next, insert a *Graphs* page, graph your data again, and figure out a way to determine your blood volume using this page.

After you have finished experimenting with weight and blood volume, move on to the questions that accompany this activity.

12. What is the significance of your answers to #10 and #11?

Answer: It means the graph will be linear.

13. What is the formula for determining the volume of blood if you know your weight?

Answer: Pints = $0.083 \times \text{weight}$ ($y = 0.083x$)

14. a. Using the regression model (best-fit line) you produced, estimate the volume of blood you have in your body.

Answer: Answers will vary.

- b. How did you make your estimation?

Answer: Several methods: putting their weight into the equation and solving for pints; tracing along the regression line; etc.

15. How much blood would there be in a person who had a mass of 75 kg? Hint: there are about 2.2 pounds in one kilogram.

Answer: 15.6 pints

16. Estimate the weight in pounds of a person who has 11.5 pints of blood in his body.

Answer: 139 pounds



17. How much blood would a 7-pound newborn baby have?

Answer: 0.6 pints

18. If this weight/blood volume relationship were true for other animals, too, how many gallons of blood would there be in a horse that had a mass of 500 kg?

Answer: 11.4 gallons

19. Estimate the weight of a person who has two gallons of blood in his body.

Answer: 193 pounds

20. If you decided to donate blood at the blood bank, you would donate one pint. Using your own weight, calculate the percentage of your blood you would be donating.

Answer: Answers will vary. Lower percentage for heavier people.

21 a. If 52% of your blood is water, what is the volume of water circulating in your blood vessels right now?

Answer: Answers will vary.

b. Which of the two main blood components contains the water?

Answer: Plasma

22. Sodium is an abundant ion in the bloodstream. Normally, there are about 2400 milligrams of sodium in one liter of blood. If one liter of blood is about the same volume as two pints of blood, approximately how much sodium do you have flowing through your blood vessels right now? Express your answer in both milligrams and grams.

Sample Answers: Answers will vary.



23. One of the most important functions of the blood is to transport oxygen to all of your cells, and the cells that take care of this for you are called erythrocytes, or red blood cells. Red blood cells are by far the most numerous cells in the blood, averaging about 4.5×10^6 cells per microliter (1000 microliter = 1ml; 1000ml = 1L). How many microliters are there in one liter? Using this information, calculate the approximate number of red blood cells you have in your body right now.

Sample Answers: Answers will vary

24. Leukocytes, or white blood cells, are another type of blood cell in your body. Human blood contains about 7.0×10^3 WBC's per microliter. Calculate the approximate number of leukocytes you have in your body right now.

Sample Answers: Answers will vary.

25. White blood cells function mainly in defending you against infections. Explain why the number of white blood cells in a person's body may tend to fluctuate a lot more than the number of red blood cells does.

Answer: WBC numbers tend to increase when a person is sick or injured.

TI-Nspire Navigator Opportunity: Screen Capture
See Note 1 at the end of the lesson.

Wrap Up

Assessment

Formative assessment will consist of questions embedded in the TI-Nspire document. The questions will be graded when the document is retrieved. The Slide Show can be utilized to give students immediate feedback on their assessment.

TI-Nspire™ Navigator™ Notes

Note 1: Screen Capture

Screen Capture can be used to monitor student progress.

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Nailing Density

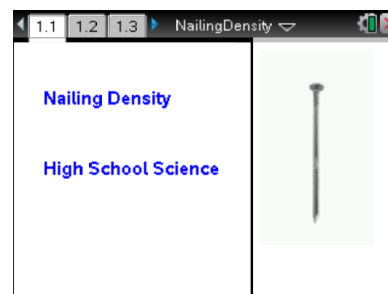
Student Activity

Name _____

Class _____

Open the TI-Nspire™ document *NailingDensity.tns*.

In this activity, you will determine the mass and volume of five nails. The mass and volume of each nail will be graphed. By analyzing the graph, you will discover a physical property of the nails.



Mass can be measured using a balance.

Volume can be calculated from the dimensions of a regularly-shaped object. For irregularly-shaped solids, water displacement can be used to determine the volume. The volume of water is measured before and after the irregular solid is added to the measuring device. The difference in volume is the volume of the object.

Another property of matter is **density**. Density is defined as the mass per unit volume of a substance. The formula for density is $D = \frac{m}{V}$ where D is density, m is mass, and V is

volume. If the mass and the volume are known, the density can be calculated using the density formula.

The units of density are commonly g/mL or g/cm³ for liquids and solids. For gases, the density is often expressed in g/L since gases are much less dense than solids or liquids.

Density is an intensive property that is NOT dependent on the amount of the substance that is measured.

Move to page 1.2.

Press **ctrl** **▶** and **ctrl** **◀** to
navigate through the lesson.

- The volume of an irregular object is most easily determined by_____.
- Which is heavier-a pound of feathers or a pound of lead?
- Explain your answer to the previous question.
- Density is defined as_____.
- Which one of the following is not a unit of density?
 - g/mL
 - g/cm³
 - g/L
 - L/g

**Move to page 2.1.**

Nails will be provided by your teacher.

6. Add enough water to the graduated cylinder to cover the tallest nail (do NOT add the nails to the water yet).
7. Read the initial volume to the nearest 0.1 mL, and record it in the spreadsheet on Page 2.1 under **volw** for 0 nails.
8. Measure the mass of the first nail to 0.01 g, and record it under **massn** for 1 nail.
9. Gently let one nail slide head first into the tilted cylinder, and measure the new volume under **volw** for 1 nail.
10. Repeat this procedure for the four remaining nails, accumulating all of the nails in the graduated cylinder.
11. Calculate the **total mass** of nails in the spreadsheet by adding each to the previous total using cell notation (in cell C2 enter =C1+B2). Repeat for the four remaining nails.
12. Calculate the **volume** of each nail by subtracting the previous water volume from the current (in cell E2 enter =D2-D1). Repeat for the remaining four nails.
13. Calculate the **density** of the nails by dividing the mass of the nail by its volume (enter = **massn/voln** in the formula bar under **dens**).

Move to page 2.3.

14. On the Data & Statistics page (Page 2.3), explore some graphs by clicking an axis and choosing the variable you want to plot.
15. Plot **massn** vs. **voln**, and determine the best fit line for the nails' volume and mass relationship by selecting **MENU > Analyze > Regression > Show Linear(mx + b)**.
17. Plot **masst** vs. **volw** and again find the best line.
 - Cycle between the last two graphs to see the similarities and differences.

Move to page 3.1.

18. a. What is the regression equation for your graph?
 - b. What is the slope of the line?
 - c. What would the units of the slope be?



Nailing Density Student Activity

Name _____

Class _____

19. The formula for Density is: $D = \frac{m}{V}$, where D is density, m is mass, and V is volume.

Rearrange the formula for density by isolating mass instead of density.

20. Rewrite the regression equation from the *Data & Statistics* page, replacing the “ x ” variable with V for volume and the “ y ” variable with m for mass.

21. How does the rearranged $D = \frac{m}{V}$ equation from question 19 compare with the equation that you wrote for question 20? Explain.

22. a. What does the slope of the graph on the *Data & Statistics* page represent?

b. What unit(s) would be assigned to the slope of this graph?

23. Why are the densities calculated for each nail not exactly the same and not exactly equal to the slope of the line?

24. Use the Internet to visit http://www.engineeringtoolbox.com/metal-alloys-densities-d_50.html. Use this page to identify the element or metal alloy whose properties would match the density that you calculated for the nail. Remember that $1 \text{ kg/m}^3 = 0.001 \text{ g/cm}^3$ and that $1 \text{ cm}^3 = 1\text{mL}$.

25. Refer to the data that was collected. What effect does increasing the mass of the nail have on the volume of the nail?

26. Refer to the data that was collected. What effect does increasing the mass of the nail have on the density of the nail?



Nailing Density

Student Activity

Name _____

Class _____

27. Which of the following is NOT true of the density of a substance?

- a. intensive property
- b. extensive property
- c. characteristic or identifying property
- d. temperature dependent

28. Summarize what you have learned about density from this experiment.



Science Objectives

- Students will determine the relationship between mass and volume.
- Students will mathematically describe the relationship between mass and volume.
- Students will relate the slope of a line to a physical property (density).

Math Objectives

- Students will generate a linear least-squares line from mass and volume data.
- Students will analyze a linear mathematical relationship.

Materials Needed

- Five (5) different-sized nails of the same material
- 0.01g balance
- 10 or 50-mL graduated cylinder (depending on the size of the nails)

Vocabulary

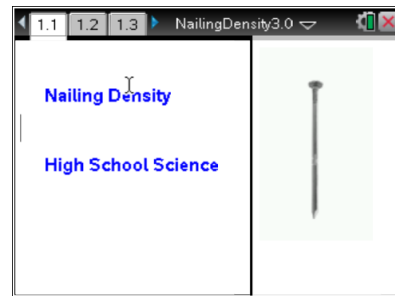
- mass
- volume
- density

About the Lesson

- This lesson involves determining the mass and volume of five nails.
- As a result, students will:
 - Determine the relationship between mass and volume.
 - Graph the mass and volume of each nail.
 - Mathematically describe the relationship between mass and volume.
 - Generate a linear least-squares line from mass and volume data.
 - Relate the slope of a line to a physical property (density).

TI-Nspire™ Navigator™ System

- Screen Capture to monitor student progress.
- Live presenter allows students to show their graphs to the class.



TI-Nspire™ Technology Skills:

- Download a TI-Nspire™ document
- Open a document
- Move between pages
- Entering and graphing data
- Tracing and interpolating

Lesson Materials:

Student Activity

- Nailing Density.pdf
- Nailing Density.doc

TI-Nspire document

- NailingDensity.tns



Discussion Points and Possible Answers

Mass can be measured using a balance.

Volume can be calculated from the dimensions of a regularly-shaped object. For irregularly- shaped solids, water displacement can be used to determine the volume. The volume of water is measured before and after the irregular solid is added to the measuring device. The difference in volume is the volume of the object.

Another property of matter is **density**. Density is defined as the mass per unit volume of a substance. The formula for density is $D = \frac{m}{V}$ where D is density, m is mass, and V is

volume. If the mass and the volume are known, the density can be calculated using the density formula.

The units of density are commonly g/mL or g/cm³ for liquids and solids. For gases, the density is often expressed in g/L since gases are much less dense than solids or liquids.

Density is an intensive property that is NOT dependent on the amount of the substance that is measured.

Move to page 1.2.

1. The volume of an irregular object is most easily determined by_____.

Answer: Water displacement.

2. Which is heavier-a pound of feathers or a pound of lead?

Answer: Neither.

3. Explain your answer to the previous question.

Answer: Neither a pound of feathers nor a pound of lead is heavier—their mass is both equal to one pound. However, the lead has a much greater density since the volume of one pound of lead would be much less than the volume of pound of feathers.

4. Density is defined as_____.

Answer: mass per unit volume



5. Which one of the following is not a unit of density?
- a. g/mL
 - b. g/cm³
 - c. g/L
 - d. L/g

Answer: d. L/g

Move to page 2.1.

Nails will be provided by your teacher.

6. Add enough water to the graduated cylinder to cover the tallest nail (do NOT add the nails to the water yet).
7. Read the initial volume to the nearest 0.1 mL, and record it in the spreadsheet on Page 2.1 under **volw** for 0 nails.
8. Measure the mass of the first nail to 0.01 g, and record it under **massn** for 1 nail.
9. Gently let one nail slide head first into the tilted cylinder, and measure the new volume under **volw** for 1 nail.
10. Repeat this procedure for the four remaining nails, accumulating all of the nails in the graduated cylinder.
11. Calculate the **total mass** of nails in the spreadsheet by adding each to the previous total using cell notation (in cell C2 enter =C1+B2). Repeat for the four remaining nails.
12. Calculate the **volume** of each nail by subtracting the previous water volume from the current (in cell E2 enter =D2-D1). Repeat for the remaining four nails.
13. Calculate the **density** of the nails by dividing the mass of the nail by its volume (enter = **massn/voln** in the formula bar under **dens**).

Move to page 2.3.

14. On the Data & Statistics page (Page 2.3), explore some graphs by clicking an axis and choosing the variable you want to plot.
15. Plot **massn** vs. **voln**, and determine the best fit line for the nails' volume and mass relationship by selecting **MENU > Analyze > Regression > Show Linear(mx + b)**.
17. Plot **masst** vs. **volw** and again find the best line.
 - Cycle between the last two graphs to see the similarities and differences.



Move to page 3.1.

18. a. What is the regression equation for your graph?

Answer: $\sim y = 7.85x + 0$

Sample Data: (steel nails)

Mass of nail (massn) g	Water volume (volw) mL
0	27.0
4.3	27.5
7.06	28.5
7.73	29.5
9.64	30.8
15.13	32.8

b. What is the slope of the line?

Answer: ~ 7.85 g/mL

c. What would the units of the slope be?

Answer: g/mL

19. The formula for Density is $D = \frac{m}{V}$, where D is density, m is mass, and V is volume.

Rearrange the formula for density by isolating mass instead of density.

Answer: $m = DV$

20. Rewrite the regression equation from the *Data & Statistics* page, replacing the “ x ” variable with V for volume and the “ y ” variable with m for mass.

Answer: $m = 7.85V + 0$

21. How does the rearranged $D = \frac{m}{V}$ equation from question 19 compare with the equation that you wrote for question 20? Explain.

Answer: The equations are the same.



22. a. What does the slope of the graph on the *Data & Statistics* page represent?

Answer: The density.

b. What unit(s) would be assigned to the slope of this graph?

Answer: g/mL

23. Why are the densities calculated for each nail not exactly the same and not exactly equal to the slope of the line?

Sample Answers: Because of experimental errors.

24. Use the Internet to visit http://www.engineeringtoolbox.com/metal-alloys-densities-d_50.html. Use this page to identify the element or metal alloy whose properties would match the density that you calculated for the nail. Remember that $1 \text{ kg/m}^3 = 0.001 \text{ g/cm}^3$ and that $1 \text{ cm}^3 = 1\text{mL}$.

Answer: Iron and steel.

25. Refer to the data that was collected. What effect does increasing the mass of the nail have on the volume of the nail?

Answer: The volume increases.

26. Refer to the data that was collected. What effect does increasing the mass of the nail have on the density of the nail?

Answer: The density is unchanged.

26. Which of the following is NOT true of the density of a substance?

- a. intensive property
- b. extensive property
- c. characteristic or identifying property
- d. temperature dependent

Answer: b. Extensive property.



27. Summarize what you have learned about density from this experiment.

Sample Answers: Answers will vary. The density of a substance is a constant, independent of mass and volume and only changes with temperature. Density is an intensive property that is characteristic of a substance. Density can be used to identify a substance.

TI-Nspire Navigator Opportunity: *Screen Capture*

See Note 1 at the end of this lesson.

Wrap Up

Upon completion of this discussion, the teacher should ensure that students understand:

- The relationship between mass and volume.
- The relationship between the slope of a line and density.

Assessment

Formative and summative assessment questions are embedded in the TI-Nspire™ document. The questions will be graded when the TI-Nspire™ documents are retrieved. The Slide Show can be utilized to give students immediate feedback on their assessment.

TI-Nspire Navigator Notes

Note 1: Screen Capture

Screen Capture can be used to monitor student progress.



Exploring Space Through MATH

Applications in Algebra 1



STUDENT
EDITION

Space Shuttle Ascent – Mass vs. Time

Background

This problem is part of a series that applies algebraic principles in NASA's human spaceflight.

The Space Shuttle Mission Control Center (MCC) and the International Space Station (ISS) Control Center use some of the most sophisticated technology and communication equipment in the world. Teams of highly qualified engineers, scientists, doctors, and technicians, known as flight controllers, monitor the systems and activities aboard the space shuttle and the ISS. They work together as a powerful team, spending many hours performing critical simulations as they prepare to support each mission and crew during normal operations and any unexpected events.

Since its first flight in 1981, the space shuttle has been used to extend research, repair satellites, and help with building the ISS. NASA plans to retire the space shuttle but, space exploration has made major advances due to the success of space shuttle missions. Critical to any space shuttle mission is the ascent into space.

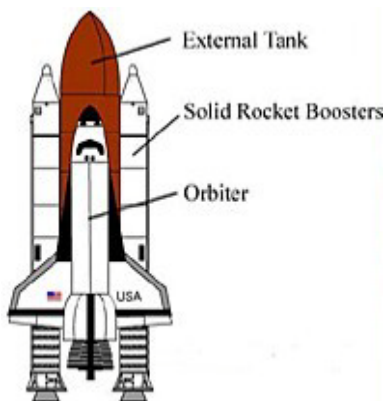


Figure 1: Main components of the space shuttle



Figure 2: Space Shuttle Discovery at liftoff

The ascent phase begins at liftoff and ends when the space shuttle reaches Earth's orbit. The space shuttle must accelerate from zero to approximately 7,850 meters per second (which is approximately 17,500 miles per hour) in eight and a half minutes to reach the minimum altitude required to orbit Earth. It takes a very unique vehicle to accomplish this task.

There are three main components of the space shuttle that enable the launch into orbit (Figure 1). The main component is the orbiter. It not only serves as the crew's home in space and is equipped to dock with the ISS, but it also contains maneuvering engines for finalizing the orbital trajectory, or flight path.



The External Tank (ET), the largest component of the space shuttle, supplies the propellant (liquid oxygen and liquid hydrogen) to the Space Shuttle Main Engines (SSMEs) which are liquid propellant rocket engines. The third component is a pair of Solid Rocket Boosters (SRBs) which are reusable. They are attached to the sides of the ET and provide the main thrust at launch (Figure 2).

One of the flight controllers in the Space Shuttle Mission Control Center is the Booster Engineer. This position, or console, known as Booster, is in charge of monitoring the SSMEs, the SRBs, and the ET during the countdown and the ascent phase, until all of those systems are safe. The components of the space shuttle experience changes in position, velocity, and acceleration during the ascent into space. These changes can be seen by taking a closer look at the entire ascent process (Figure 3).

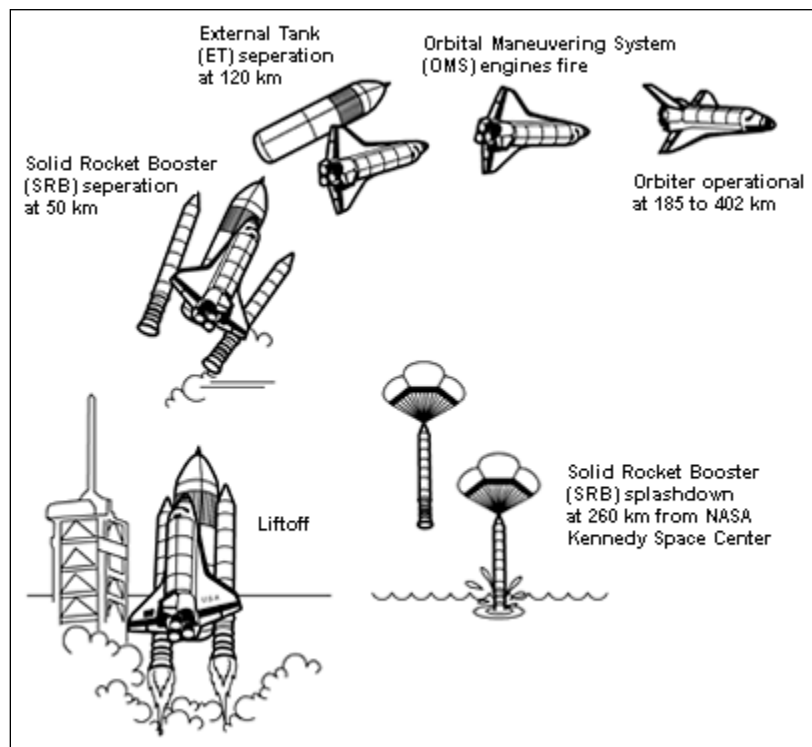


Figure 3: Space shuttle ascent process

The ascent process begins with the liftoff from the launch pad. Propellant burns from the SRBs and the ET causing the space shuttle to accelerate very quickly. This high-rate of acceleration causes a rapid increase in dynamic pressure, known as Q in aeronautics (sometimes called velocity pressure). As the space shuttle breaks the sound barrier, its structure can only withstand a certain level of dynamic pressure before it suffers damage. Before this critical level is reached, the engines of the space shuttle are throttled down to about 67% of full power to avoid damage. About 50 seconds after liftoff, the dynamic pressure reaches its maximum aerodynamic load (Max Q). The air density then drops rapidly due to the thinning atmosphere, and the space shuttle can be throttled to full power without fear of structural damage. The command is given, "Go at throttle up!"

As the space shuttle climbs, the velocity is increasing and the density of the air is decreasing. About 2 minutes after liftoff the atmosphere is so thin that the dynamic pressure drops to near zero. The SRBs, having used their propellant, are commanded by the space shuttle's onboard computer to separate from the ET. The jettisoning of these booster rockets marks the end of the first ascent stage and the beginning of the second. The spent SRBs fall into the ocean and are recovered, refurbished, reloaded with propellant, and reused for several missions. The second stage of ascent lasts about six and a half



minutes, during which time the Booster flight controller continues to monitor the ET and the SSMEs until MECO (Main Engine Cut Off) and ET Separation. The ET re-enters the Earth's atmosphere, breaking up before impact in the ocean, and the space shuttle maneuvers into orbit. This lesson focuses on the first ascent stage, which occurs during the first two minutes after liftoff.

Instructional Objectives

- You will create scatter plots from a data table.
- You will determine the correlation of the data and interpret its meaning.
- You will find linear regression equations.
- You will find the slope and y -intercept of a linear equation.
- You will communicate the meanings of slope and y -intercept as they relate to a real-world problem.

View the video, *Space Shuttle Ascent-Clip_ STS-121*, and reference the Background section to answer questions 1-9.

1. In the launch of the Space Shuttle Discovery what does “auto sequence start” mean?
2. What are the 3 main components of the space shuttle?
3. Which component is the first to ignite? Which component ignites next and what is the result?
4. At about 40 seconds after launch, due to the velocity of Discovery, what occurs?
5. About how many seconds after liftoff do the main engines throttle back to about 67% of rated performance to reduce the structural stress that occurs as the space shuttle breaks the sound barrier?
6. “Discovery Houston, Go at throttle up!” is the command given when the atmosphere is so thin that there is no danger of structural damage due to dynamic pressure. About how many seconds after liftoff does this occur?
7. What occurs at approximately 2 minutes into flight?
8. What happens to the depleted SRBs?
9. What powers Discovery after SRB separation?



Problem

On July 4, 2006, Space Shuttle Discovery was launched from Kennedy Space Center on mission STS-121 to begin a rendezvous with the International Space Station, or ISS. Before each mission, the projected data is compiled to assist in the launch of the space shuttle and to ensure safety and success during the ascent. To complete this data flight design specialists take into consideration a multitude of factors, such as space shuttle mass, propellant used, mass of payload being carried to space and mass of payload returning. They must also factor in atmospheric density, which is changing throughout the year. After running multiple tests, information is compiled in a table showing exactly what should happen each second of the ascent.

Table 1: STS-121 Discovery Ascent data (total mass)

Time (s)	Space Shuttle Total Mass (kg)
0	2,051,113
10	1,935,155
20	1,799,290
30	1,681,120
40	1,567,611
50	1,475,282
60	1,376,301
70	1,277,921
80	1,177,704
90	1,075,683
100	991,872
110	913,254
120	880,377

Table 1 shows the total mass of Discovery for mission STS-121 every 10 seconds from liftoff to SRB separation. Total mass includes the orbiter, SRBs, ET, propellant, and payload. It is during the first stage of the ascent, that the space shuttle is burning the greatest amount of propellant. You can see in the table that the space shuttle has a total mass of 2,051,113 kg at $t = 0$. After 2 minutes its total mass is only 880,377 kg, or 43 % of the original mass. The burning of this vast amount of propellant is needed to get the space shuttle through Earth's atmosphere and into orbit.

10. What happens to the mass as time progresses?

11. If this data were to be graphed with time on the x -axis and mass on the y -axis, which of the following would be characteristic of the graph?

- The graph slopes down and the y -intercept is negative
- The graph slopes down and the y -intercept is positive
- The graph slopes up and the y -intercept is negative
- The graph slopes up and the y -intercept is positive



On your TI-Nspire Handheld open the file titled, *NASA_Shuttle_Ascent-Mass_Time*. Read the directions and review the data on pages 1.1-1.4 embedded in the Nspire document. Create a scatter plot of the mass of the space shuttle vs. time on Nspire page 1.5 and model the data using linear regression. Answer questions 12-17 (found on Nspire pages 1.6 - 2.3) in your group. Discuss answers to be sure everyone understands and agrees on the solutions.

12. Does the line fit the data? Explain
13. What is the correlation of the data?
14. How much propellant does Discovery burn per second? Explain what this represents with regard to the equation.
15. What is the y -intercept of the equation of the line that models the mass versus time data? Explain what this represents in relation to the space shuttle.
16. To gain perspective regarding the magnitude of the propellant consumption of the space shuttle, find the approximate number of each type of object that it would take to equal the mass of the entire space shuttle system at launch. Round to the nearest whole number.

Table 2: Mass of various Objects (also located on Nspire page 2.2)

Object	Approximate mass (kg)	Approximate number of objects to equal the mass of the space shuttle at launch
Statue of Liberty	204,117	
Boeing 747 airplane	158,757	
Fuel tank truck	27,216	
School bus	11,340	

17. A Boeing 767 airplane burns about 24,500 kg of fuel on a 6 hour flight from New York to Los Angeles. Approximately how much time would it take the space shuttle to burn an equivalent amount of propellant?



Table 3 is on page 3.2 in the TI-Nspire document. Complete the scatterplot on page 3.4 using your TI-Nspire handheld and answer questions 18-22 (found on Nspire pages 3.5 – 3.9).

On May 12, 2009, Space Shuttle Atlantis launched from Kennedy Space Center on mission STS-125 to repair the Hubble Space Telescope. Astronauts installed two new instruments, repaired two inactive ones, and performed the component replacements to keep the telescope functioning into at least 2014. Table 3 shows the total mass of Atlantis for mission STS-125 every 10 seconds from liftoff to SRB separation.

Table 3: STS-125 Atlantis Ascent data (total mass)

Time (s)	Space Shuttle Total Mass (kg)
0	2,049,780
10	1,932,475
20	1,795,086
30	1,676,053
40	1,562,508
50	1,468,886
60	1,374,449
70	1,264,663
80	1,163,639
90	1,061,679
100	978,131
110	902,427
120	874,457

18. Does the data appear to be linear? Explain.
19. What is the correlation of the data? (positive, negative, constant, or no correlation)?
20. What is the slope of your equation? Explain what this represents in relation to the space shuttle.
21. What is the y -intercept of the equation of your line that models the mass versus time data? Explain what this means in relation to the space shuttle.
22. Compare the rate of burn of propellant (slope) for missions STS-121 (Discovery) and STS-125 (Atlantis). Which space shuttle has the fastest burn rate and what might be the reason.



Exploring Space Through MATH

Applications in Algebra 1



EDUCATOR
EDITION

Space Shuttle Ascent: Mass vs. Time

Note: This problem is related to the Algebra 1 problem, *Space Shuttle Ascent: Altitude vs. Time*, in the Exploring Space Through Math series.

Instructional Objectives

The 5-E's Instructional Model (Engage, Explore, Explain, Extend, Evaluate) will be used to accomplish the following objectives.

Students will

- create scatter plots from a data table;
- determine correlation and interpret its meaning;
- find linear regression equations;
- find the slope and y -intercept from a linear equation; and
- communicate the meanings of slope and y -intercept as they relate to a real-world problem.

Prerequisites

Students should have prior knowledge of scatter plots, types of correlations, linear equations (slope and y -intercept) and linear graphs. Students should also have experience using a TI-Nspire graphing technology to create scatter plots and to find linear regression equations.

Background

This problem is part of a series that applies algebraic principles in NASA's human spaceflight.

The Space Shuttle Mission Control Center (MCC) and the International Space Station (ISS) Control Center use some of the most sophisticated technology and communication equipment in the world. Teams of highly qualified engineers, scientists, doctors, and technicians, known as flight controllers, monitor the systems and activities aboard the space shuttle and the ISS. They work together as a powerful team, spending many hours performing critical simulations as they prepare to support each mission and crew during normal operations and any unexpected events.

Since its first flight in 1981, the space shuttle has been used to extend research, repair satellites, and help with building the ISS. NASA plans to retire the space shuttle, but space exploration has made major advances due to the success of space shuttle missions. Critical to any space shuttle mission is the ascent into space.

Key Concept

Modeling data with linear regression equations

Problem Duration

80 minutes

Technology

TI-Nspire Handhelds, computer with projector

Materials

- Student Edition
- TI-Nspire File
- Space Shuttle Launch Video

Degree of Difficulty

Moderate to Difficult

Skills

Use TI-Nspire technology to create scatter plots, find regression equations; interpret graphs and equations of linear data

NCTM Standards

- Number and Operations
- Algebra
- Data Analysis and Probability
- Problem Solving
- Communication
- Connections



The ascent phase begins at liftoff and ends when the space shuttle reaches Earth's orbit. The space shuttle must accelerate from zero to approximately 7,850 meters per second (which is approximately 17,500 miles per hour) in eight and a half minutes to reach the minimum altitude required to orbit Earth. It takes a very unique vehicle to accomplish this task.

There are three main components of the space shuttle that enable the launch into orbit (Figure 1). The main component is the orbiter. It not only serves as the crew's home in space and is equipped to dock with the ISS, but it also contains maneuvering engines for finalizing the orbital trajectory, or flight path. The External Tank (ET), the largest component of the space shuttle, supplies the propellant (liquid oxygen and liquid hydrogen) to the Space Shuttle Main Engines (SSMEs) which are liquid propellant rocket engines. The third component is a pair of Solid Rocket Boosters (SRBs) which are reusable. They are attached to the sides of the ET and provide the main thrust at launch (Figure 2).

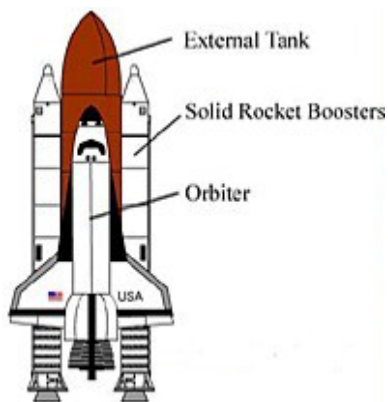


Figure 1: Main components of the space shuttle



Figure 2: Space Shuttle Discovery at liftoff

One of the flight controllers in the Space Shuttle Mission Control Center is the Booster Engineer. This position, or console, known as Booster, is in charge of monitoring the SSMEs, the SRBs, and the ET during the countdown and the ascent phase, until all of those systems are safe. The components of the space shuttle experience changes in position, velocity, and acceleration during the ascent into space. These changes can be seen by taking a closer look at the entire ascent process (Figure 3).

The ascent process begins with the liftoff from the launch pad. Propellant burns from the SRBs and the ET causing the space shuttle to accelerate very quickly. This high-rate of acceleration causes a rapid increase in dynamic pressure, known as Q in aeronautics (sometimes called velocity pressure). As the space shuttle breaks the sound barrier, its structure can only withstand a certain level of dynamic pressure before it suffers damage. Before this critical level is reached, the engines of the space shuttle are throttled down to about 67% of full power to avoid damage. About 50 seconds after liftoff, the dynamic pressure reaches its maximum aerodynamic load (Max Q). The air density then drops rapidly due to the thinning atmosphere, and the space shuttle can be throttled to full power without fear of structural damage. The command is given, "Go at throttle up!"

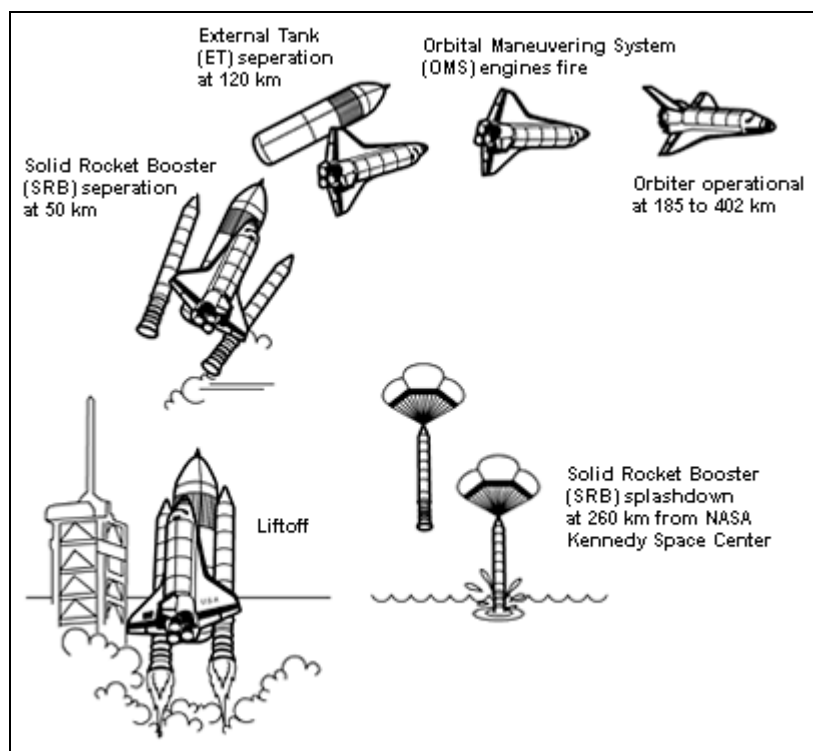


Figure 3: Space shuttle ascent process

As the space shuttle climbs, the velocity is increasing and the density of the air is decreasing. About two minutes after liftoff the atmosphere is so thin that the dynamic pressure drops to near zero. The SRBs, having used their propellant, are commanded by the space shuttle's onboard computer to separate from the ET. The jettisoning of these booster rockets marks the end of the first ascent stage and the beginning of the second. The spent SRBs fall into the ocean and are recovered, refurbished, reloaded with propellant, and reused for several missions. The second stage of ascent lasts about six and a half minutes, during which time the Booster flight controller continues to monitor the ET and the SSMEs until Main Engine Cut Off (MECO) and ET Separation. The ET re-enters the Earth's atmosphere, breaking up before impact in the ocean, and the space shuttle maneuvers into orbit. This lesson focuses on the first ascent stage, which occurs during the first two minutes after liftoff.

NCTM Principles and Standards

Number and Operations

- Develop a deeper understanding of very large and very small numbers and of various representations of them.

Algebra

- Understand relations and functions and select, convert flexibly among, and use various representations for them.
- Analyze functions of one variable by investigating rates of change, intercepts, zeros, asymptotes, and local and global behavior.
- Use symbolic algebra to represent and explain mathematical relationships.
- Identify essential quantitative relationships in a situation and determine the class or classes of functions that might model the relationships.
- Approximate and interpret rates of change from graphical and numerical data.



Data Analysis and Probability

- For bivariate measurement data, be able to display a scatter plot, describe its shape, and determine regression coefficients, regression equations, and correlation coefficients using technological tools.
- Identify trends in bivariate data and find functions that model the data or transform the data so that they can be modeled.

Problem Solving

- Solve problems that arise in mathematics and in other contexts.
- Apply and adapt a variety of appropriate strategies to solve problems.

Communication

- Use the language of mathematics to express mathematical ideas precisely.

Connections

- Recognize and apply mathematics in contexts outside of mathematics.

Lesson Development

Following are the phases of the 5-E's model in which students can construct new learning based on prior knowledge and experiences. The time allotted for each activity is approximate. Depending on class length, the lesson may be broken into multiple class periods.

Note: TI-Nspire embedded questions begin in the Explain section of the activity. Download file: [NASA_Shuttle_Ascent-Mass_Time.tns](#)

1 – Engage (20 minutes)

- Either assign or let students choose small groups of 3-4 in order to work through this activity. Each group should review the background section for several minutes to be sure that they understand the material. Ask if any group needs clarification.
- This video shows the launch of Space Shuttle Discovery STS 121 mission on July 4, 2006. To access the video, follow the link provided and choose the video titled: “The Rocket’s Red Glare.” http://www.nasa.gov/mission_pages/shuttle/shuttlemissions/sts121/launch/sts121-allvideos.html.
- Instruct students to complete questions 1-9.
- In their small groups, students discuss and share their answers to the questions. Circulate to facilitate discussion in small groups.

2 – Explore (10 minutes)

- Ask students to work through questions 10-11 in their groups.
- Call on students to give their answers and discuss.

3 – Explain (15 minutes)

- Have students open the file, *NASA_Shuttle_Ascent-Mass_Time*, on their TI-Nspire handhelds. They will then need to read through pages 1.1-1.4 and follow the directions to create and interpret a scatter plot on page 1.5.
- Have students work with their team to answer questions 12-15 that are embedded in the TI-Nspire file (pages 1.6 -1.9).

**4 – Extend** (15 minutes)

- Have students read the information on page 2.1 and complete question 16 (located on Nspire page 2.2) in the TI-Nspire file as directed.
- Have the students work with their group to answer question 17 (located on Nspire page 2.3).
- Call on students to give their answers and discuss.

5 – Evaluate (20 minutes)

- Have students read through Nspire pages 3.1- 3.3 and follow the directions to create and interpret a scatterplot on Nspire page 3.4.
- Have students complete questions 18-22 (located on Nspire pages 3.5 - 3.9) individually. Questions 18-22 can also be given as homework or an assessment by printing the page rather than having students answer with TI-Nspire handhelds.

ENGAGE**Video – Space Shuttle Ascent: Mass vs. Time****Solution Key**

1. In the launch of the Space Shuttle Discovery what does “auto sequence start” mean?

In the video, right after the statement, “And we have a go for auto sequence start”, the next statement we hear is, “Discovery’s onboard computers have primary control of all the vehicle’s critical functions.”

2. What are the 3 main components of the space shuttle?

The orbiter, the external tank (ET), and the solid rocket boosters (SRBs).

3. Which component is the first to ignite? Which component ignites next and what is the result?

The orbiter’s main engines are the first to ignite. Then the solid rocket boosters ignite causing liftoff.

4. At about 40 seconds after launch, due to the velocity of Discovery, what occurs?

Discovery breaks the sound barrier.

5. About how many seconds after liftoff do the main engines throttle back to about 67% of rated performance to reduce the structural stress that occurs as the space shuttle breaks the sound barrier?

40 seconds

6. “Discovery Houston, Go at throttle up!” is the command given when the atmosphere is so thin that there is no danger of structural damage due to dynamic pressure. About how many seconds after liftoff does this occur?

60 seconds

7. What occurs at approximately 2 minutes into flight?

SRB separation.

8. What happens to the depleted SRBs?

The SRBs are recovered from the ocean, refurbished, reloaded with propellant, and reused for several missions.

9. What powers Discovery after SRB separation?



The orbiter's 3 main engines burning propellant from the external tank.

EXPLORE

Solution Key

Problem

On July 4, 2006, Space Shuttle Discovery was launched from Kennedy Space Center on mission STS-121, to begin a rendezvous with the International Space Station (ISS). Before each mission the projected data is compiled to assist in the launch of the space shuttle and to ensure safety and success during the ascent. To complete this data flight design, specialists take into consideration a multitude of factors, such as space shuttle mass, propellant used, mass of payload being carried to space, and mass of payload returning. They must also factor in atmospheric density, which is changing throughout the year. After running multiple tests, information is compiled in a table showing exactly what should happen each second of the ascent.

Table 1: STS-121 Discovery Ascent data (total mass)

Time (s)	Space Shuttle Total Mass (kg)
0	2,051,113
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60	1,376,301
70	1,277,921
80	1,177,704
90	1,075,683
100	991,872
110	913,254
120	880,377

Table 1 shows the total mass of Discovery for mission STS-121 every 10 seconds from liftoff to SRB separation. Total mass includes the orbiter, SRBs, ET, propellant, and payload. It is during the first stage of the ascent, that the space shuttle is burning the greatest amount of propellant. You can see in the table that the space shuttle has a total mass of 2,051,113 kg at $t = 0$. After 2 minutes its total mass is only 880,377 kg, or 43 % of the original mass. The burning of this vast amount of propellant is needed to get the space shuttle through Earth's atmosphere and into orbit.

10. What happens to the mass as time progresses?

It decreases.

11. If this data were to be graphed with time on the x-axis and mass on the y-axis, which of the following would be characteristic of the graph?

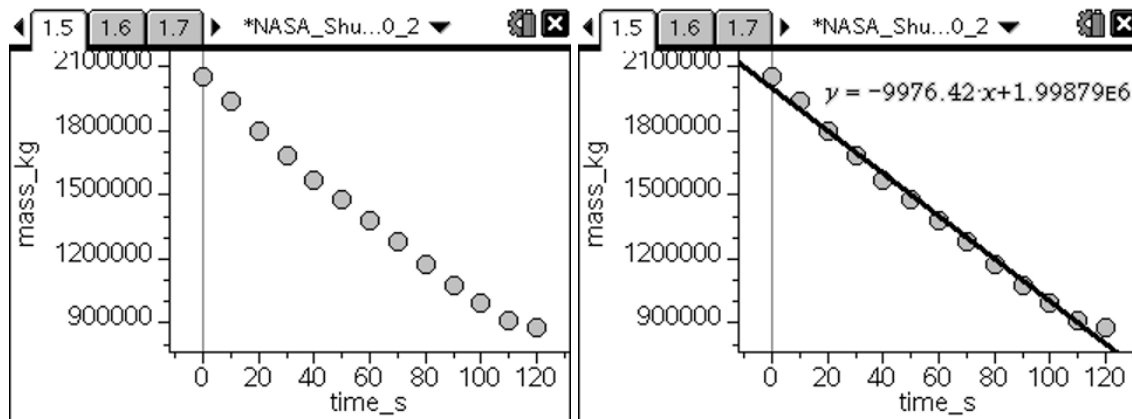
The graph slopes down and it has a positive y-intercept.



EXPLAIN

Solution Key

Create scatter plot on page 1.5 in the TI-Nspire file and model data using linear regression.



12. Does the line fit the data? Explain.

Yes, because the points of the scatter plot appear to be on the line or are very close to it on either side.

13. What is the correlation of the data?

Negative

14. How much propellant does Discovery burn per second? Explain what this represents with regard to the equation.

The space shuttle burns 9,976 kg of propellant per second. This represents the slope of the line which is -9,976.

15. What is the y -intercept of the equation of the line that models the mass versus time data? Explain what this represents in relation to the space shuttle.

The y -intercept is 1,998,791. This represents the mass of the shuttle at liftoff, or when $t = 0$.



EXTEND

Solution Key

16. To gain perspective regarding the magnitude of the propellant consumption of the space shuttle, find the approximate number of each type of object that it would take to equal the mass of the entire space shuttle system at launch. Round to the nearest whole number.

Table 2: Mass of various Objects (also located on Nspire page 2.2)

Object	Approximate mass (kg)	Approximate number of objects to equal the mass of the space shuttle at launch
Statue of Liberty	204,117	
Boeing 747 airplane	158,757	
Fuel tank truck	27,216	
School bus	11,340	

Complete the table on page 2.2 in the TI-Nspire file.

object	mass_kg	number
Space Shuttle	2051113	-
Statue of Liberty	204117	10
Boeing 747 plane	158757	13
fuel tank truck	27216	75
school bus	11340	181

object	mass_...	number
Space Shuttle	2051113	1
Statue of Liberty	204117	10
Boeing 747 plane	158757	13
fuel tank truck	27216	75
school bus	11340	181

17. A Boeing 767 airplane burns about 24,500 kg of fuel on a 6 hour flight from New York to Los Angeles. Approximately how much time would it take the space shuttle to burn an equivalent amount of propellant?

$$\frac{24500}{9976} = 2.5 \text{ seconds}$$



EVALUATE

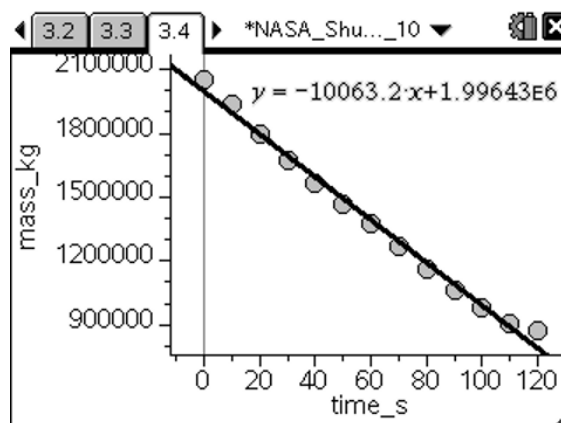
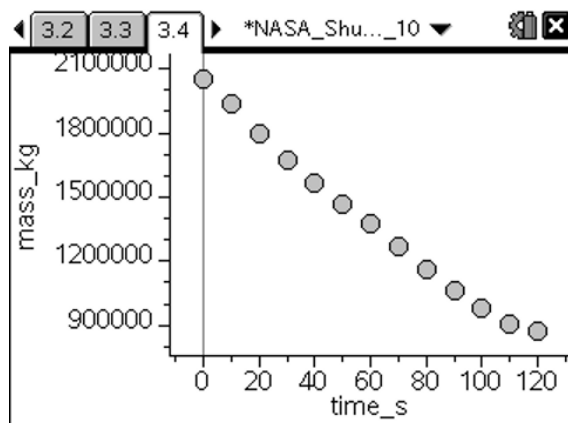
Solution Key

On May 12, 2009, Space Shuttle Atlantis was launched from Kennedy Space Center on mission STS-125 to repair the Hubble Space Telescope. Astronauts installed two new instruments, repaired two inactive ones, and performed the component replacements to keep the telescope functioning until 2014. Table 3 shows the total mass of Atlantis for mission STS-125 every 10 seconds from liftoff to SRB separation.

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60	1,374,449
70	1,264,663
80	1,163,639
90	1,061,679
100	978,131
110	902,427
120	874,457

Complete the scatter plot on page 3.4 in the TI-Nspire document.



18. Does the data appear to be linear? Explain.

Yes, because the points of the scatter plot appear to be on the line or are very close to it on either side.



19. What is the correlation of the data?

Negative

20. What is the slope of the equation? Explain what this represents with regard to the space shuttle.

The slope is $-10,063$. This means that the space shuttle is burning about $10,063$ kg of propellant each second.

21. What is the y -intercept of the equation of the line that models the mass versus time data? Explain what this represents in relation to the space shuttle.

The y -intercept is $1,996,427$. This represents the mass in kg of the space shuttle at liftoff, or when $t=0$.

22. Compare the propellant burn rate (slope) for each mission. Which space shuttle has the fastest burn rate and what might be the reason.

Atlantis. Possibly because the payload is heavier.

Contributors

This problem was developed by the Human Research Program Education and Outreach (HRPEO) team with the help of NASA subject matter experts and high school mathematics educators.

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MATH AND SCIENCE @ WORK

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SPACE SHUTTLE ASCENT

Background

Exploration provides the foundation of our knowledge, technology, resources, and inspiration. It seeks answers to fundamental questions about our existence, responds to recent discoveries, and puts in place revolutionary techniques and capabilities to inspire our nation, the world, and the next generation. Through NASA, we touch the unknown, we learn and we understand. As we take our first steps toward sustaining a human presence in the solar system, we can look forward to far-off visions of the past becoming realities of the future.

Since its first flight in 1981, the space shuttle has been used to extend research, repair satellites, and help with building the International Space Station, or ISS. However, by 2010 NASA plans to retire the space shuttle in favor of a new Crew Exploration Vehicle, or CEV. Until then, space exploration depends on the continued success of space shuttle missions. Critical to any space shuttle mission is the ascent into space.



Figure 1: Space Shuttle Discovery at lift-off during STS 121.



Figure 2: Onlookers view the launch of STS 121.

The ascent phase begins at liftoff and ends at insertion into a circular or elliptical orbit around the Earth. To reach the minimum altitude required to orbit the Earth, the space shuttle must accelerate from zero to 8,000 meters per second (almost 18,000 miles per hour) in eight and a half minutes. It takes a very unique vehicle to accomplish this.

There are three main components of the space shuttle that enable the launch into orbit. The orbiter is the main component. It not only serves as the crew's home in space and is equipped to dock with the International Space Station, but contains maneuvering engines for finalizing orbit. The external tank, the largest component of the space shuttle, supplies the propellant to the orbiter's three main maneuvering engines. The two solid rocket boosters, the third component, provide the main thrust at launch and are attached to the sides of the external tank (Figure 1). The components of the space



shuttle experience changes in position, velocity and acceleration during the ascent into space. These changes can be seen when one takes a closer look at the entire ascent process (Figure 3).

The ascent process begins with the liftoff from the launch pad. Propellant is being burned from the Solid Rocket Boosters, or SRB, and the external tank, or ET, causing the space shuttle to accelerate very quickly. This high-rate of acceleration as the space shuttle launches through the Earth's atmosphere causes a rapid increase in dynamic pressure, known as Q in aeronautics. The structure of the space shuttle can only withstand a certain level of dynamic pressure (critical Q) before it suffers damage. Before this critical level is reached, the engines of the space shuttle are throttled down to about 70%. At about one minute after launch the dynamic pressure reaches its maximum level (max Q). The air density then drops rapidly due to the thinning atmosphere and the space shuttle can be throttled to full power without fear of structural damage.

At about 2 minutes after launch, the atmosphere is so thin that the dynamic pressure drops down to zero. The SRB, having used their propellant, are commanded by the space shuttle's onboard computer to separate from the external tank. The jettison of the booster rockets marks the end of the first ascent stage and the beginning of the second.

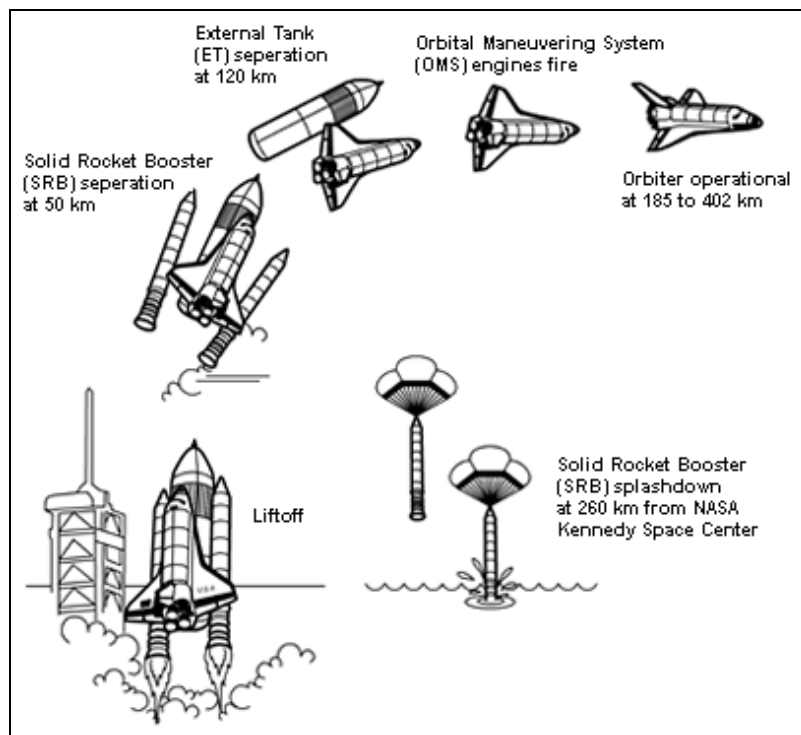


Figure 3: Space Shuttle Ascent Process

The second stage of ascent lasts about six and a half minutes. The space shuttle gains more altitude above Earth and the speed increases to the nearly 7,850 m/s (17,500 mph) required to achieve orbit. The main engines are commanded by the onboard computer to reduce power, ensuring that acceleration of the space shuttle does not exceed 29.4 m/s^2 (3 g). Within thirty seconds the space shuttle reaches Main Engine Cut-Off, or MECO. For the next eleven seconds, the space shuttle coasts through space. At nine minutes, the command to jettison the nearly empty external tank is given by the onboard computer leaving the space shuttle's maneuvering engines to control any movement needed to achieve final orbit.

As we look to the future of space exploration, the ascent stage will remain a critical part of any successful mission.



Problem

Open the TI-Nspire document (ShuttleAscent.tns), read through the problem set-up, and complete the questions in the document. Table 1 is also on page 1.7 of the TI-Nspire document. It is provided here for you to refer to as you work through the problem.

Table 1: STS-121 Ascent Data

Time (s)	Altitude (m)	Velocity (m/s)	Acceleration (m/s ²)
0	-8	0	2.45
20	1244	139	18.62
40	5377	298	16.37
60	11,617	433	19.40
80	19,872	685	24.50
100	31,412	1026	24.01
120	44,726	1279	8.72
140	57,396	1373	9.70
160	67,893	1490	10.19
180	77,485	1634	10.68
200	85,662	1800	11.17
220	92,481	1986	11.86
240	98,004	2191	12.45
260	102,301	2417	13.23
280	105,321	2651	13.92
300	107,449	2915	14.90
320	108,619	3203	15.97
340	108,942	3516	17.15
360	108,543	3860	18.62
380	107,690	4216	20.29
400	106,539	4630	22.34
420	105,142	5092	24.89
440	103,775	5612	28.03
460	102,807	6184	29.01
480	102,552	6760	29.30
500	103,297	7327	29.01
520	105,069	7581	0.10

Note: Notice from the table that the altitude is negative at liftoff. Zero altitude can be described as a specific distance from the center of the Earth. Since the Earth is not perfectly spherical the location of the launch just happens to be below this specified point. Also, because this is a calculated number, some degree of error may be present.



- A. Answer the following based on Table 1 (TI-Nspire page 1.7).
- I. Create a scatterplot of the space shuttle's altitude in relation to time. Remember to adjust your viewing window.
 - II. Use the regression functions on your TI-Nspire handheld to determine which type of function best fits the data (i.e. linear, quadratic, cubic, quartic, exponential, power, etc.). Store the equation in $f1(x)$.
- B. Write the function describing the space shuttle's altitude. Let h stand for altitude and t stand for time. In writing the equation, you will need to decide what decimal place to round the coefficients to. An alternative to this is to write the coefficients using significant figures. In that case, you will need to decide how many significant figures to use. Explain your reasoning for your decision. (In your handheld, keep the original equation in $f1(x)$ to be used for following questions.)
- C. Set $f2(x)$, the velocity function, to be the first derivative and apply the first derivative test to $f2(x)$ to determine the relative extrema on the interval $[0, 520]$. Remember to adjust your viewing window. Explain what the extrema represent about the altitude of the space shuttle. How does this compare with the data in Table 1 (TI-Nspire page 1.7)?
- D. Determine the points of inflection of the altitude function. Keep your function needed to find the points of inflection in $f3(x)$. Describe the concavity of the altitude function.
- E. Analyze the altitude function along the interval $[0, 160]$. What is happening to the space shuttle when the concavity changes?



- F. Answer the following based on Table 1 (TI-Nspire page 1.7).
- I. Make a scatterplot of the velocity versus time.
 - II. Explain what is happening to the velocity of the space shuttle over the interval $[0, 520]$.
 - III. Determine the regression equation for velocity. Write the velocity function letting v stand for velocity and t stand for time. Store this equation in $f4(x)$.
- G. Answer the following based on Table 1 (TI-Nspire page 1.7).
- I. Create a scatterplot of acceleration vs. time.
 - II. Identify where the following points occur on the graph.
 - Max Q
 - Solid Rocket Booster Separation
 - III. Why does the space shuttle's acceleration increase in a quadratic fashion along the interval $[120, 460]$?
 - IV. What is happening to the acceleration on the interval $[480, 500]$ and why?
 - V. Why does the acceleration drop drastically along the interval $[500, 520]$?



- H. Using the scatterplot from question G, part I, answer the following:
- I. Is there one function that best fits the acceleration data? Why or why not?

 - II. What is the acceleration function that describes the interval $[120, 460]$? Let a stand for acceleration and t stand for time. Store this equation in $f5(x)$ on your handheld. The data for time and acceleration during this interval are stored in ***maintime*** and ***mainacceleration*** in columns E and F of the Lists and Spreadsheets page.

 - I. Compare the graphs in $f2(x)$ (the first derivative of the altitude function) and in $f4(x)$, (the velocity function found by doing the regression of the data). Do this by hiding all other equations and plots. Do not clear the other equations. Remember to adjust your viewing window. How do these graphs compare? Explain the differences in what they are representing.

 - J. Now compare the graphs in $f3(x)$ (the second derivative of the altitude function) and in $f5(x)$ (the acceleration function found by doing the regression of the data). How do these graphs compare? Explain the differences in what they are representing.



MATH AND SCIENCE @ WORK

AP* CALCULUS Educator Edition



SPACE SHUTTLE ASCENT

Instructional Objectives

Students will

- create and analyze scatter plots given a table;
- find regression functions using a graphing technology;
- apply the first derivative test to find local extrema;
- find inflection points to analyze the concavity of a function; and
- make connections to real world problems.

Degree of Difficulty

This problem requires students to have a good understanding of the TI-Nspire handheld. Students will also be connecting data and making multiple conjectures relating graphs and tables to a real life situation.

- For the average AP Calculus AB student the problem may be moderate to very difficult depending on their experience with the TI-Nspire.
- For the average AP Calculus BC student the problem may be moderately difficult.

Media Resources

This problem has two media files for use during the introduction and post discussion of the problem. These files will engage students in a space shuttle launch and introduce them to the different events that take place during the space shuttle's ascent into space.

- Space Shuttle Launch Video (10 minutes).
This video shows the launch of Space Shuttle Discovery STS 121 mission on July 4, 2006. To access the video, follow the link provided and choose the video titled: "The Rocket's Red Glare." This should be shown to students during the introduction of the problem and is necessary for them to answer part of the problem. It is highly recommended that the instructor become familiar with the video before showing it to students.

http://www.nasa.gov/mission_pages/shuttle/shuttlemissions/sts121/launch/sts121-allvideos.html

Appendix A provides a discussion guide that can be used with the video.

Grade Level
11-12

Key Topic
Applications of
Differentiation

Degree of Difficulty
Calculus AB:
Moderate to Difficult
Calculus BC: Moderate

Teacher Prep Time
10 minutes

Problem Duration
60-90 minutes

Technology
TI-Nspire Handheld,
computer with projector
and movie player

Materials
Student Edition including:
- Background handout
- Problem worksheet
- ShuttleAscent.tns

NCTM Principles and Standards
- Algebra
- Data Analysis and Probability
- Problem Solving
- Communication

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- Google Earth Space Shuttle Ascent Trajectory (5-10 minutes). The file, AscentTrajectory_Tour.kmz, shows the ascent phase of the Space Shuttle Discovery during STS 119 in Google Earth. The file is provided for download with this problem.

Appendix B provides instructions for using this file.

Background

This problem is part of a series of problems that apply math and science principles to human space exploration at NASA.

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Since its first flight in 1981, the space shuttle has been used to extend research, repair satellites, and help with building the International Space Station, or ISS. However, by 2010 NASA plans to retire the space shuttle in favor of a new Crew Exploration Vehicle, or CEV. Until then, space exploration depends on the continued success of space shuttle missions. Critical to any space shuttle mission is the ascent into space.



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Figure 2: Onlookers view the launch of STS 121.

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The ascent process begins with the liftoff from the launch pad. Propellant is being burned from the Solid Rocket Boosters, or SRB, and the external tank, or ET, causing the space shuttle to accelerate very quickly. This high-rate of acceleration as the space shuttle launches through the Earth's atmosphere causes a rapid increase in dynamic pressure, known as Q in aeronautics. The structure of the space shuttle can only withstand a certain level of dynamic pressure (critical Q) before it suffers damage. Before this critical level is reached, the engines of the space shuttle are throttled down to about 70%. At about one minute after launch the dynamic pressure reaches its maximum level (max Q). The air density then drops rapidly due to the thinning atmosphere and the space shuttle can be throttled to full power without fear of structural damage.

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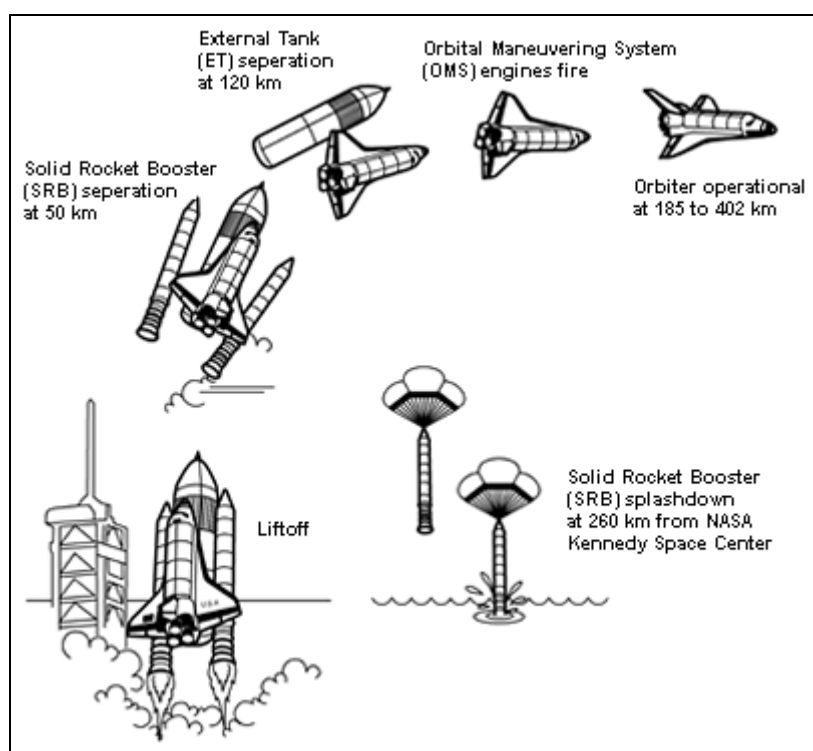


Figure 3: Space Shuttle Ascent Process

The second stage of ascent lasts about six and a half minutes. The space shuttle gains more altitude above Earth and the speed increases to the nearly 7,850 m/s (17,500 mph) required to achieve orbit. The main engines are commanded by the onboard computer to reduce power, ensuring that acceleration of the space shuttle does not exceed 29.4 m/s^2 (3 g). Within thirty seconds the space shuttle reaches Main Engine Cut-Off, or MECO. For the next eleven seconds, the space shuttle coasts through space. At nine minutes, the command to jettison the nearly empty external tank is given by the onboard computer leaving the space shuttle's maneuvering engines to control any movement needed to achieve final orbit.

As we look to the future of space exploration, the ascent stage will remain a critical part of any successful mission.



AP Course Topics

Functions, Graphs, and Limits

- Analysis of Graphs
 - With the aid of technology, graphs of functions are often easy to produce. The emphasis is on the interplay between the geometric and analytic information and on the use of calculus both to predict and to explain the observed local and global behavior of a function

Derivatives

- Concept of the derivative
 - Derivative presented graphically, numerically, and analytically
- Derivative as a function
 - Corresponding characteristics of graphs of f and f'
 - Relationship between the increasing and decreasing behavior of f and the sign of f'
- Second derivatives
 - Corresponding characteristics of the graphs of f , f' , and f''
 - Relationship between the concavity of f and the sign of f''
 - Points of inflection as places where concavity changes
- Application of derivatives
 - Analysis of curves, including the notions of monotonicity and concavity
 - Interpretation of the derivative as a rate of change in varied applied contexts, including velocity, speed, and acceleration

NCTM Principles and Standards

Algebra

- Understand patterns, relations, and functions.
- Represent and analyze mathematical situations and structures using algebraic symbols.
- Use mathematical models to represent and understand quantitative relationships.

Data Analysis and Probability

- Select and use appropriate statistical methods to analyze data.

Problem Solving

- Build new mathematical knowledge through problem solving.
- Monitor and reflect on the process of mathematical problem solving.

Communication

- Organize and consolidate their mathematical thinking through communication.
- Communicate their mathematical thinking coherently and clearly to peers, teachers, and others.
- Use the language of mathematics to express mathematical ideas precisely.

Problem

Note: Students are given the following problem information within the TI-Nspire document, ShuttleAscent.tns. They are also provided Table 1 on the student handout that they can reference while doing the problem. Students can submit their answers within the ShuttleAscent.tns file, or they can write their answers on the student handout.

Before each mission, projected data is compiled to assist in the launch of the space shuttle to ensure safety and success during the ascent. To complete this data, flight design specialists take into consideration a multitude of factors such as the weight of the space shuttle, propellant used, mass of



payload being carried to space, and mass of payload returning. They must also factor in atmospheric density, which is changing throughout the year. After running multiple scenarios through computer modeling, information is compiled in a table showing exactly what should happen each second of the ascent. This information helps the NASA engineers and flight controllers to quickly evaluate whether or not the space shuttle is operating as expected during the launch phase.

Table 1: STS-121 Ascent Data (TI-Nspire page 1.7)

Time (s)	Altitude (m)	Velocity (m/s)	Acceleration (m/s ²)
0	-8 0		2.45
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360 108,54	3	3860	18.62
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500 103,29	7	7327	29.01
520 105,06	9	7581	0.10

Note: Notice from the table that the altitude is negative at liftoff. Zero altitude can be described as a specific distance from the center of the Earth. Since the Earth is not perfectly spherical the location of the launch just happens to be below this specified point. Also, because this is a calculated number, some degree of error may be present.

On July 4, 2006 Space Shuttle Discovery launched from Kennedy Space Center on mission STS-121, to begin a rendezvous with the ISS. Data for mission STS-121 showing the altitude, velocity, and acceleration of the space shuttle every 20 seconds from liftoff to MECO, is displayed in Table 1.



In the following questions you will use the data from Table 1 to determine a position function, a velocity function, and an acceleration function. *Position* is defined as a location in a coordinate system. In this problem, the altitude of the space shuttle in relation to time after launch is the space shuttle's vertical position. *Velocity* is defined as the rate of change of the vertical position. It describes how fast the space shuttle is moving. It is measured in meters per second (m/s). *Acceleration* is defined as the rate of change of velocity. It describes how the velocity of the space shuttle is changing and is measured in meters/second² (m/s²).

Because of the power and speed of lift off, precision is of utmost importance. Keep this in mind as you work with the data in this problem.

Open the TI-Nspire document (ShuttleAscent.tns), read through the problem set-up, and complete the questions in the document.

- A. Answer the following based on Table 1(TI-Nspire page 1.7).
 - I. Create a scatterplot of the space shuttle's altitude in relation to time. Remember to adjust your viewing window.
 - II. Use the regression functions on your TI-Nspire handheld to determine which type of function best fits the data (i.e. linear, quadratic, cubic, quartic, exponential, power, etc.). Store the equation in $f1(x)$.
- B. Write the function describing the space shuttle's altitude. Let h stand for altitude and t stand for time. In writing the equation, you will need to decide what decimal place to round the coefficients to. An alternative to this is to write the coefficients using significant figures. In that case, you will need to decide how many significant figures to use. Explain your reasoning for your decision. (In your handheld, keep the original equation in $f1(x)$ to be used for following questions.)
- C. Set $f2(x)$, the velocity function, to be the first derivative and apply the first derivative test to $f2(x)$ to determine the relative extrema on the interval $[0, 520]$. Remember to adjust your viewing window. Explain what the extrema represent about the altitude of the space shuttle. How does this compare with the data in Table 1(TI-Nspire page 1.7)?
- D. Determine the points of inflection of the altitude function. Keep your function needed to find the points of inflection in $f3(x)$. Describe the concavity of the altitude function.
- E. Analyze the altitude function along the interval $[0, 160]$. What is happening to the space shuttle when the concavity changes?
- F. Answer the following based on Table 1(TI-Nspire page 1.7).
 - I. Make a scatterplot of the velocity versus time.
 - II. Explain what is happening to the velocity of the space shuttle over the interval $[0, 520]$.
 - III. Determine the regression equation for velocity. Write the velocity function letting v stand for velocity and t stand for time. Store this equation in $f4(x)$.
- G. Answer the following based on Table 1(TI-Nspire page 1.7).
 - I. Create a scatterplot of acceleration vs. time.

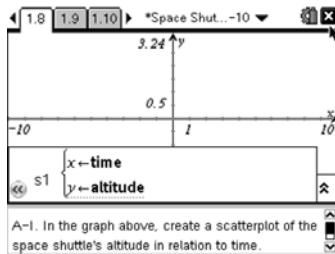


- II. Identify where the following points occur on the graph.
- Max Q
 - Solid Rocket Booster Separation
- III. Why does the space shuttle's acceleration increase in a quadratic fashion along the interval $[120, 460]$?
- IV. What is happening to the acceleration on the interval $[480, 500]$ and why?
- V. Why does the acceleration drop drastically along the interval $[500, 520]$?
- H. Using the scatterplot from question G, part I, answer the following:
- I. Is there one function that best fits the acceleration data? Why or why not?
 - II. What is the acceleration function that describes the interval $[120, 460]$? Let a stand for acceleration and t stand for time. Store this equation in $f5(x)$ on your handheld. The data for time and acceleration during this interval are stored in **maintime** and **mainacceleration** in columns E and F of the Lists and Spreadsheets page.
- I. Compare the graphs in $f2(x)$ (the first derivative of the altitude function) and in $f4(x)$, (the velocity function found by doing the regression of the data). Do this by hiding all other equations and plots. Do not clear the other equations. Remember to adjust your viewing window. How do these graphs compare? Explain the differences in what they are representing.
- J. Now compare the graphs in $f3(x)$ (the second derivative of the altitude function) and in $f5(x)$ (the acceleration function found by doing the regression of the data). How do these graphs compare? Explain the differences in what they are representing.

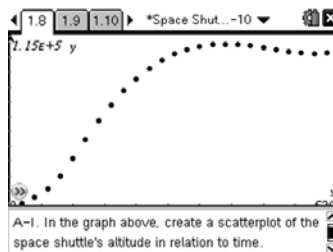
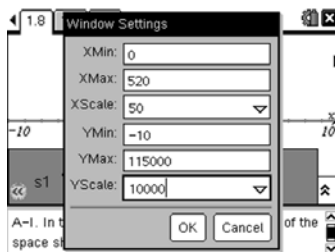
Solution Key (One Approach)

Note: A TI-Nspire document with solutions shown (ShuttleAscent_Solutions.tns) is provided for download with this problem.

- A. Answer the following based on Table 1(TI-Nspire page 1.7).
- I. Create a scatterplot of the space shuttle's altitude in relation to time. Remember to adjust your viewing window.
- Step 1:** Change the graph type (TI-Nspire page 1.8) to a Scatter Plot.
- Step 2:** Enter **time** for the x-list and **altitude** for the y-list.



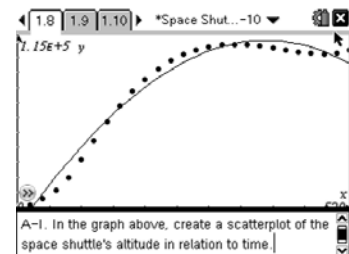
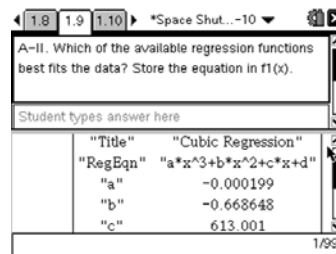
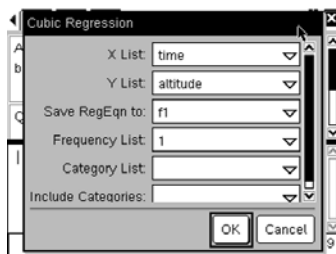
Step 3: Change the window settings to fit the table data and graph. An example is shown.



- II. Use the regression functions on your TI-Nspire handheld to determine which type of function best fits the data (i.e. linear, quadratic, cubic, quartic, exponential, power, etc.). Store the equation in $f1(x)$.

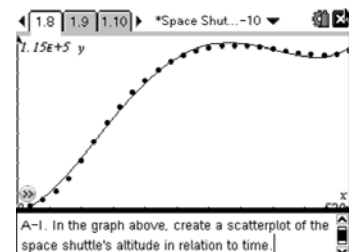
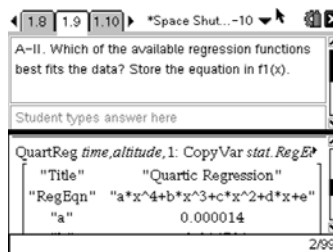
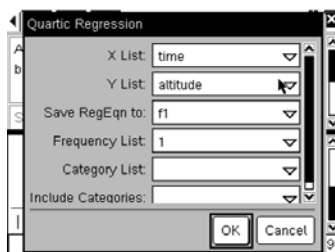
Students should see that the data is not very linear and that it is not shaped like a parabola, ruling out linear and quadratic functions. They can do the regressions for cubic and quartic then graph the equations to see which matches the graph better. When they try to do the regressions for exponential and logarithmic, they will get a domain error on their handheld ruling them out.

Cubic Regressions gives the following:



On visual inspection, students will see that the first inflection point is missing and can thus rule out cubic.

Quartic regression gives the following:





The students should see the quartic regression best matches the data.

Note: You may want to discuss the R^2 value shown in the regression and what that means about the data.

- B. Write the function describing the space shuttle's altitude? Let h stand for altitude and t stand for time. In writing the equation, you will need to decide what decimal place to round the coefficients to. An alternative to this is to write the coefficients using significant figures. In that case, you will need to decide how many significant figures to use. Explain your reasoning for your decision. (In your handheld, keep the original equation in $f1(x)$ to be used for following questions.)

Rounding to three decimal places would not be appropriate in this case because that would round the coefficient of x^4 to 0 making the function cubic rather than quartic. If you round the coefficients you would need to round to at least 6 decimal places in order for the function to fit the data well. Using three significant figures would also be appropriate and would still fit the data.

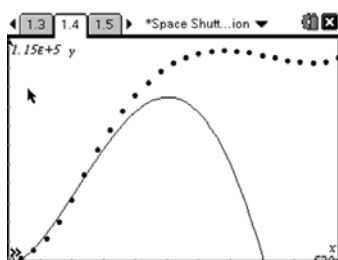
Rounding coefficients to six decimal places gives:

$$h(t) = 0.000014t^4 - 0.014791t^3 + 4.150837t^2 + 79.754386t - 2475.799324$$

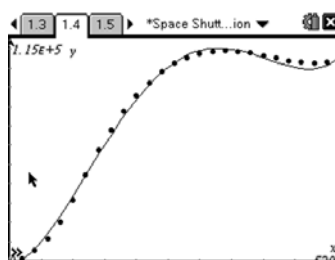
Expressing coefficients in three significant figures gives:

$$h(t) = (1.40 \times 10^{-5})t^4 - (1.48 \times 10^{-2})t^3 + 4.15t^2 + 79.8t - 2480$$

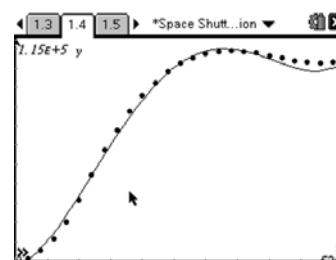
Note: This problem would be good to discuss as a class and come to a consensus on how to represent the equations as a class. Some students will be more familiar with using significant figures than others depending on which Science classes they have taken. This would be a great time to discuss why significant figures are the rule in science rather than rounding. The following screen shots show what students will find as they explore which method to use.



Coefficients rounded to 5 decimal places



Coefficients rounded to 6 decimal places

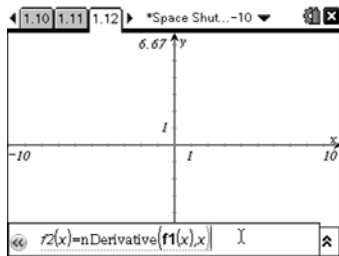


Coefficients expressed as 3 significant figures

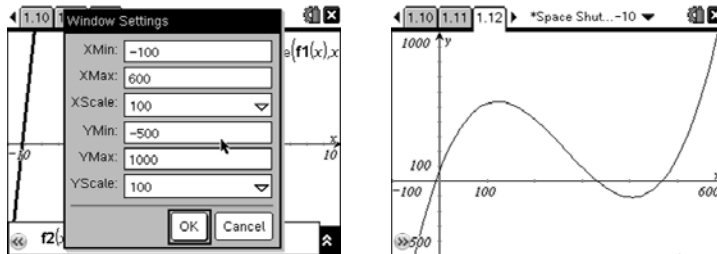
- C. Set $f2(x)$ the velocity function, to be the first derivative and apply the first derivative test to $f2(x)$ to determine the relative extrema on the interval $[0, 520]$. Remember to adjust your viewing window. Explain what the extrema represent about the altitude of the space shuttle. How does this compare with the data in Table 1 (TI-Nspire page 1.7)?

The local extrema can be found by finding the zeros of the first derivative of the function.

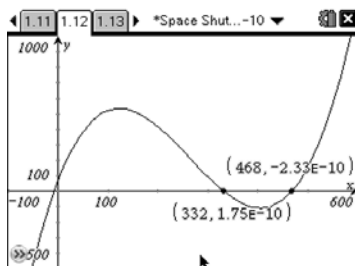
Step 1: Enter the derivative of $f1(x)$ into $f2(x)$ as shown.



Step 2: Change the window settings to fit the data. An example is shown.



Step 3: Find the zeros by using the Zero feature in the Analyze menu. You may need to drag the coordinates of the zeros in order to see them clearly.



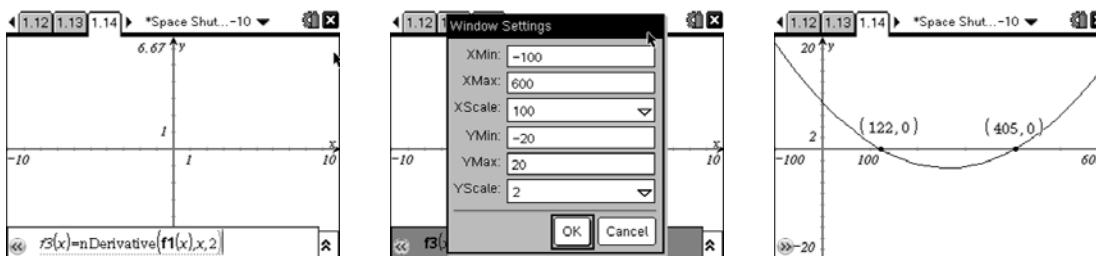
The local extrema are at $t = 332$ seconds and $t = 468$ seconds.

By looking at the altitude function one can see when time reaches 332 seconds we have a local maximum and when time reaches 468 seconds we have a local minimum.

On our function when time is 332 seconds the altitude is 110,718 meters. When time is 468 seconds, the altitude is 100,928 meters. Looking at the table, the highest altitude the space shuttle reaches is 108,942 meters and occurs at 340 seconds. The space shuttle then dips down a bit to an altitude of 102,552 meters at 480 seconds before again increasing altitude. So our function is pretty closely aligned with the data in the table.

- D. Determine the points of inflection of the altitude function. Keep your function needed to find the points of inflection in $f3(x)$. Describe the concavity of the altitude function.

Find where the second derivative of the function equals zero. To do this on the handheld enter the derivative function into $f3(x)$, change the window, and use the Zero feature in the Analyze menu to find the zeros.



The points of inflection can be found at $t = 122$ seconds and $t = 405$ seconds.

The altitude function is concave up on the interval $[0, 122]$ concave down on the interval $[122, 405]$ and concave up on the interval $[405, 520]$.

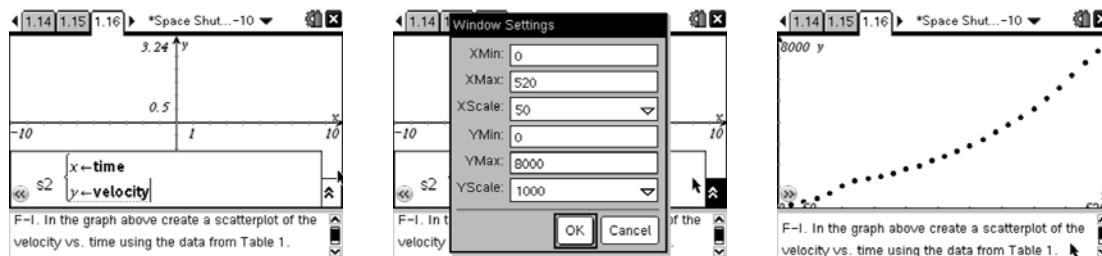
- E. Analyze the altitude function along the interval $[0, 160]$. What is happening to the space shuttle when the concavity changes?

At approximately 2 minutes (120 seconds) the Solid Rocket Boosters, or SRB, separate from the rocket.

- F. Answer the following based on Table 1 (TI-Nspire page 1.7).

- I. Make a scatterplot of the velocity versus time.

On the handheld first change the graph type to a Scatter Plot and hide $S1$. Then plot $S2$ as shown. Adjust the window and graph.



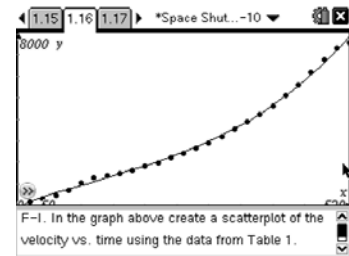
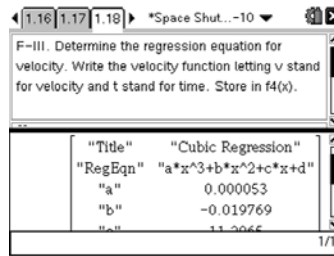
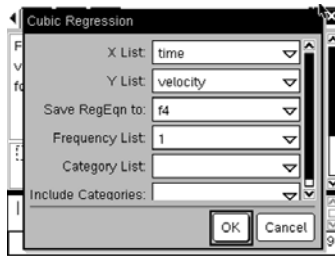
- II. Explain what is happening to the velocity of the space shuttle over the interval $[0, 520]$.

On the interval $[0, 120]$ the velocity is increasing at a fluctuating rate. It continues to increase in an almost quadratic manner until it gets to 500 seconds. Then the velocity appears to stay constant.

- III. Determine the regression equation for velocity. Write the velocity function letting v stand for velocity and t stand for time. Store this equation in $f4(x)$.

Since we used a quartic equation for the altitude function, the velocity function should be a cubic function because it should be the derivative of the altitude function.

Calculate the cubic regression equation and place it in $f4(x)$. Check the graph to be sure it matches the data.



Rounding coefficients to six decimal places gives:

$$v(t) = 0.000053t^3 - 0.019769t^2 + 11.2065t - 51.5758$$

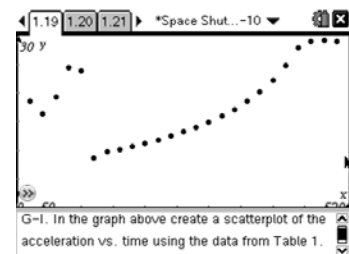
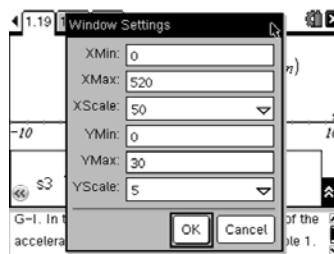
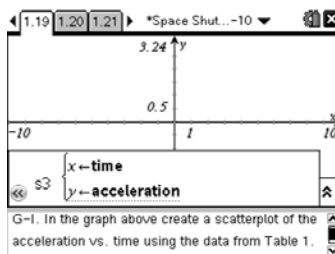
Expressing coefficients in three significant figures gives:

$$v(t) = (5.28 \times 10^{-5})t^3 - (1.98 \times 10^{-2})t^2 + 11.2t - 51.6$$

G. Answer the following based on Table 1 (TI-Nspire page 1.7).

- I. Create a scatterplot of acceleration vs. time.

On the handheld hide plot S2 and all current equations. Then set plot S3 as shown. Adjust the window and graph.



- II. Identify where the following points occur on the graph.

- Max Q is at about 40 seconds where the acceleration begins to increase again.
- Solid Rocket Booster Separation occurs at about 120 seconds. The acceleration drops and then begins increase smoothly.

- III. Why does the space shuttle's acceleration increase in a quadratic fashion along the interval [120, 460]?

Propellant in the ET is burning (reducing mass). As the mass continues to decrease the acceleration increases at a faster rate until the space shuttle reaches its maximum acceleration of 3 g at 450 seconds.

- IV. What is happening to the acceleration on the interval [480, 500] and why?

The space shuttle is at maximum acceleration (3 g) where it stays constant until it is ready for orbit.

- V. Why does the acceleration drop drastically along the interval [500, 520]?



The main engines are cut off (MECO).

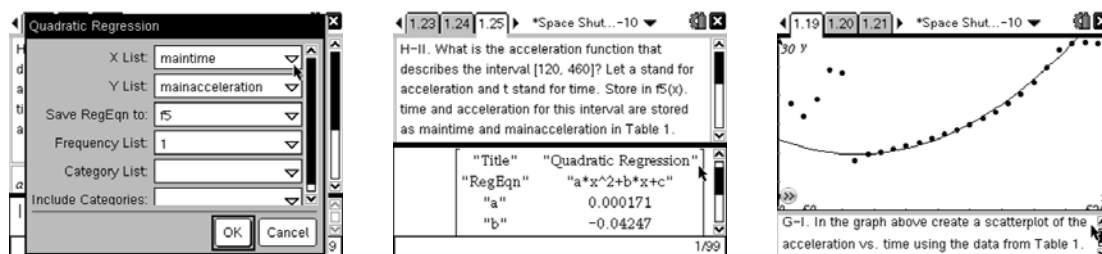
H. Using the scatterplot from question G, part I, answer the following:

- I. Is there one function that best fits the acceleration data? Why or why not?

There is not one function that would fit this data. It appears to be a piecewise function. There would be a different function for each of the intervals discussed in question F.

- II. What is the acceleration function that describes the interval [120, 460]? Let a stand for acceleration and t stand for time. Store this equation in $f5(x)$ on your handheld. The data for time and acceleration during this interval are stored in **maintime** and **mainacceleration** in columns E and F of the Lists and Spreadsheets page.

To find the equation on the interval [120, 460], students should calculate the quadratic regression as shown below and then graph it on the plot made in question G to verify.



Rounding coefficients to six decimal places gives:

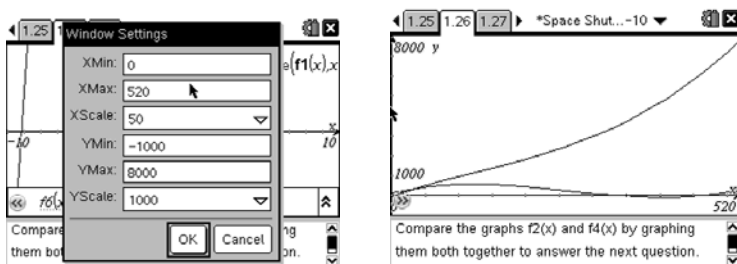
$$a(t) = 0.000171t^2 - 0.04247t + 12.3591$$

Expressing coefficients in three significant figures gives:

$$a(t) = (1.71 \times 10^{-4})t^2 - (4.25 \times 10^{-2})t + 12.4$$

- I. Compare the graphs in $f2(x)$ (the first derivative of the altitude function) and in $f4(x)$, (the velocity function found by doing the regression of the data). Do this by hiding all other equations and plots. Do not clear the other equations. Remember to adjust your viewing window. How do these graphs compare? Explain the differences in what they are representing.

Hide all plots and all equations but $f2(x)$ and $f4(x)$, adjust window, and graph.



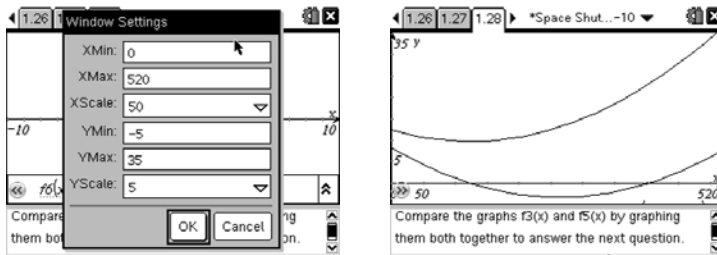
- J. These graphs should both describe the velocity of the space shuttle, however the derivative of the altitude function explains only the vertical velocity of the space shuttle and the data given in



the table is the total velocity of the space shuttle. The shuttle is not moving just vertically but at an angle in order to go into orbit. Thus there is a vertical velocity and a horizontal velocity.

- K. Now compare the graphs in $f_3(x)$ (the second derivative of the altitude function) and in $f_5(x)$ (the acceleration function found by doing the regression of the data). How do these graphs compare? Explain the differences in what they are representing.

Hide $f_2(x)$ and $f_4(x)$ and turn on $f_3(x)$ and $f_5(x)$, adjust window, and graph.



These graphs both describe the acceleration of the space shuttle, but again the second derivative of the altitude function describes the vertical acceleration and the data given in the table describes the total acceleration.



Scoring Guide

Suggested 21 points total to be given.

Question	Distribution of points
A <i>2 points</i>	1 point for the scatter plot 1 point for the quartic regression equation
B <i>2 points</i>	1 point for the equation 1 point for the explanation
C <i>2 points</i>	1 point for the local extrema 1 point for the explanation of what the extrema represent
D <i>2 points</i>	1 point for the inflection points 1 point for the description of concavity
E <i>1 point</i>	1 point for the conclusion of SRB separation
F <i>3 points</i>	1 point for the scatter plot 1 point for the explanation 1 point for the velocity function
G <i>6 points</i>	1 point for the scatter plot 1 point for locating maxQ 1 point for locating SRB separation 1 point for explanation of acceleration increase on [120,460] 1 point for explanation of acceleration on [480,500] 1 point for identifying main engine cut off on [500,520]
H <i>1 points</i>	1 point for the acceleration function
I <i>1 points</i>	1 point for explaining the differences in the velocity functions
J <i>1 points</i>	1 point for explaining the differences in the acceleration functions



Appendix A

Discussion Guide for STS 121 Launch Video “The Rocket’s Red Glare”

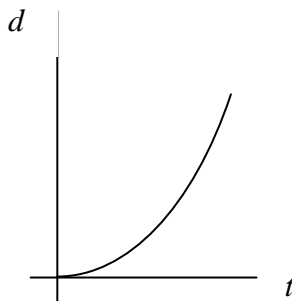
Before playing the launch video, encourage students to pay close attention to the communication that goes on between the space shuttle crew and mission control and to strive to gain a sense of what the space shuttle is physically experiencing during the climb to orbit.

After the students have watched the video discuss what they observed. The following questions and answers are just a few examples of questions that could be used in a class discussion of the video.

1. Name some of the forces that are involved in the ascent process.

Throttle down occurs as the space shuttle approaches and passes through the sound barrier where the pressure of the atmosphere produces enormous force on the space shuttle system and the crew inside the vehicle. “Accelerating more slowly” reduces these forces. Throttle up occurs after this point of maximum dynamic pressure (Max Q) has passed and allows the space shuttle to accelerate continuing its ascent.

2. After the space shuttle has cleared the tower the video image is from the Solid Rocket Booster (SRB). You can literally see Florida “fall down” below the rising space shuttle. Sketch a d - t graph of this portion of the ascent or explain what it would look like.



The graph is concave up, does not have a constant slope, and its origin is at the launch pad.

3. As the Solid Rocket Boosters (SRBs) burn out and the space shuttle approaches SRB separation, what is happening to its acceleration?

As the SRBs burn out they are no longer able to contribute significantly to accelerating the space shuttle to orbit. Therefore, the space shuttle, although still accelerating due to its own engines, slows its rate of acceleration rapidly. After SRB separation there is a good size jolt as the space shuttle is able to accelerate more quickly now that it has lost a huge amount of mass.

4. Consider the statement “from zero to 17,500 mph in 8.5 min.” Ponder the enormity of these values in comparison to the fastest car you’ve ever heard of. What are the factors that contribute to the space shuttle achieving such a magnificently huge orbital velocity?

Some factors include decreasing mass (propellant use and jettison of SRBs), constant thrust, and decreasing atmospheric drag.

5. Pay special attention to the camera angle provided of the Earth as it slips past in the background. How would you describe the space shuttle’s progress (constant speed, accelerating, at rest...)?

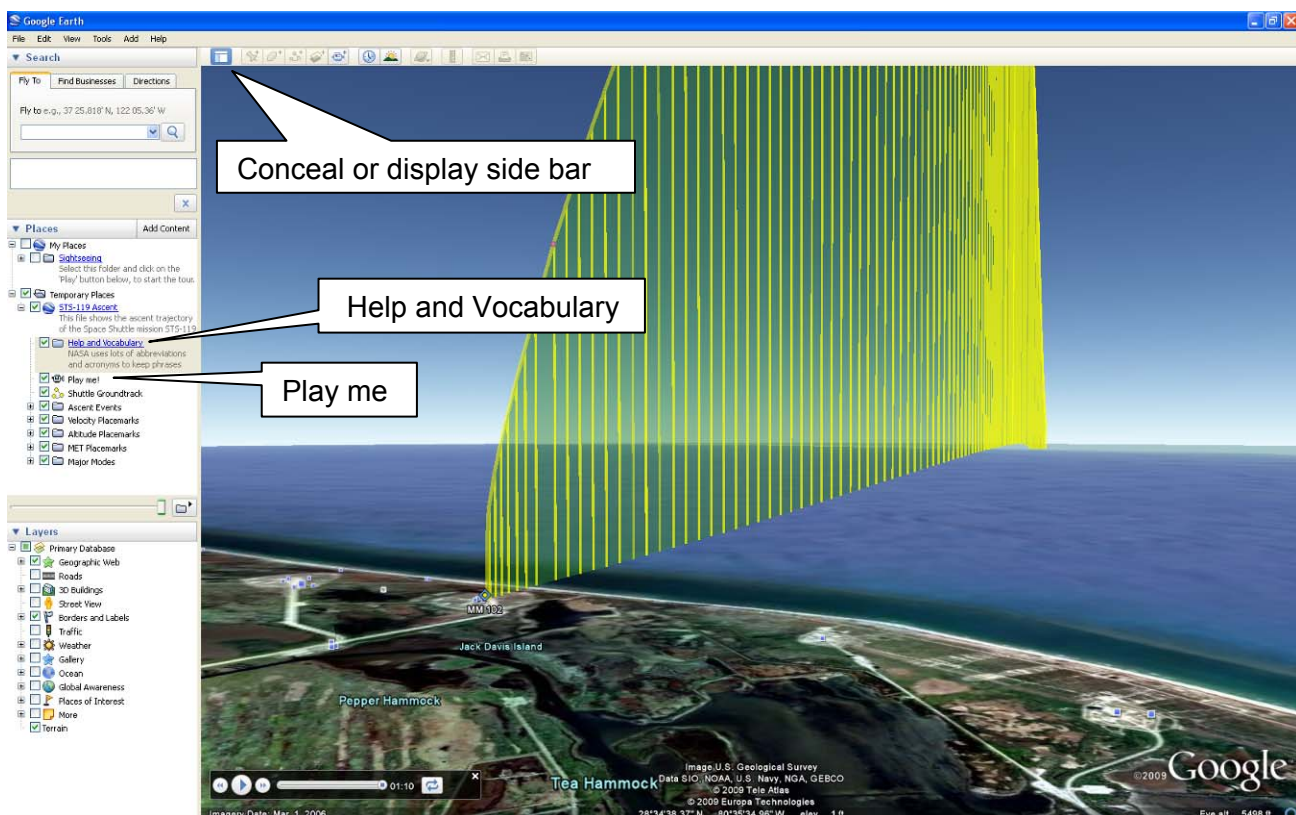


Because the Space Shuttle's altitude is so great now it is nearly impossible to tell from the video that it is still accelerating. Recall, however, that the main engines are still running, propellant mass is decreasing quickly and there is no atmospheric drag. One can conclude that the space shuttle is accelerating.

Appendix B

Instructions for Google Earth Space Shuttle Ascent Trajectory with Tour

1. Prior to presenting this file to your students, you should become familiar with its features and the features of Google Earth.
2. To access the file, you must first have Google Earth installed on the computer. To download a free version of Goggle Earth, follow the link below and choose "Download Google Earth 5". <http://earth.google.com>. The Google Earth user guide can be found under the help menu and gives a good overview of the software.
3. Download the provided file AscentTrajectory_Tour.kmz.
4. Open the file (AscentTrajectory_Tour.kmz) by selecting File > Open and select the file.



5. To learn more about this file, click on **Help and Vocabulary**, located on the left frame under **Temporary Places**.
6. An animated tour of the ascent trajectory is provided with this file and is 1:10 minutes long. To start the animation, double click on "**Play Me!**"



7. While watching the tour you can conceal the side bar by clicking the Conceal button located at the top left of the tool bar.
8. The tour begins with an overview of the entire space shuttle ascent from several different angles. This overview is 20 seconds long.
9. After the overview, the sequence will begin again. There are three 5 second pauses for inserting explanations of the ascent events: SRB Separation, MECO, and ET Separation. Each event is marked with a black and red circle.
10. There are additional features that you may want to explore with students at the conclusion of the tour. You may also want to use the following subtopics to unclutter the animation, (for example, uncheck the altitude and velocity folders).

To expand a folder in the left frame, click on the “+” next to the folder. To collapse the folder, click on the “-” next to it. For each subtopic there is a pop-up information box that can be opened by clicking on the subtopic. To close the pop-up information box, click on the “x” in the upper right corner of the box (or uncheck the small checked box to the left of the subtopic by clicking on it).

- Ascent Events Folder (expanded)
 - Click on an event and a pop-up information box will appear on the graph.
 - Notice the bullets for the events are the same as the markers (red and black circles) that appear on the graph for these events.
- Velocity Placemarks Folder (expanded)
 - Click on a velocity and a pop-up information box will appear on the graph.
 - Notice the bullets for the velocities are the same as the markers (green circles) that appear on the graph for these velocities.
- Altitude Placemarks Folder (expanded)
 - Click on an altitude and a pop-up will information box will appear on the graph.
 - Notice the bullets for the altitudes are the same as the markers (pink circles) that appear on the graph for these altitudes.
- MET (Mission Elapsed Time) Placemarks Folder (expanded)
 - Click on an MET and a pop-up information box will appear on the graph.
 - Notice the bullets for the METs are the same as the markers (orange circles) that appear on the graph for these METs.
- Major Modes (MM) Folder (expanded)
 - Click on a major mode and a pop-up information box will appear on the graph.
 - Notice the bullets for the major modes are the same as the markers (blue diamonds) that appear on the graph for these major modes.



Contributors

Thanks to the subject matter experts for their contributions in developing this problem:

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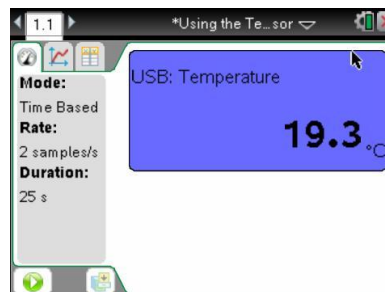
Using the Temperature Sensor

Student Activity

Name _____

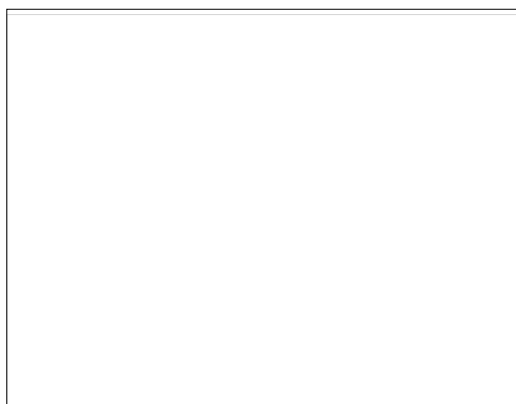
Class _____

In this activity, you will learn how to collect data with a temperature sensor and the TI-Nspire™ by setting up a 25-second experiment. You will be challenged to interpret and explain the data.



Turn on your TI-Nspire handheld.

- Open a new document by pressing **on** and selecting **New Doc.**
 - A Save message box might appear. Press **enter** to save, or press **tab** and **enter** to not save; ask your teacher what you should do.
- Obtain a temperature sensor from your teacher. **DO NOT TOUCH** the metal part of the sensor as it will ruin this experiment. Connect the temperature sensor cable to your TI-Nspire handheld. Make sure the cable is pushed in securely. What happens to your handheld?
- Select **MENU > Experiment > Collection Setup**. Press **tab** to move through the field cells. Set the **Rate (samples/second)** to 2 and the **Duration (seconds)** to 25 s and press **enter**. How many temperature readings will the system collect?
- Listen to your teacher carefully. You will be assigned to one of two groups, each with different instructions. Once you are clear on your instructions, take a moment to sketch in the space below what you think your graph of temperature vs time will look like. Label some key points.







Using the Temperature Sensor

Student Activity

Name _____

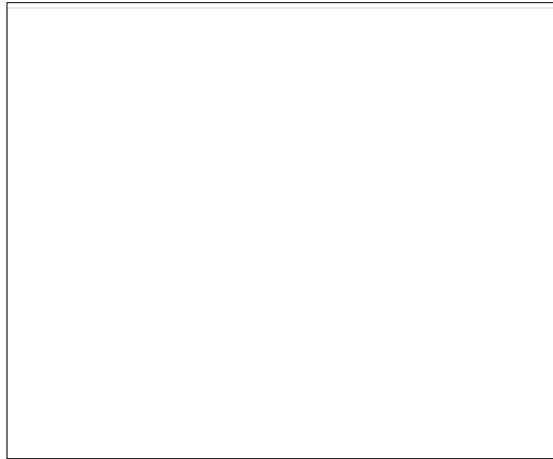
Class _____

5. When instructed to do so, click  on the Start button  and move your fingers on the sensor as assigned. Watch the graph develop as you go. The experiment will end automatically.

Does your graph look like your predicted sketch? Consider some of your labeled key points.

6. Share your graph with someone of the same group, and develop an explanation for the shape of the graph.

7. Knowing what the other group's procedure was, and having an explanation for your data, predict what you think the graphs from the other group will look like. Sketch your prediction here.



8. Share your data graph with others from the other group. Develop a hypothesis on the operation of the temperature sensor that explains the results.

9. Can you suggest some experiments that would be interesting to do with this temperature sensor?

Science Objectives

- Students will set up a data collection experiment.
- Students will make predictions based on given instructions.
- Students will collect and interpret data.
- Students will consider applications of the temperature sensor.

Math Objectives

- Students will make predictions based on given instructions.
- Students will sketch plots of bivariate data.
- Students will interpret the data they collect.

Materials

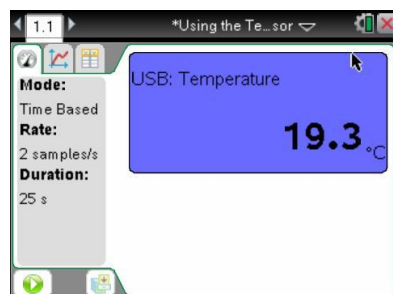
- Vernier Easy-Temp™ or the Easy-Link™ and the Stainless Steel Temperature sensor

About the Lesson

- This activity involves collecting data with a temperature sensor.
- As a result, students will:
 - Learn how to set up the experimental parameters to fit the situation.
 - Predict what they expect to see, compare results, and try to explain the results.
 - Set up and use the temperature sensor in other experiments.

TI-Nspire™ Navigator™ System

- Screen Capture can show results from different groups. Pick representative or exemplary results to use in discussing the conclusions.

**TI-Nspire™ Technology Skills:**

- Open a new document
- Set up a data collection experiment
- Collect data with a sensor

Tech Tips:

- Data collection occurs in the Vernier® DataQuest™ application, which can be viewed as a meter, a graph, or as a data table.

Lesson Materials:*Student Activity*

- Using_the_Temperature_Sensor_Student.doc
- Using_the_Temperature_Sensor_Student.pdf



Discussion Points and Possible Answers

Tech Tip: Ensure that students (and you) do not touch the metal part of the temperature sensor at all before beginning the experiment because fingers will heat up the sensor and the metal will conduct that heat as well. It takes several minutes for the sensor to return to room temperature.

Teacher Tip: When opening a new document, the system might give a warning message about saving the previous document. Decide ahead of time what might have been open on the handheld, and whether it should be saved or discarded.

TI-Nspire Navigator Opportunity: *Screen Capture*
See Note 1 at the end of this lesson.

2. What happens to your handheld?

Answer: The handheld automatically detects the temperature sensor and opens the Vernier® DataQuest™ application.

Tech Tip: If a student does not automatically see the Vernier DataQuest application, make sure the temperature sensor is completely plugged into the handheld and that a New Document was created.

The temperature sensor runs from the TI-Nspire(TM) handheld's battery. Ensure that the handhelds are charged sufficiently to run the sensor.

3. How many temperature readings will the system collect?

Answer: The system will collect an initial (time = 0) reading and two temperatures per second for 25 seconds = 51 temperature readings.



4. Divide the room in half. Call one side group A, and the other side group B. Explain the procedure to everyone.
 - Group A will start to collect data, then immediately rub their fingers on the base of the metal part of the sensor. Rub hard to create friction and move fingers toward the tip for a time of about 10 s. Stay at the tip for about 2 s, then, still rubbing, move the fingers back toward the base for about 10 s.
 - Group B will start to collect data, then immediately rub their fingers on the tip of the metal part of the sensor. Rub hard to create friction and move the fingers toward the base for a time of about 10 s. Stay at the base for about 2 s, then, still rubbing, move the fingers back toward the tip for about 10 s.
 - Answer any questions, and then have the students predict what they think the data plot will look like. Key points to consider are the start temperature and the maximum temperature, but let them decide.

Teacher Tip: It is important that the students predict what they think will happen. This not only promotes higher order thinking skills but also motivates them to continue with the activity to find out if they are right or not. Discussing the results is also a necessary component.

5. Consider key points in the actual data and encourage discussion about what the initial temperature should have been, and why the maximum temperature did not reach body temperature.
6. The students should share only within their group at this time. Their task is to try to explain the shape of their data plot.
7. Encourage discussion so they can make individual or group predictions about the other group's data.

TI-Nspire Navigator Opportunity: *Screen Captures*
See Note 2 at the end of this lesson.

8. There might be several explanations. The reason for the difference between the groups is that the thermistor (the actual sensor) is embedded inside the metal rod near the tip. The tip is therefore more sensitive than the base. The metal rod does conduct heat, so the temperature starts to rise when near the tip. The metal rod also takes time to cool down, so once the tip is heated, the temperature does not drop right away. The sensor takes some time to react to temperature changes.



Tech Tip: The temperature sensor has an operational range of -40°C to 135°C . Its response rate depends on the environment. For a 90% change in reading, it takes about 10 s in water while stirring and 400 s in still air. This can make an interesting discussion for students studying heat and heat transfer.

9. Students can be very creative in suggesting uses for the temperature sensor. This can be a motivational moment to foreshadow future activities you might have planned for the students.

Wrap Up

This activity provides students with an opportunity to think, talk, and work with experimental design issues while learning some basic concepts about heat and how the temperature sensor works. It can be a short, fun activity to lead to more detailed activities about interpreting data plots, or it can be about understanding the technology and heat concepts a little better.

Assessment

An opportunity to assess students' understanding of experimental set-up and the use of the temperature sensor is a short challenge. Ask them how hot they could get the temperature sensor using only their hands. Have them change the experiment set-up to something appropriate and be ready to start in a designated amount of time (2–4 minutes). With TI-Nspire Navigator, you can tell students you will display their work as they go.

TI-Nspire Navigator

Note 1

Question 1, Screen Captures: These can be a useful tool to monitor student progress and detect difficulties early. Do not display screen shots unless you want the class to look at and talk about them; they can be distracting.



Note 2

Question 7, Screen Capture: Here is an ideal place to display screen captures to focus student attention and discussion. Screen captures can be displayed with or without student names. Decide whether you want to praise someone's work, or just display some representative work anonymously.

This activity promotes the following **Common Core State Standards Mathematical Practices:**

2. Reason abstractly and quantitatively
3. Construct viable arguments and critique the reasoning of others
5. Use appropriate tools strategically
7. Look for and make use of structure

And the following **Constructivist 5-E's Processes:**

- Engagement
- Exploration
- Explanation
- Elaboration

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Overview

- With this Action/consequence TI-Nspire™ document, you will develop an understanding of kinetic energy, gravitational potential energy, and the conservation of mechanical energy.

Materials

- TI-Nspire™ handheld
- RollerCoasterEnergy.tns

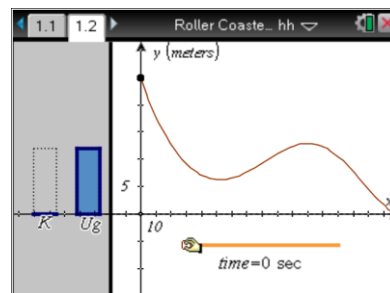
Frictionless roller coasters depict conservation of mechanical energy

Watch the animation on the TI-Nspire, or move the cursor to the open point for time, and press to grab and then move the time. Observe the bar graph.

1. Describe what is happening to the kinetic energy (K) bar graph and the gravitational potential energy (U_g) bar graph. What connections can you make?

2. Identify the important parts of the graph on the right.

- a) Is this a distance versus time graph? _____
- b) What variable is on the horizontal axis? _____
- c) What is the vertical axis? _____
- d) How many meters above ground level is the roller coaster at the start? _____



3. a) Describe the gravitational potential energy when the roller coaster is at its highest point.

- b) Describe the kinetic energy when the time=0 and the roller coaster is at its highest.

4. a) In the part of the roller coaster shown, how many times does the U_g , the gravitational potential energy, equal K, the kinetic energy?

- b) Why? What is the approximate height when $U_g = K$?

 **Roller Coaster Energy**

If the roller coaster animation is on, press pause. Grab the open point for time and manually move the roller coaster.

5. Even though you cannot see what happens to the roller coaster from 9 to 10 seconds, use your observations of the energy bar graphs to explain what happens. Does the roller coaster go up again or down? Explain how the bar graphs help you determine this. Can you tell about how high the roller coaster goes at the end of 10 seconds?

6. Gravitational potential energy is measured from some arbitrary ground level. Grab the small open point on the origin and move it up and down. Press play, and observe the energy bar graphs.
 - a) What happens to the gravitational potential energy bar graph?

 - b) Can potential energy ever be negative?

 - c) When the ground level is changed, does this affect the kinetic energy? If so, how?

 - d) Can the kinetic energy ever be negative?

7. Since kinetic energy is the energy of motion, where is the roller coaster moving the fastest? Explain your answer using the energy bar graphs.

8. The total mechanical energy of a system is the sum of the kinetic and the potential energies. Describe the sum total of the two bar graphs for this frictionless roller coaster.

9. What did you learn from this exploration activity?



Overview

- With this Action/consequence TI-Nspire™ document, students will explore the relationship between kinetic energy and gravitational potential energy for a frictionless roller coaster.
- Students will develop an understanding of kinetic energy, potential energy, and the conservation of energy.

Materials

- TI-Nspire™ handheld
- RollerCoasterEnergy.tns

Related Activity

Potential and Kinetic Energy by Peter Fox #9601

Frictionless roller coasters depict conservation of mechanical energy.

On the Teacher Software, press the play button to animate the frictionless roller coaster. Students should grab and move the point on the handheld, and observe the bar graph.

Tech Tip: There are so many calculations that the animation on the handheld is a bit sluggish. If a student presses pause, it will take several seconds for it to stop.

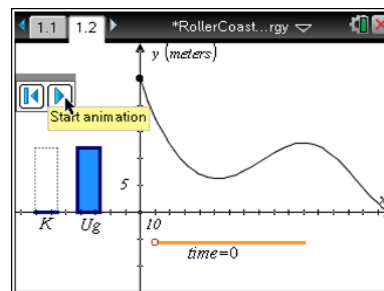
1. Describe what is happening to the kinetic energy (K) bar graph and the gravitational potential energy (U_g) bar graph. What connections can you make?

This open ended opening question allows students to make any initial observations. The following questions will help students take note of important aspects of the graphs.

Sample Answers: The kinetic energy bar goes up when the gravitational potential energy bar goes down. The lower the roller coaster is, the greater the kinetic energy. When the coaster is high, the U_g is large.

2. Identify the important parts of the graph on the right.

- a) Is this a distance versus time graph? **Answer:** No.
- b) What variable is on the horizontal axis? **Answer:** distance in x-dir
- c) What is the vertical axis? **Answer:** Distance in y-direction measured in meters
- d) How many meters above ground level is the roller coaster at the start? **Answer:** 25 meters





Roller Coaster Energy

3. a) Describe the gravitational potential energy when the roller coaster is at its highest point.

Answer: The gravitational potential is at a maximum.

- b) Describe the kinetic energy when the time=0 and the roller coaster is at its highest.

Answer: The kinetic energy is a minimum.

4. a) In the part of the roller coaster shown, how many times does the U_g , the gravitational potential energy, equal K , the kinetic energy?

Answer: Three times. Once at about 1.8 seconds, then again at 5.6 and 6.5 seconds.

- b) Why? What is the approximate height when $U_g = K$?

Answer: $U_g = K$ when the height of the roller coaster is half the total. Height = 12.5 meters

Press pause. Grab the open point for time, and manually move the roller coaster.

5. Even though you cannot see what happens to the roller coaster from 9 to 10 seconds, use your observations of the energy bar graphs to explain what happens. (Does the roller coaster go up again or down? Explain how the bar graphs help you determine this. Can you tell about how high the roller coaster goes at the end of 10 seconds?)

Answer: The potential energy bar graph increases again, and the kinetic energy bar graph get smaller. This indicates that the roller coaster is going back up a hill. It appears to be about the same gravitational potential energy it had when the coaster was at 10 meters.

6. Gravitational potential energy is measured from some arbitrary ground level. Grab the small open point on the origin, and move it up and down. Press play. Observe the energy bar graphs.

- a) What happens to the gravitational potential energy bar graph?

Answer: When the ground level is raised the potential energy gets smaller. If the ground level is lowered, the potential energy gets larger.

- b) Can potential energy ever be negative?

Answer: Yes, U_g can be negative when the ground level is above the current height.



Roller Coaster Energy

c) When the ground level is changed, does this affect the kinetic energy? If so, how?

Answer: No, the kinetic energy is unaffected when the ground level is changed.

d) Can the kinetic energy ever be negative?

Answer: No. *Students will at least observe the kinetic energy is not negative for this situation. When students learn $K = \frac{1}{2}mv^2$, they should again realize that kinetic energy cannot be negative.*

7. Since kinetic energy is the energy of motion, where is the roller coaster moving the fastest? Explain your answer using the energy bar graphs.

Answer: The kinetic energy bar graph is the largest when the y -position is the smallest, it is moving the fastest at the bottom of the hills.

8. The total mechanical energy of a system is the sum of the kinetic and the potential energies. Describe the sum total of the two bar graphs for this frictionless roller coaster.

Answer: Mechanical energy appears to be conserved. The U_g bar graph appears to be decreasing at the same rate the K bar graph is increasing. The maximum U_g look like it is equal to the maximum K , but they occur at different times. Qualitatively, the sum of the kinetic and potential energy appears to be constant.

For further discussion: Ask students "What do you think would be different about the bar graph if this was not a frictionless roller coaster? If there were friction, how would that affect the total energy?"

Answer: The total energy would not stay constant. Friction would slow it down. The maximum kinetic energy would be less than it is in the current simulation.

9. What did you learn from this exploration activity?

Answer: This might have served as an introduction to kinetic, potential, and mechanical energy and their conservation. Students might have become better at interpreting bar graphs.

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Reflection and Absorption of Light

Would you feel cooler wearing a light or dark-colored shirt on a hot, sunny day? The color and texture of an object influences how much radiant energy from the sun it will absorb or reflect. Every color reflects a certain amount of light while absorbing the rest as heat energy. The amount of reflected light is called the color's *light reflectance value*. Dark colors with low light reflectance values tend to reflect little light while absorbing lots of heat energy, whereas light colors with high reflectance values reflect a lot of light and absorb little energy. People in warm, sunny climates are more likely to purchase light-colored cars since they don't heat up as quickly as dark-colored ones. Many house paints come with a predetermined light reflectance value to guide consumers when making color choices for their homes. Since the Earth's surface is made of many colors and textures, it is heated unevenly. Snow, ice, and clouds reflect a lot of energy back into space while green forests and vegetated lands absorb energy.

In this experiment, you will investigate the relationship between the percent reflectivity of various colors and the temperature change due to energy absorption. You will measure the amount of light reflected from paper of various colors using a Light Sensor and calculate percent reflectivity. You will also measure the temperature change of the air under the paper due to energy absorption by the paper using a Temperature Probe.

OBJECTIVES

In this experiment, you will

- Use a Light Sensor to measure the amount of reflected light.
- Calculate percent reflectivity of various colored paper.
- Use a Temperature Probe to measure the energy absorbed from light.

MATERIALS

TI-Nspire handheld **or**
computer and TI-Nspire software
data-collection interface
Light Sensor
Temperature Probe
4 cm piece of drinking straw
lamp and 150 W clear bulb
aluminum foil

white paper
black paper
2 other pieces of colored paper
ring stand
2 utility clamps
tape
ruler

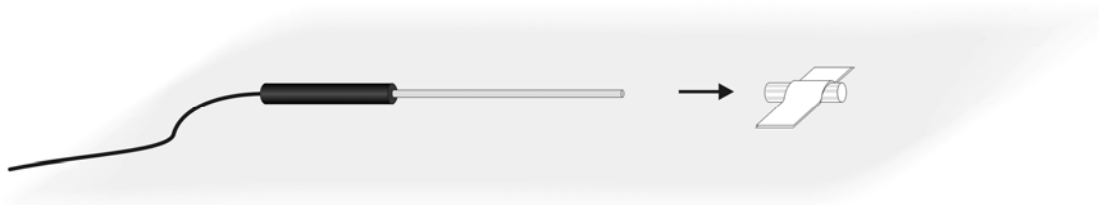








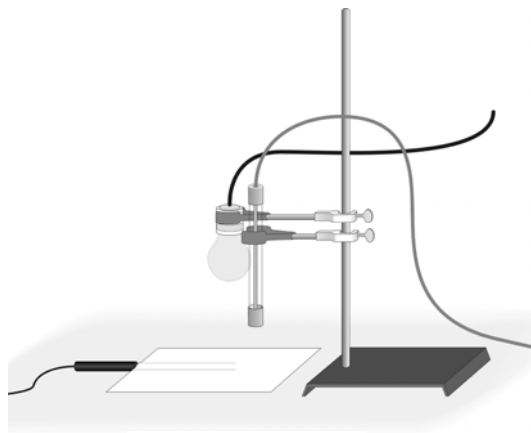


Figure 1

DataQuest 6**PROCEDURE**

1. Prepare the sensors for data collection.
 - a. Tape the straw to the table surface as shown in Figure 1.
 - b. Insert a Temperature Probe into the straw as far as it will go. Check to make sure the end of the Temperature Probe is not touching the tabletop.
 - c. Place the piece of white paper over the Temperature Probe.
 - d. Use a utility clamp and ring stand to fasten a Light Sensor 5 cm above the paper as shown in Figure 2. Set the Light Sensor switch to the 0–6000 lux position.
 - e. Use the other utility clamp to fasten the lamp and bulb to the ring stand 10 cm above the paper.
 - f. The classroom lights should be on.
2. Connect the Light Sensor and Temperature Probe to the data-collection interface. Connect the interface to the TI-Nspire handheld or computer.
3. Choose New Experiment from the  Experiment menu. Choose Collection Setup from the  Experiment menu. Enter **0.1** as the rate (samples/second) and **600** as the experiment duration (seconds). The number of points collected should be 61. Select OK.
4. Switch on the light bulb and immediately start data collection (). When data collection is complete, turn off the light bulb.
5. Determine and record the mean light reflection value and the minimum and maximum temperature readings.
 - a. Choose Statistics ► Illumination from the  Analyze menu. Record the mean light reflection value in your data table (to the nearest whole lux). The lux is the SI unit for light illumination.
 - b. Choose Statistics ► Temperature from the  Analyze menu. Record the minimum and maximum temperature readings (round to the nearest 0.1°C).
6. Click the Store Latest Data Set button () to save the first run data. Replace the white paper with the black paper. Repeat Steps 4–5 for black paper.
7. Click the Store Latest Data Set button () to save the second run data. Replace the black paper with aluminum foil. Repeat Steps 4–5 for aluminum foil.
8. If time allows, collect data for two additional colors of paper. Be sure to store the latest data set () before collecting new data.

*Figure 2*

DATA

Color	White	Black	Aluminum	_____	_____
Starting temperature (°C)					
Final temperature (°C)					
Change in temperature (°C)					
Reflection value (lux)					
Percent reflectivity	%	%	100%	%	%

PROCESSING THE DATA

1. Subtract to find the change in temperature for each color paper. Record your values in the data table.
2. Calculate the percent reflectivity of each color paper using the relationship:

$$\% \text{ Reflectivity} = \frac{\text{reflection value for paper}}{\text{reflection value for aluminum}} \times 100$$

Record your values in the data table.

QUESTIONS

1. Which color paper had the largest temperature increase?
2. Which color paper had the smallest temperature increase?
3. Solar collectors can be used to absorb the sun's radiation and change it to heat. What color would work best for solar collectors? Explain.
4. Which color paper has the highest reflectivity?
5. Which color paper has the lowest reflectivity?
6. What relationship do you see between percent reflectivity and temperature change?
7. What types of surfaces might give a planet a high reflectivity? Explain.
8. Does the planet Earth have high reflectivity? Why or why not?

EXTENSIONS

1. Design an experiment to test the reflectivity of sand, soil, water, and other materials. Perform the experiment you designed.
2. Design an experiment to test the effect of texture on reflectivity. Perform the experiment you designed.

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Science Objectives

- Students will set up a data collection experiment.
- Students will predict the shape of motion graphs.
- Students will determine and interpret the slope of v vs. t graph as acceleration.
- Students will calculate the angle slope of an incline.
- Students will consider differences in rolling and sliding acceleration.

Math Objectives

- Students will consider the implications of differently shaped graphs.
- Students will find the equation and slope of a line.
- Students will give meaning to slope and intercept, including units.
- Students will use basic trigonometry to calculate the slope angle of an incline and components of a vector.

Vocabulary

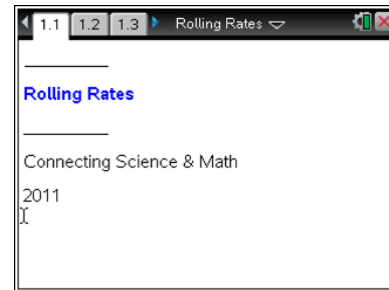
- velocity
- acceleration
- incline slope
- frictionless
- vector component

Materials & Advance Preparation

- CBR 2™
- Table that can be tilted (or long, wide board)
- Several blocks to tilt table
- Tape measure (10' or 3 m minimum)
- Ball (soccer, volley, basket, and so on)

About the Lesson

- This lesson involves collecting motion data as a ball rolls down and incline.
- As a result, students will:
 - Set up data collection equipment and technology.
 - Calculate the slope of their table from measurements.
 - Predict what the graphs of d vs. t , v vs. t , and a vs. t should look like.
 - Find the acceleration of the rolling ball after viewing each graph of collected data.
 - Use their measured table slope in a vector diagram to determine the theoretical acceleration of a frictionless sliding object, and compare this value to their measured acceleration.



TI-Nspire™ Technology Skills:

- Open a document
- Set up a data collection experiment and collect data with a CBR 2™
- Analyze data
- Use Scratchpad
- Show hidden point and drag to make a dynamic diagram

Tech Tips:

- If students accidentally create extra pages, they can be deleted in Page View. Press **ctrl** ▲, move to the unwanted page, and press **del**.

Lesson Materials:

TI-Nspire document

- Rolling_Rates.tns




TI-Nspire™ Navigator™ System

- Send the TI-Nspire document to class.
- Observe progress through Screen Capture
- Send out a Quick Poll to initiate discussion and clarify a concept.
- Use Collect from Class and Review Workspace features to check student work.
- Use Live Presenter to engage students and assess understanding of concepts.

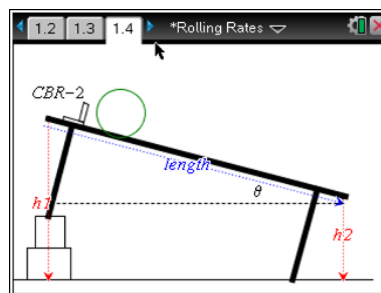
Discussion Points and Possible Answers



Tech Tip: The CBR 2 sends out a cone of ultrasound to measure distances by timing echoes. If the face of the CBR 2 is pointed too low, it might be affected by the surface.

Move to page 1.4.

Ensure the table is blocked in a stable position with room to move about. Scratchpad can be opened by pressing . The slope angle of the table is found by the formula:

$$\theta = \sin^{-1}((h_1 - h_2)/\text{length})$$



Tech Tip: To set the TI-Nspire handhelds to degree mode, press , press **Settings > Settings > General > Angle > Degree** and press .

TI-Nspire Navigator Opportunity: Quick Polls (Open Response) and Live Presenter
See Note 1 at the end of this lesson.

Move to page 1.5.

Questions are contained in the TI-Nspire document.

1. When I let the ball roll and collect data, I expect the shape of the position vs time graph to be:

Answer: quadratic curving up



Move to page 1.6.

2. I expect the shape of the velocity vs. time graph to be:

Answer: linear with positive slope

Move to page 1.7.

3. I expect the graph of acceleration vs time to be:



Answer: linear with zero slope

TI-Nspire Navigator Opportunity: *Collect from Class*

See Note 2 at the end of this lesson.

Tech Tip: If planning to collect information from students through TI-Nspire Navigator, a good tip is to have students press **ctrl** ▲ after finishing a set of questions. When Screen Capture is turned on with auto refresh, black circles will indicate which students have finished the questions.

Move to page 1.8.

Students might need to run more than one trial. To store data from a good run, just click the Store button  then click the Start button  again to perform another trial. To discard data from a poor run, just click Start and the system will overwrite the data.

Have students look at all three graphs: position, velocity and acceleration. Discuss why the graphs are not perfect. Reasons can be related to how and when they let go of the ball and the time that the ball reached the end of the table. Bumpy rolling will also affect quality of data. Acceleration is typically the most variable, thus we use the v vs t graph to get a better average value for acceleration.

Move to page 1.9.

Tech Tip: If a new DataQuest™ page does not appear, or the device does not seem to recognize the CBL 2, insert a new page and/or select **MENU > Experiment > New Experiment**.



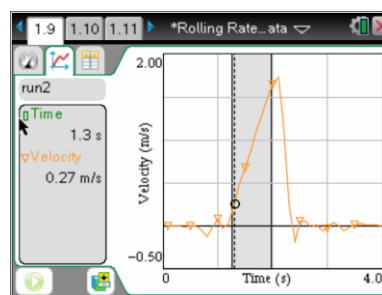
Move to page 1.10.

The three different graphs will have different ideal shapes: position should curve up, velocity should be linear with positive slope, and acceleration should be horizontal with some positive value.

In practice, the acceleration will likely be very rough as the ball may not roll smoothly nor reflect the pulse uniformly. There might also be some poor data, especially as the ball starts rolling and as it gets to the end of the table. A discussion of these issues is valuable for understanding how data and mathematics relate to the real world.

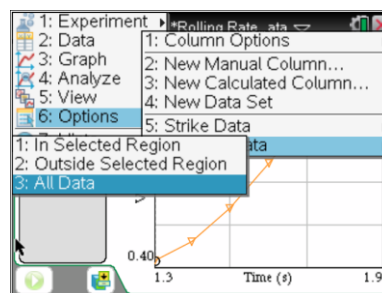
Move to page 1.11.

Selecting the data range is a little tricky at first. Practice and demo for the students.



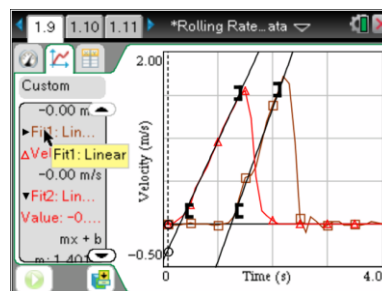
Move to page 1.12.

Struck data can be restored through the menu. It is not counted in any analysis calculations.



Move to page 1.13.

Several different trials can be analyzed. Scroll down the Graph Details box, and click on the results desired.



Move to page 1.14.

4. What are the units of the slope of a velocity vs. time graph?

Answer: m/s^2



Move to page 1.15.

5. What does the slope of a velocity vs. time graph represent?

Answer: rate change of velocity, which is acceleration

Move to page 1.16.

6. What was the acceleration of the ball rolling down the incline in your experiment?

Sample Answers: Answers will vary depending on the slope of the table. Insist on the students including units! m/s^2

Move to page 1.17.

7. When you put a line on your velocity vs. time graph, the equation of the line was in the form of: $m1(x) = mx + b$ where m and b are numbers related to your data. What does the value for b represent (based on the match of the line to the data)?

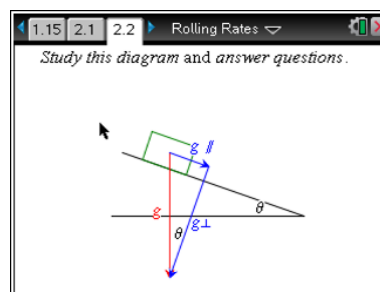
Answer: The value b , often called the y -intercept, represents the speed of the ball at time 0, or the initial speed of the ball when you started collecting data.

Teacher Tip: The initial speed might show as a negative value because the ball might have started rolling after data collection started. Use this as an example of the dangers of extrapolating blindly.

Teacher Tip: This is a good time to compare results around the class and discuss differences.

Move to page 2.2.



Remind the students that this represents a frictionless situation. Get the students involved in a discussion by asking questions like: What should happen to the block? Why? What causes the ball to roll down the slope? How are these two cases similar? What direction does gravity act? What direction do the block and the ball move?



TI-Nspire Navigator Opportunity: *Live Presenter*

See Note 3 at the end of this lesson.



Tech Tip: The diagram on Page 2.2 has a hidden point that makes the diagram dynamic. The issue of why a block will slide (or a ball will roll) faster on a steeper slope can be illustrated showing the increase of $g_{//}$ as the slope increases. To do this, select **MENU > Actions > Hide/Show**. Move the cursor over the shadowed point labeled A, then press  and . Drag point A to change the slope and watch the changes in vector $g_{//}$.

Move to page 2.3.

8. What might the vector “g” in the diagram represent?

Answer: It could represent the weight of the block, or more appropriately in this context, the acceleration due to gravity.

Move to page 2.4.

9. If we consider acceleration of the block being caused by gravity, what is the value of vector “g”?

Answer: 9.8 m/s^2 in the vertically downward direction.

Move to page 2.5.

10. Which vector component causes the block to slide down the incline?

Answer: $g_{//}$

Move to page 2.6.

11. Knowing your slope angle, what is the acceleration of a frictionless block down the incline?

Sample Answers: Answers vary depending on the slope. $g_{//} = g \sin\theta$ Insist on including units.

Move to page 2.7.

12. Compare the observed acceleration of the ball (Page 1.15) to the theoretical acceleration of a frictionless block (Page 2.6). The ball's acceleration was:



Answer: less than a frictionless block

TI-Nspire Navigator Opportunity: *Collect from Class*

See Note 4 at the end of this lesson.

Move to page 2.8.

13. How can you explain your answer to Q12 on the previous page?

Answer: A rolling ball also undergoes angular acceleration and gains rotational kinetic energy. Some of the work done by gravity goes into making the ball rotate, thus it has less translational kinetic energy or linear speed.

Here is an opportunity for students to ask or discuss a wide variety of questions about the mathematics of the motion graphs and equations and about concepts of motion.

TI-Nspire Navigator Opportunity: *Collect from Class*

See Note 5 at the end of this lesson.

Tech Tip: If planning to delete a file from the student handhelds, make sure the students close the document before you initiate the final *Collect from Class*. Otherwise the document will still be open on the handheld and an unaware student might save it on the handheld so that the document, with the answers, would be available for the next user.

Wrap Up

This activity provides students with a real situation in which to explore the meaning of motion graphs, evaluate data, compare results with other groups, and relate the situation to theory. The concepts of motion—velocity, acceleration, sliding, and rotation—are observed and discussed. Connections to mathematics can be made.

Assessment

Informal, formative assessment can occur throughout this activity. Teacher-led question and answer at various points (TI-Nspire Navigator-enabled, if available) can serve as a check on student understanding and an opportunity for students to think and formulate conceptual answers. Questions in the TI-Nspire document can be reviewed (or collected



with TI-Nspire Navigator, placed into student Portfolio, and de-briefed as a class in Slide Show).

TI-Nspire Navigator

Note 1

Question 1, Quick Polls (Open Response) and Live Presenter: If you have TI-Nspire Navigator, send out an Open Response Quick Poll and ask, “Which trigonometric function is used to find the slope angle of the table?” Also, you can make a student a Live Presenter in Screen Capture by selecting that student’s screen capture image and clicking on Make Presenter. Ask the rest of the students to coach the Presenter to answer your questions by clicking or moving the cursor so everyone can see what you are asking about. For example: “Click on the hypotenuse of the triangle we will use to determine the slope angle of the table.”

Note 2

Question 3, Collect from Class: This might be a good time to review student answers by using Collect from Class, Save to Portfolio, and Open in Class Analysis. Use the Slide Show to discuss any student misconceptions. You can review, re-teach, or proceed based on the results. Without TI-Nspire Navigator, it is still a good time to discuss the expected shapes of the graphs and the reasons why.

Note 3

Page 2.2, Live Presenter: This is another opportunity to engage the class and check understanding if you make a student a Live Presenter in Screen Capture. Ask the rest of the students to coach the Presenter to answer your questions by clicking or moving the cursor so everyone can see what you are asking about. For example: “Which vector is the cause of the block sliding down the slope?”

Note 4

Question 12, Collect from Class: This is another good time to review student answers from the TI-Nspire document by using the TI-Nspire Navigator Review Workspace features. Without TI-Nspire Navigator, it is still a good time to discuss the expected shapes of the graphs and the reasons why.

Note 5

Page 2.9, Collect from Class: You might want to do a final Collect from Class and delete the TI-Nspire document by checking the “Delete from handheld after collecting” box. This will ensure that the next users will have a fresh document when you send it out next time.



However, you also might want to leave the document so that students can do further work on it at a later time.

This activity promotes the following **Common Core State Standards Mathematical Practices:**

1. Make sense of problems and persevere in solving them
2. Reason abstractly and quantitatively
3. Construct viable arguments and critique the reasoning of others
4. Model with mathematics
5. Use appropriate tools strategically

And the following **Constructivist 5-E's Processes:**

- Engagement
- Exploration
- Explanation
- Elaboration

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Teacher Software

TI PROFESSIONAL DEVELOPMENT

Activity Overview:

In this activity, you will explore basic features of the TI-Nspire™ Teacher Software. You will explore the **Welcome Screen**, add pages with *Calculator* and *Graphs* applications, and explore the menus and submenus of each application. You will explore the five tabs within the **Documents Toolbox**, as well as the options available in the **Documents** toolbar and the **Status** bar.

Materials

- TI-Nspire™ Teacher Software

Step 1:

Open the TI-Nspire™ Teacher Software. The **Welcome Screen** displays an icon for each of the seven applications: *Calculator*, *Graphs*, *Geometry*, *Lists & Spreadsheet*, *Data & Statistics*, *Notes*, *Vernier DataQuest™*, and *Question*. To see a brief description of each application, hover the cursor over each icon.

The **Welcome Screen** also allows you to view content, manage handhelds, transfer documents, and open documents. To see a brief description of each option, hover the cursor over each icon on the right. To view the **Welcome Screen** at any time, go to **Help > Welcome Screen**

To create a new document with a *Calculator* application as the first page, click .




Teacher Software


TI PROFESSIONAL DEVELOPMENT

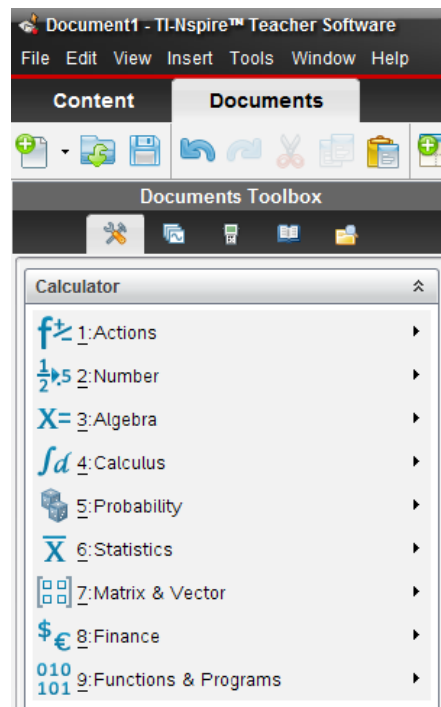
Step 2:

The *Calculator* application allows you to enter and evaluate mathematical expressions as well as create functions and programs.


In most cases, each application has a unique menu of commands and tools. To view the *Calculator* menu, go to the **Documents Toolbox** and select the  **Document Tools** tab.

Each item in the *Calculator* menu has a submenu. Explore the various menus and submenus by entering and evaluating your own expressions.

Note: To access the *Calculator* menu on the handheld, press .

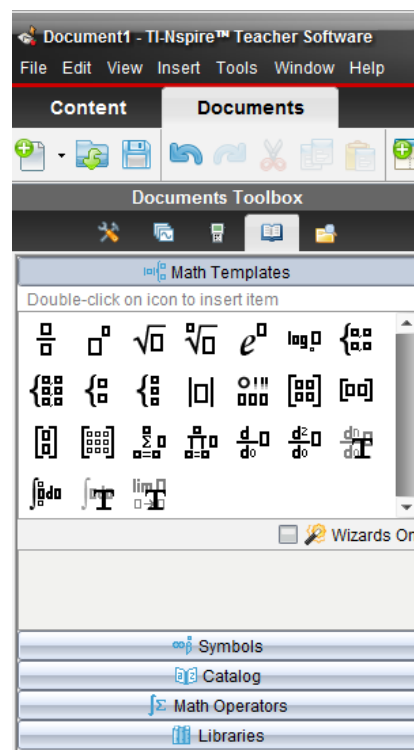


Step 3:

The  **Utilities** tab contains **Math Templates**, **Symbols**, **Catalog**, **Math Operators**, and **Libraries** panes. Only one pane is displayed at a time, and the **Math Templates** pane is the default pane. Explore each of the other panes by clicking them.

To insert a **Math Template** into the *Calculator* application, double-click it. Explore various **Math Templates** by evaluating your own expressions involving fractions, exponents, square roots, logarithms, and absolute value expressions.


Note: When evaluating expressions, the *Calculator* application displays rational expressions by default. To display a decimal approximation when evaluating an expression, press **CTRL + Enter**.





Teacher Software

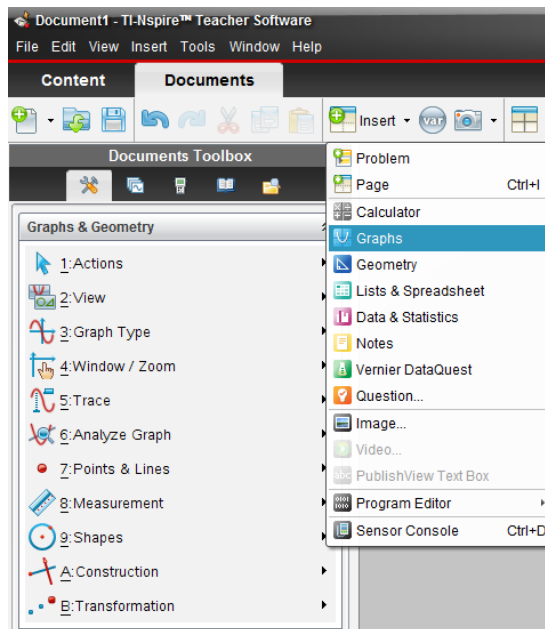
TI PROFESSIONAL DEVELOPMENT

Step 4:

The  **Insert** menu allows you to insert problems and pages, along with each of the eight applications. A problem can contain multiple pages, and variables that are linked within a problem are linked across pages.


Insert a *Graphs* application by selecting  **Insert >  Graphs**.

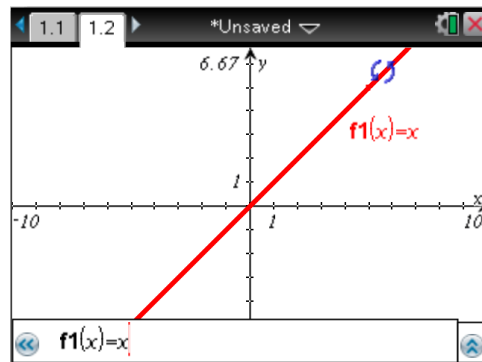
The *Graphs* application allows you to graph and analyze relations and functions. Explore the various menus and submenus available in the *Graphs* application.




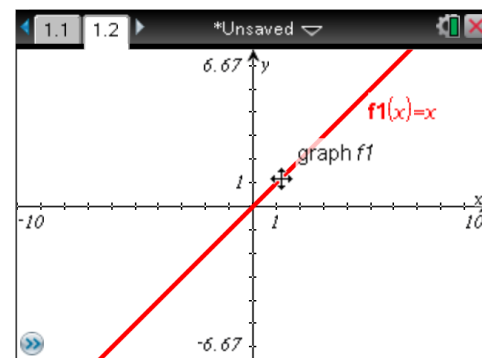
Step 5:

Graph the function $f(x) = x$ by typing x into the function entry line and pressing **Enter**.

Rotate the line by hovering the cursor over the upper-right corner of the graph. When the rotational cursor  appears, rotate the line by clicking and dragging it.



Translate the line by hovering the cursor over the line near the origin. When the translational cursor  appears, translate the line up and down by clicking and dragging it.




Teacher Software

TI PROFESSIONAL DEVELOPMENT


Step 6:

Since you have inserted a *Calculator* application and a *Graphs* application, your TI-Nspire™ document now has two pages. The **Page Sorter** view allows you to view thumbnail images of all pages in the current TI-Nspire™ document.

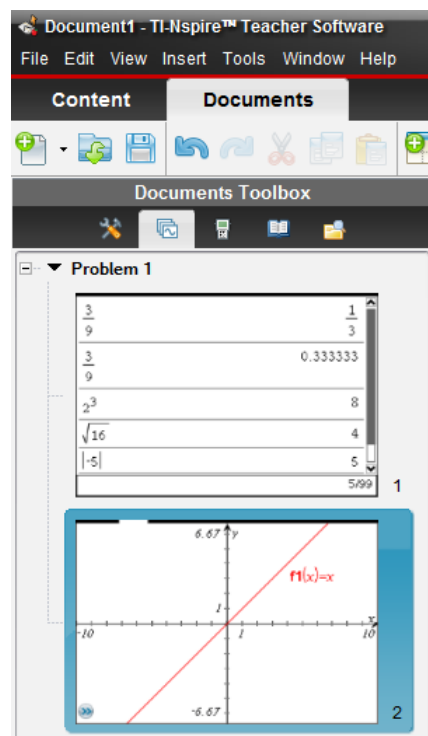
Access the **Page Sorter** by going to the **Documents**

Toolbox and clicking the  **Page Sorter** tab. Pages can be rearranged by grabbing and moving them. Right-clicking allows for pages to be cut, copied, and pasted.

Note: To access **Page Sorter** in the handheld, press



ctrl . To right-click in the handheld, press

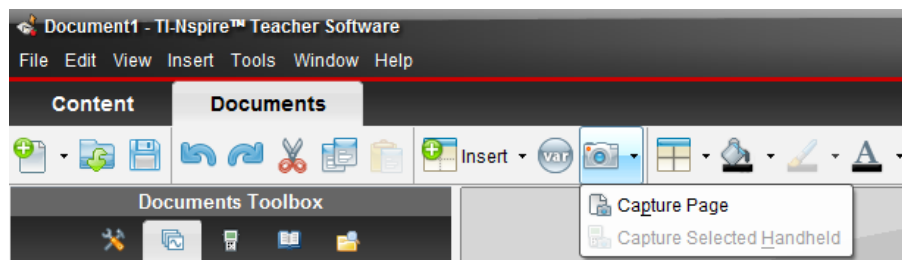
ctrl **menu**.



Step 7:

The **Documents** toolbar allows you to create, open, and save a TI-Nspire™ document. Commands such as **Undo**, **Redo**, **Cut**, **Copy**, and **Paste** are also available. Explore these options by hovering the cursor over each icon. Pages, problems, and applications can be inserted and variables can be stored.



Take a **Screen Capture** of the current page by selecting  **Take Screen Capture > Capture Page**. This **Screen Capture** can be saved as an image. Page layouts allow multiple applications to appear on one screen. Explore the various page layouts that are available by clicking  **Page Layout**. Fill color, line color, and text color can also be changed.

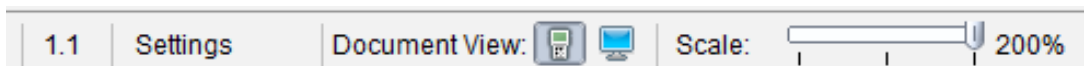


Teacher Software


TI PROFESSIONAL DEVELOPMENT

Step 8:


The **Status Bar** allows the user to access settings, change the Document View from Handheld mode to Computer mode, and adjust the scale of the screen. Change the Document View to Computer mode by clicking  **Computer mode**. Change the Document View back to Computer mode by clicking  **Handheld mode**.

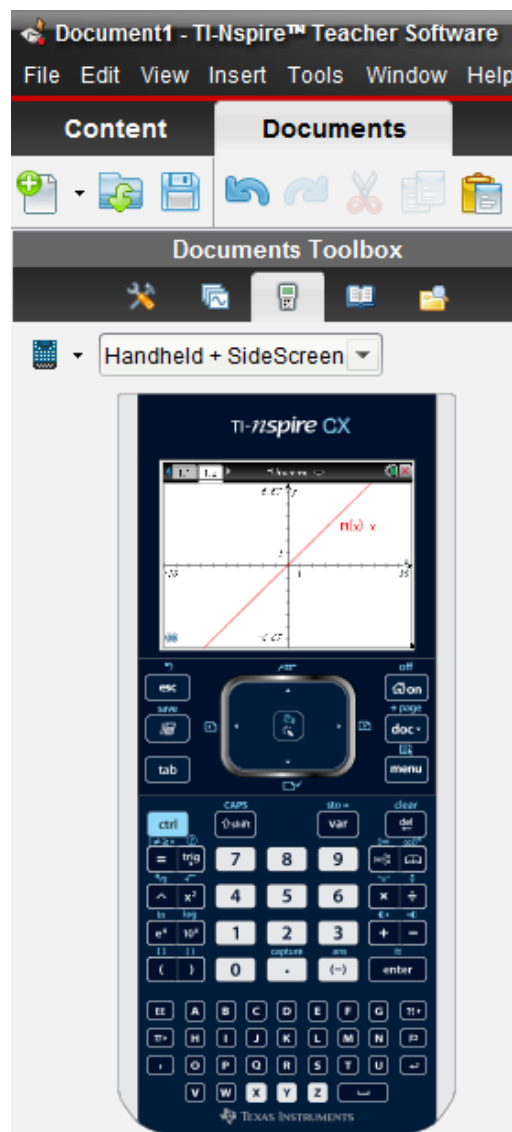


Step 9:

To access the **TI-SmartView** emulator, go to the **Documents Toolbox** and select the  **TI-SmartView** tab.

TI-SmartView has three available views: **Handheld** only, **Keypad + SideScreen**, and **Handheld + Side Screen**. Explore each of these views.

TI-SmartView has three available keypads: TI-Nspire CX™, TI-Nspire™ with Touchpad, and TI-Nspire™ with Clickpad. Each keypad has three available views: Normal, High Contrast, and Outline. Click the  **Keypad** menu and explore each keypad and view.



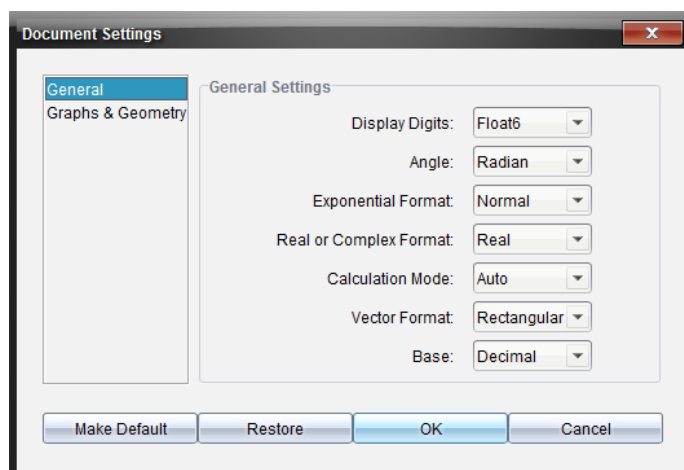
Teacher Software

TI PROFESSIONAL DEVELOPMENT

Step 10:


View the **Document Settings** by going to **File > Document Settings**. The **Document Settings** can also be viewed by going to the **Status Bar** and clicking **Settings**.

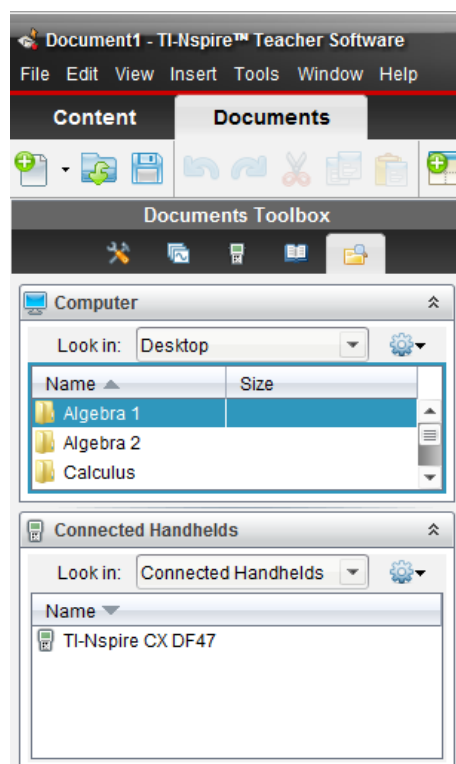
General settings apply to the entire TI-Nspire™ document, while **Graphs & Geometry** settings apply only to the *Graphs* and *Geometry* applications.



Note: To move across fields in the **Document Settings** window, press **tab**. To change the setting in a given field, press **▼**, select the desired setting, and press **enter**. To exit the window, press **tab** until **OK** is highlighted and press **enter**.

Step 11:

The **Content Explorer** allows you to access local content on your computer and manage content on connected handhelds. Explore the **Content Explorer** by clicking the  **Content Explorer** tab.





Activity Overview:

In this activity, you will explore resources available at education.ti.com, learn about Science Nspired, and view sample activities for Biology, Chemistry, and Physics classrooms.

Materials

- Computer with Internet connection
-

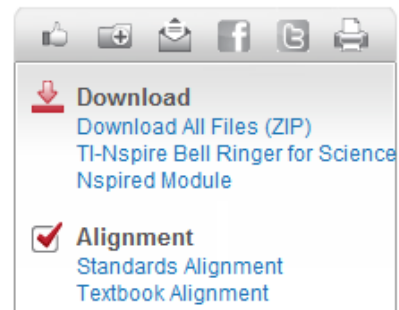
Step 1: Go to education.ti.com > Downloads & Activities > Science Nspired. This page can also be accessed directly at www.sciencenspired.com. Click the “About Science Nspired” channel on the left and read about the different activity types.

Step 2: Click the “Sneak Peek” channel on the left. Click the Biology, Chemistry, or Physics tab. The sample lesson for each subject contains a Lesson Guide, Bell Ringer Activity, Exploration, and Data Collection Lab. Explore each of these components.

Step 3: Depending upon which component you choose, you will observe a variety of “Download” or “Alignment” links on the right. The .zip folder contains all activity files, and individual files can be downloaded by clicking each respective link.

Icons above the **Downloads** section allow you to recommend, save, email, and print an activity. Links to Facebook and Twitter are also available. The **Downloads** section contains links to activity files. Links for **Standards Alignment**, **Textbook Alignment**, and relevant **Tech Tip Videos** are also available.

If Alignment links appear, explore the “Standards Alignment” and “Textbook Alignment.”



Step 4: Additionally, go to education.ti.com. Explore each of the following pages by clicking the appropriate tab:

- Products
- Downloads & Activities
- In Your Subject
- Professional Development
- Funding & Research
- Student Zone

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Evaporation and Intermolecular Attractions

In this experiment, Temperature Probes are placed in various liquids. Evaporation occurs when the probe is removed from the liquid's container. This evaporation is an endothermic process that results in a temperature decrease. The magnitude of a temperature decrease is, like viscosity and boiling temperature, related to the strength of intermolecular forces of attraction. In this experiment, you will study temperature changes caused by the evaporation of several liquids and relate the temperature changes to the strength of intermolecular forces of attraction. You will use the results to predict, and then measure, the temperature change for several other liquids.

You will encounter two types of organic compounds in this experiment—alkanes and alcohols. The two alkanes are pentane, C_5H_{12} , and hexane, C_6H_{14} . In addition to carbon and hydrogen atoms, alcohols also contain the $-OH$ functional group. Methanol, CH_3OH , and ethanol, C_2H_5OH , are two of the alcohols that we will use in this experiment. You will examine the molecular structure of alkanes and alcohols for the presence and relative strength of two intermolecular forces—hydrogen bonding and dispersion forces.

OBJECTIVES

In this experiment, you will

- Study temperature changes caused by the evaporation of several liquids.
- Relate the temperature changes to the strength of intermolecular forces of attraction.

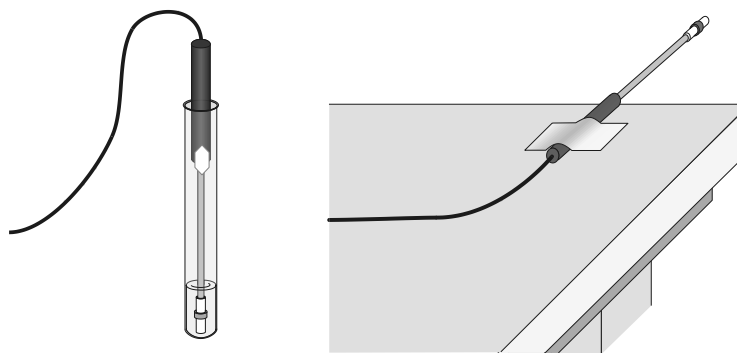


Figure 1

MATERIALS

TI-Nspire handheld **or**
computer and TI-Nspire software
data-collection interface
2 Temperature Probes
6 pieces of filter paper (2.5 cm × 2.5 cm)
2 small rubber bands
masking tape



methanol (methyl alcohol)
ethanol (ethyl alcohol)
1-propanol
1-butanol
n-pentane
n-hexane

DataQuest 20**PRE-LAB QUESTIONS**

Prior to doing the experiment, complete the Pre-Lab table. The name and formula are given for each compound. Draw a structural formula for a molecule of each compound. Then determine the molecular weight of each of the molecules. Dispersion forces exist between any two molecules, and generally increase as the molecular weight of the molecule increases. Next, examine each molecule for the presence of hydrogen bonding. Before hydrogen bonding can occur, a hydrogen atom must be bonded directly to an N, O, or F atom within the molecule. Tell whether or not each molecule has hydrogen-bonding capability.

Substance	Formula	Structural formulas	Molecular weight	Hydrogen bond (yes or no)
ethanol	C ₂ H ₅ OH			
1-propanol	C ₃ H ₇ OH			
1-butanol	C ₄ H ₉ OH			
n-pentane	C ₅ H ₁₂			
methanol	CH ₃ OH			
n-hexane	C ₆ H ₁₄			

PROCEDURE

1. Obtain and wear goggles! **CAUTION:** The compounds used in this experiment are flammable and poisonous. Avoid inhaling their vapors. Avoid contacting them with your skin or clothing. Be sure there are no open flames in the lab during this experiment. Notify your teacher immediately if an accident occurs.
2. Connect the Temperature Probes to the data-collection interface. Connect the interface to the TI-Nspire handheld or computer.
3. Choose New Experiment from the  Experiment menu. Choose Collection Setup from the  Experiment menu. Enter **240** as the experiment duration in seconds (4 minutes). The number of points collected should be 481. Select OK.
4. Wrap Probe 1 and Probe 2 with square pieces of filter paper secured by small rubber bands as shown in Figure 1. Roll the filter paper around the probe tip in the shape of a cylinder. **Hint:** First slip the rubber band on the probe, wrap the paper around the probe, and then finally slip the rubber band over the paper. The paper should be even with the probe end.
5. Stand Probe 1 in the ethanol container and Probe 2 in the 1-propanol container. Make sure the containers do not tip over.
6. Prepare 2 pieces of masking tape, each about 10 cm long, to be used to tape the probes in position during Step 7.

Evaporation and Intermolecular Attractions



7. After the probes have been in the liquids for at least 30 seconds, start data collection (▶). A live graph of temperature vs. time for both Probe 1 and Probe 2 is being plotted on the screen. Live readings are also displayed. Monitor the temperature for 15 seconds to establish the initial temperature of each liquid. Then simultaneously remove the probes from the liquids and tape them so the probe tips extend 5 cm over the edge of the table top as shown in Figure 1. **Note:** avoid moving near the sensors as air movement can affect your results.
8. Data collection will stop after 240 seconds. Click any data point and use ▶ and ◀ to examine the data pairs on the displayed graph. Based on your data, determine the maximum temperature, t_1 , and minimum temperature, t_2 for both probes. Record t_1 and t_2 for each probe in the data table.
9. For each liquid, subtract the minimum temperature from the maximum temperature to determine Δt , the temperature change during evaporation.
10. Based on the Δt values you obtained for these two substances, plus information in the Pre-Lab exercise, *predict* the size of the Δt value for 1-butanol. Compare its hydrogen-bonding capability and molecular weight to those of ethanol and 1-propanol. Record your predicted Δt , then explain how you arrived at this answer in the space provided. Do the same for n-pentane. It is not important that you predict the exact Δt value; simply estimate a logical value that is higher, lower, or between the previous Δt values.
11. Test your prediction in Step 10. Click on the Store Latest Data Set button (📁). Repeat Steps 5–9 using 1-butanol with Probe 1 and n-pentane with Probe 2.
12. Based on the Δt values you have obtained for all four substances, plus information in the Pre-Lab exercise, predict the Δt values for methanol and n-hexane. Compare the hydrogen-bonding capability and molecular weight of methanol and n-hexane to those of the previous four liquids. Record your predicted Δt , then explain how you arrived at this answer in the space provided.
13. Test your prediction in Step 12. Click on the Store Latest Data Set button (📁). Repeat Steps 5–9, using methanol with Probe 1 and n-hexane with Probe 2.

DataQuest 20**DATA**

Substance	t_1 (°C)	t_2 (°C)	$\Delta t (t_1 - t_2)$ (°C)	Predicted Δt (°C)	Explanation
ethanol					
1-propanol					
1-butanol					
n-pentane					
methanol					
n-hexane					

PROCESSING THE DATA

Plot a graph of Δt values of the four alcohols versus their respective molecular weights. Plot molecular weight on the horizontal axis and Δt on the vertical axis.

- Insert a new problem in the document, then Insert a new DataQuest App into problem 2. Click on the Table View tab () to view the Table.
- Double click on the X column to access the column options. Enter **Molecular Weight** for the Name, **Weight** for the short name, and **amu** for the units. Change the Display Precision to 0 decimal places. Select OK.
- Double click on the Y column to access the column options. Enter **ΔT** for the column name. Enter **°C** as the units. Select OK.
- Using the data recorded in the tables, enter the values in the DataQuest Table.
- Click on the Graph View tab () to view the graph.

QUESTIONS

- Two of the liquids, n-pentane and 1-butanol, had nearly the same molecular weights, but significantly different Δt values. Explain the difference in Δt values of these substances, based on their intermolecular forces.
- Which of the alcohols studied has the strongest intermolecular forces of attraction? The weakest intermolecular forces? Explain using the results of this experiment.
- Which of the alkanes studied has the stronger intermolecular forces of attraction? The weaker intermolecular forces? Explain using the results of this experiment.

TEACHER INFORMATION

Evaporation and Intermolecular Attractions

1. Editable Microsoft Word versions of the student pages and pre-configured TI-Nspire files can be found on the CD that accompanies this book. See *Appendix A* for more information.
2. This experiment, as written, is not intended for use with Easy or Go! products since data from two sensors must be collected at the same time. A single, multi-channel interface is preferred.
3. If you are using Easy or Go! products, or if you have a limited number of temperature probes, you can do this experiment with only a single sensor, testing a single alcohol with each run. Similarly, you can use more than two temperature probes if you have a multi-channel interface.
4. We recommend wrapping the probes with paper as described in the procedure. Wrapped probes provide more uniform liquid amounts, and generally greater Δt values, than bare probes. Chromatography paper, filter paper, and various other paper types work well.
5. Snug-fitting rubber bands can be made by cutting short sections from a small rubber hose. Surgical tubing works well. Orthodontist's rubber bands are also a good size.
6. Other liquids can be substituted. Although it has a somewhat larger Δt , 2-propanol can be substituted for 1-propanol. Some petroleum ethers have a high percentage of hexane and can be used in its place. Other alkanes of relatively high purity, such as n-heptane or n-octane can be used. Water, with a Δt value of about 5°C , emphasizes the effect of hydrogen bonding on a low-molecular weight liquid. However, students might have difficulty comparing its hydrogen bonding capability with that of the alcohols used.
7. Sets of the liquids can be supplied in 13×100 mm test tubes stationed in stable test-tube racks. This method uses very small amounts of the liquids. Alternatively, the liquids can be supplied in sets of small bottles kept for future use. Adjust the level of the liquids in the containers so it will be above the top edge of the filter paper.
8. Because several of these liquids are highly volatile, keep the room well-ventilated. Cap the test tubes or bottles at times when the experiment is not being performed. The experiment should not be performed near any open flames.
9. Other properties, besides Δt values, vary with molecular size and consequent size of intermolecular forces of attraction. Viscosity increases noticeably from methanol through 1-butanol. The boiling temperatures of methanol, ethanol, 1-propanol, and 1-butanol are 65°C , 78°C , 97°C , and 117°C , respectively.
10. **HAZARD ALERTS:**
n-Hexane: Flammable liquid; dangerous fire risk; may be irritating to respiratory tract.
Hazard Code: B—Hazardous.

Methanol: Flammable; dangerous fire risk; toxic by ingestion (ingestion may cause blindness). Hazard Code: B—Hazardous.

Experiment 20

Ethanol: Dangerous fire risk; flammable; addition of denaturant makes the product poisonous—it cannot be made non-poisonous; store in a dedicated flammables cabinet or safety cans. If a flammables cabinet or safety cans are not available, store in a Flinn *Saf-Stor*[®] Can. Hazard Code: C—Somewhat hazardous.

n-Pentane: Flammable liquid; narcotic in high concentrations. Hazard Code: B—Hazardous.

1-Propanol: Flammable liquid; dangerous fire risk; harmful to eyes and respiratory tract. Hazard Code: B—Hazardous.

1-Butanol: Moderate fire risk; toxic on prolonged inhalation; eye irritant; absorbed by skin. Hazard Code: B—Hazardous.

The hazard information reference is: Flinn Scientific, Inc., *Chemical & Biological Catalog Reference Manual*, 1-800-452-1261, www.flinnsci.com. See *Appendix F* for more information.

11. Piping which can be purchased at a yard goods or sewing store can serve as an appropriate sleeve for the temperature probe. You have to cut it pieces and remove the "rope".

ANSWERS TO PRE-LAB QUESTIONS

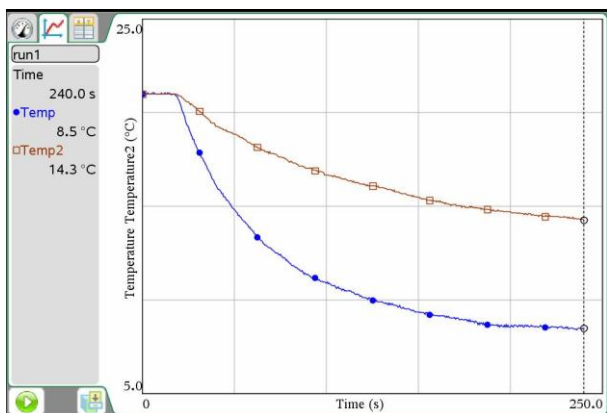
Substance	Formula	Structural Formulas	Molecular Weight	Hydrogen Bond (Yes or No)
ethanol	C ₂ H ₅ OH	<pre> H H H-C-C-O-H H H </pre>	46	yes
1-propanol	C ₃ H ₇ OH	<pre> H H H H-C-C-C-O-H H H H </pre>	60	yes
1-butanol	C ₄ H ₉ OH	<pre> H H H H H-C-C-C-C-O-H H H H H </pre>	74	yes
n-pentane	C ₅ H ₁₂	<pre> H H H H H H-C-C-C-C-C-H H H H H H </pre>	72	no
methanol	CH ₃ OH	<pre> H H-C-O-H H </pre>	32	yes

n-hexane	C_6H_{14}	<pre> H H H H H H H-C-C-C-C-C-C-H H H H H H H </pre>	86	no
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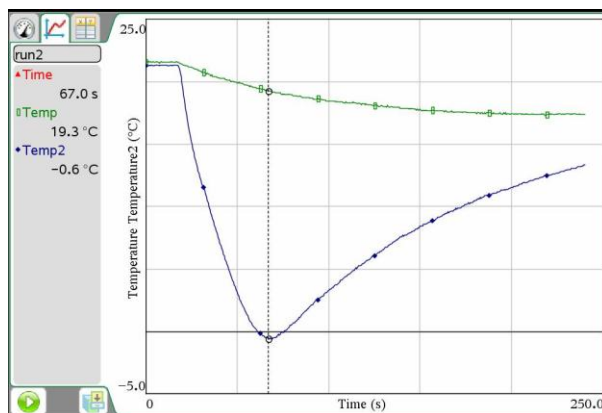
SAMPLE RESULTS

Substance	t_1 (°C)	t_2 (°C)	Δt ($t_1 - t_2$) (°C)
ethanol	21.0	8.5	12.5
1-propanol	21.1	14.3	6.8
1-butanol	21.5	17.4	4.1
n-pentane	21.3	-0.6	21.9
Methanol	21.0	1.3	19.7
n-hexane	22.8	6.7	16.1

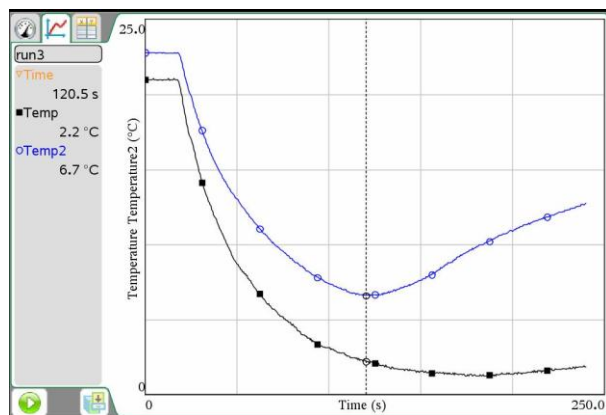
Predicted Δt (°C)	Explanation
varies ($< 4.9^\circ C$)	It has a higher molecular wt. than 1-propanol (both have H-bonds).
varies ($> 8.3^\circ C$)	It has a higher molecular wt. than either, but no H-bonding.
varies ($> 8.3^\circ C$)	It has a lower molecular wt. than ethanol (both have H-bonds).
varies ($< 16.1^\circ C$)	It has a higher molecular wt. than n-pentane; also no H-bonding.



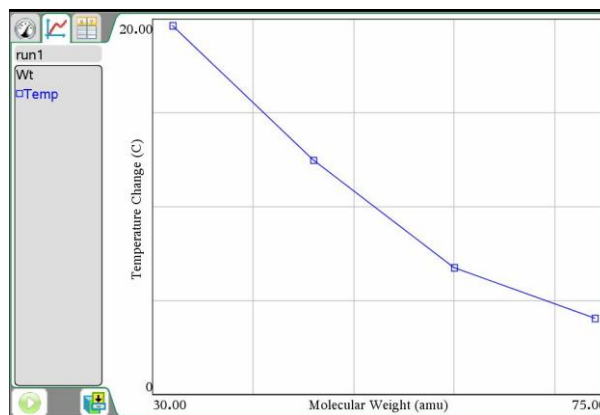
Evaporation of ethanol (●)
and 1-propanol (□).



Evaporation of 1-butanol (□)
and n-pentane (◆)

Experiment 20

Evaporation of methanol (■) and n-hexane (○).



Temperature change vs. alcohol molecular weight.

ANSWERS TO QUESTIONS

1. Even though n-pentane and 1-butanol have molecular weights of 72 and 74, respectively, 1-butanol has a much smaller Δt due to the presence of hydrogen bonding between its molecules. This results in a stronger attraction, and a slower rate of evaporation.
2. The 1-butanol has the strongest attractions between its molecules. Methanol has the weakest attractions. The 1-butanol has the largest molecules and resulting strongest dispersion forces. This gives it the lowest evaporation rate and the smallest Δt .
3. The n-hexane has the stronger attractions between its molecules. The n-pentane has the weaker attractions. The n-hexane has the larger molecules and the resulting stronger dispersion forces. This gives it a lower evaporation rate and the smallest Δt .



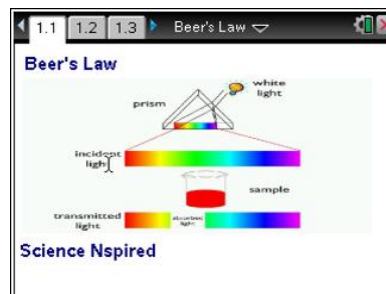
Beer's Law Student Activity

Name _____

Class _____

Open the TI-Nspire document *Beers Law.tns*.

In this activity, you will determine the concentration of an unknown nickel (II) sulfate solution using a Colorimeter.

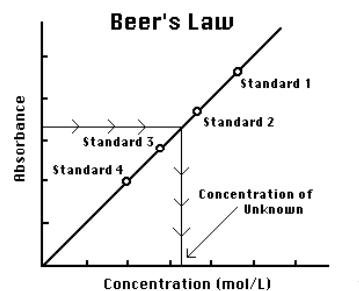


As demonstrated by the illustration of a Colorimeter on Page 1.1, red light from the LED light source will pass through the solution and strike a photocell. The NiSO_4 solution used in this experiment has a deep green color. A higher concentration of the colored solution absorbs more light (and transmits less) than a solution of lower concentration. The Colorimeter monitors the light received by the photocell as either a percent absorbance or a percent transmittance value.

In this lab, you will prepare five nickel sulfate solutions of known concentration (standard solutions). Each is transferred to a small, rectangular cuvette that is placed into the actual Colorimeter. The amount of light that penetrates the solution and strikes the photocell is used to compute the absorbance of each solution.

When a graph of absorbance vs. concentration is plotted for the standard solutions, a direct relationship should result, as shown in the figure to the right. The direct relationship between absorbance and concentration for a solution is known as **Beer's Law**.

The concentration of an unknown NiSO_4 solution is then determined by measuring its absorbance with the Colorimeter. By locating the absorbance of the unknown on the vertical axis of the graph, the corresponding concentration can be found on the horizontal axis (follow the arrows in the figure to the right). The concentration of the unknown can also be found using the slope of the Beer's Law curve.



¹ © Vernier Software & Technology.



Move to pages 1.4 through 1.7.

Press **ctrl** **▶** and **ctrl** **◀** to
navigate through the lesson.

Answer the following questions on your handheld.

1. The wavelength of light used by the colorimeter should be _____ by the colored solution.
2. The NiSO_4 solution used in the experiment has a deep _____ color.
3. For this experiment, the LED of the colorimeter needs to be set to _____.
4. A higher concentration of solution absorbs _____ light.
5. The relationship between absorbance and concentration is _____.
6. The linear relationship between absorbance and concentration is called _____ Law.
7. The concentration of the unknown can be determined by using the _____ of the regression line on the graph.

Lab Set-Up and Procedures

8. Obtain and wear goggles.
9. **CAUTION:** Be careful not to ingest any nickel(II) sulfate solution or spill any on your skin.
9. Label five clean, dry test tubes with the numbers 1–5.
10. From a burette, deliver 2, 4, 6, 8, & 10 mL of 0.40 M nickel(II) sulfate solution into Test Tubes 1–5, respectively.
11. From the second burette, deliver 8, 6, 4, 2, and 0 mL of distilled water into Test Tubes 1–5, respectively.
12. Thoroughly mix each solution with a stirring rod.
13. Clean and dry the stirring rod between stirrings. Concentrations for the trials are: 0.08 M, 0.16M, 0.24M, 0.32M, and 0.40M, respectively.
14. Prepare a blank by filling an empty cuvette 3/4 full with distilled water.

Note: To correctly use a cuvette, remember:

- All cuvettes should be wiped clean and dried on the outside with a tissue.
- Handle cuvettes only by the top edge of the ribbed sides.
- All solutions should be free of bubbles.
- Always position the cuvette so the light passes through the clear sides.



Move to page 2.2.

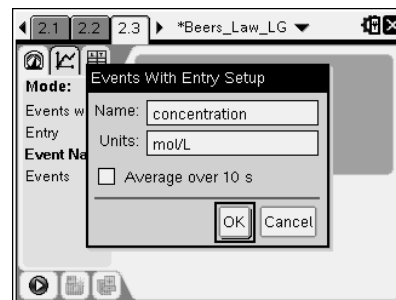
The image shows the correct set-up for the TI-Nspire, colorimeter, and solutions.



8. Following the image shown on Page 2.2, connect the Colorimeter to the TI-Nspire Lab Cradle™, and connect the interface to the TI-Nspire™ handheld.
9. Calibrate the Colorimeter by placing the blank in the cuvette slot of the Colorimeter and closing the lid.
 - Press the < or > buttons on the Colorimeter to set the wavelength to 635 nm (Red).
 - Then calibrate by pressing the **CAL** button on the Colorimeter. When the LED stops flashing, the calibration is complete.



Move to page 2.3.

10. To set up the data-collection mode and change the scale options for the graph, select **MENU > Experiment > New Experiment** to reset the device.
 - Select **MENU > Experiment > Collection Mode > Events with Entry**.
 - Enter **Concentration** as the Name and **mol/L** as the Units. Click **OK**.
 - Select **MENU > Options > Autoscale Settings**.






Change the **After Collection** setting to **Autoscale from Zero**, and click **OK**.

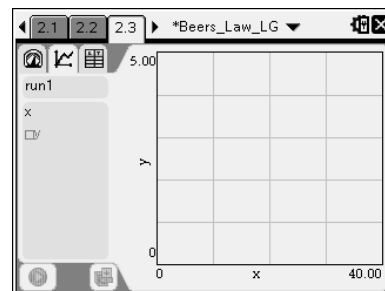
You are now ready to collect data for the five standard solutions.

11. Start data collection by pressing .
12. Empty the water from the cuvette.
13. Using the solution in **Test Tube 1 (0.08)**, rinse the cuvette twice with ~1 mL amounts and then fill it 3/4 full.
14. Wipe the outside with a tissue, place it in the Colorimeter, and close the lid.
15. When the value displayed on the screen has stabilized, click the **Keep**  button, enter 0.080 as the concentration in mol/L, and click **OK**.
 - The absorbance and concentration values have now been saved for the first solution.
16. Discard the cuvette contents as directed by your instructor.
17. Using the solution in **Test Tube 2 (0.16)**, repeat Steps 13 – 16.
18. Repeat the procedure for **Test Tube 3** (0.24 M concentration) and **Test Tube 4** (0.32 M concentration), and **Test Tube 5** (0.40 M concentration).



Note: Do not test the unknown solution yet.

19. Stop data collection by pressing .
20. Click **Table View**  to display the data table on the handheld.
21. Record the absorbance and concentration data values in your data table at the end of this worksheet as well.
22. Display a graph of absorbance vs. concentration with a linear regression curve by clicking **Graph View** .
 - Select **MENU > Analyze > Curve Fit > Linear**.
 - The linear-regression statistics are displayed in the form:
 $y = mx + b$ where x is concentration, y is absorbance, m is the slope, and b is the y -intercept.
23. Sketch the graph you obtained.



Note: One indicator of the quality of your data is the size of b . It is a very small value if the regression line passes through or near the origin. The correlation coefficient, r , indicates how closely the data points match up with (or fit) the regression line. A value of 1.00 indicates a nearly perfect fit.


The graph should indicate a direct relationship between absorbance and concentration, the relationship known as **Beer's Law**. The regression line should closely fit the five data points and pass through (or near) the origin of the graph.

Now you are ready to determine the absorbance value of the unknown NiSO_4 solution.

24. Select **MENU > View > Meter**.
25. Obtain about 5 mL of the unknown NiSO_4 in another clean, dry, test tube. Record the number of the unknown in your data table at the end of this worksheet.
26. Rinse the cuvette twice with the unknown solution and fill it about 3/4 full. Wipe the cuvette dry, and place in the Colorimeter.
27. Monitor the absorbance value. When this value has stabilized, record it in your data table at the end of this worksheet.
28. Discard the solutions as directed by your teacher.


Move to page 2.4.

Perform your calculations to determine the concentration of the unknown NiSO_4 solution by interpolating along the regression line to convert the absorbance value of the unknown to concentration.

29. Click **Graph View** , select **MENU > Analyze > Interpolate**, and select any point on the regression curve.
30. Use **▶** and **◀** to find the absorbance value that is closest to the absorbance reading you obtained in Step 27. The corresponding NiSO_4 concentration, in mol/L, will be displayed.
31. Record the concentration value in your data table at the end of this worksheet.

Move to pages 3.1 through 3.4.

32. As the concentration of the NiSO_4 solution increased, the absorbance _____.
33. The closer the value of _____ was to zero, the better your data.
34. The closer the value of r is to _____, the better your data.
35. To find the concentration of the unknown, you need to _____ your graph.

Data Table

Trial	Concentration (mol/L)	Absorbance
1	0.08	
2	0.16	
3	0.24	
4	0.32	
5	0.40	
6	Unknown number _____	
Concentration of unknown		_____ mol/L

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Science Objectives

- Students will make a serial dilution of a NiSO_4 standard solution.
- Students will use a Colorimeter to measure the absorbance value of each standard solution.
- Students will find the relationship between absorbance and concentration of a solution.
- Students will use the results of this experiment to determine the unknown concentration of another NiSO_4 solution.

Vocabulary

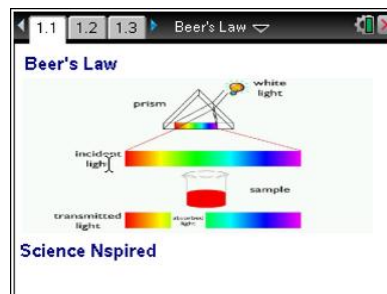
- absorbance
- Colorimeter
- correlation coefficient
- slope
- transmittance
- y-intercept

About the Lesson

- This lesson involves absorbance data for solutions of various concentration.
- As a result, students will:
 - Prepare five (5) NiSO_4 standard solutions.
 - Use a Colorimeter to measure the absorbance value of each standard solution.
 - Find the relationship between absorbance and concentration of a solution.
 - Use the results of this experiment to determine the unknown concentration of another NiSO_4 solution.

TI-Nspire™ Navigator™ System



- Send *Beers_Law.tns* file to students.
- Use Screen Capture to monitor student progress.
- Collect and grade *Beers_Law.tns* file.



TI-Nspire™ Technology Skills:

- Download a TI-Nspire™ document
- Open a document
- Move between pages
- Use DataQuest App

Tech Tips:

- Make sure the font size on your TI-Nspire handhelds is set to Medium.
- You start and stop data collection by pressing  and .

Lesson Files:

Student Activity
Beers_Law_Student.pdf
Beers_Law_Student.doc

TI-Nspire document
Beers_Law.tns

Visit www.sciencenspired.com for lesson updates and tech tip videos.

**Activity Materials**

- TI-Nspire™ Technology
- TI Lab Cradle™ or EasyLink™
- Vernier® Colorimeter
- Two burettes
- Double burette clamp
- Ring stand
- Wash bottle & distilled water
- One cuvette
- Test tube rack & five (5) 20X150 mm test tubes
- Stirring rod
- KimWipes or tissues (preferably lint-free)
- 5 mL of “NiSO₄” unknown solution (for example-55 mL of “stock” solution and 45 mL of water-0.22 M)
- 8-9 drops of green food coloring per liter of water to mimic 0.40 M NiSO₄. (Nickel is a carcinogen, so the green food coloring is an excellent substitute.) Check the absorbance of this stock solution to be certain it falls in the range of 0.40 to 0.80.

Activity Overview

- Please print the student worksheet and make it available to students before beginning the lab. Lab background information as well as lab procedures are included only in the student worksheet. Always remember to review any safety precautions thoroughly with your students prior to starting the lab.
- Students can answer the questions posed in the .tns file and submit for grading with TI-Nspire Navigator (optional) or students can answer directly on the student worksheet
- Ensure that students collect data on the 5 known substances and look at the graph before they actually measure the absorbance of the unknown solution. This will allow them to make predictions based on the graph of the data.



Discussion Points and Possible Answers

TI-Nspire Navigator Opportunity

Use the TI-Nspire™ Navigator™ System to monitor student progress using Screen Capture.

Have students answer the pre-lab questions directly on their student worksheets or on Pages 1.4 – 1.7 prior to starting the lab procedure. Students will need to have read the background information presented in the Student Worksheet.

1. The wavelength of light used by the colorimeter should be _____ by the colored solution.

Answer: absorbed

2. The NiSO₄ solution used in the experiment has a deep _____ color.

Answer: green

3. For this experiment, the LED of the colorimeter needs to be set to _____.

Answer : red

4. A higher concentration of solution absorbs _____ light.

Answer: more

5. The relationship between absorbance and concentration is _____.

Answer: direct

6. The linear relationship between absorbance and concentration is called _____ Law.

Answer: Beer's

7. The concentration of the unknown can be determined by using the _____ of the regression line on the graph.

Answer: slope

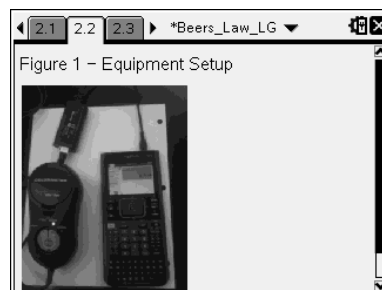


Lab Set-Up and Procedures

Please note that detailed lab procedures are outlined in the Student Worksheet, and key steps are included here for convenience.

Move to page 2.2.

After students have read through the lab set up and procedures on the handout, they can see a picture of the equipment set-up on Page 2.2. Calibrating the colorimeter is a critical step in obtaining accurate data during the experiment.



Analyze the Data

Students will perform calculations to determine the concentration of the unknown NiSO_4 solution by interpolating along the regression line to convert the absorbance value of the unknown to concentration.

Data Table (Sample Data)

Trial	Concentration (mol/L)	Absorbance
1	0.080	0.089
2	0.16	0.186
3	0.24	0.281
4	0.32	0.374
5	0.40	0.463
6	Unknown number ____	0.308
Concentration of unknown		0.265 mol/L

Tech Tip: If students have not done an Interpolation before, you might encourage them to watch the TechTip video available with this activity. It will walk them step by step through this process.



Post-lab Assessment

Have students respond to the questions (below) directly on their student worksheets (or on Pages 3.1 through 3.4) once they have completed the lab.

8. As the concentration of the nickel(II) sulfate solution increased, the absorbance _____.

Answer: increased

9. The closer the value of _____ was to zero, the better your data.

Answer: b

10. The closer the value of r is to _____, the better your data.

Answer: 1

11. To find the concentration of the unknown, you need to _____ your graph.

Answer: interpolate

TI-Nspire Navigator Opportunity

Use the TI-Nspire™ Navigator™ System to collect, grade, and save the .tns file to the Portfolio. Use Slide Show to view student responses.

Wrap Up

Upon completion of the lab and discussion, the teacher should ensure that students are able to understand:

- The importance of accurately preparing solutions for the lab.
- How to gather and analyze data.
- The relationship between the absorbance and concentration of a solution.

Assessment

Students can complete the embedded multiple choice questions in the *Beers_Law.tns* file. In addition, students can answer questions on the student activity sheet.

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Sound Waves and Beats

Sound waves consist of a series of air pressure variations. A microphone diaphragm records these variations by moving in response to the pressure changes. The diaphragm motion is then converted to an electrical signal. Using a microphone, you can explore the properties of common sounds.

The first property you will measure is the *period*, or the time for one complete cycle of repetition. Since period is a time measurement, it is usually written as T . The reciprocal of the period ($1/T$) is called the *frequency*, f , the number of complete cycles per second. Frequency is measured in hertz (Hz). $1 \text{ Hz} = 1 \text{ s}^{-1}$.

Another property of sound is the *amplitude*. As the pressure varies, it goes above and below the average pressure in the room. The maximum variation above or below the pressure mid-point is called the amplitude. The amplitude of a sound is closely related to its loudness.

In analyzing your data, you will see how well a sine function model fits the data. The displacement of the particles in the medium carrying a periodic wave can be modeled with a sinusoidal function. Your science textbook might have an expression resembling this one:

$$y = A \sin(2\pi f t)$$

Your math textbook may have an expression resembling this one: $y = A \sin(B(t - C)) + D$.

In the case of sound, a longitudinal wave, the y refers to the change in air pressure that makes up the wave. A is the amplitude of the wave (a measure of loudness), and f is the frequency. Time is represented with t , and the sine function requires a factor of 2π when evaluated in radians. In the math model, the value of B is $2\pi f$. The values of C and D represent the horizontal and vertical shifts in the graph.

OBJECTIVES

- Measure the frequency and period of sound waves from tuning forks or an electronic keyboard.
- Measure the amplitude of sound waves from tuning forks or an electronic keyboard.

MATERIALS




TI-Nspire™ handheld **or**
computer and TI-Nspire™ software
data-collection interface

Vernier® Microphone
2 tuning forks or an electronic keyboard


DataQuest 32**PRELIMINARY QUESTIONS**

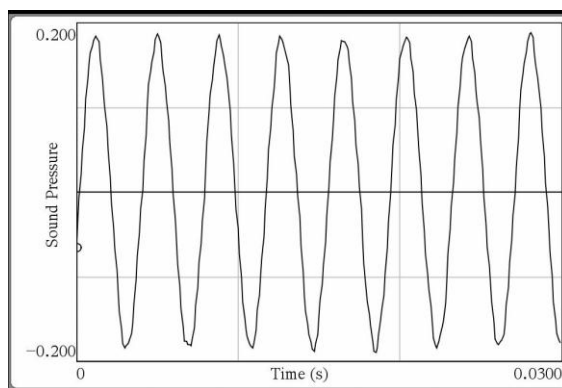
1. Why are instruments tuned before being played as a group? In which ways do musicians tune their instruments?
2. Given that sound waves consist of a series of air pressure increases and decreases, what would happen if an air pressure increase from one sound wave was located at the same place and time as a pressure decrease from another of the same amplitude?

PROCEDURE

1. Connect the microphone to the data-collection interface. Connect the interface to the TI-Nspire handheld or computer.
2. Be sure your handheld or computer software is set to perform angle calculations in Radians.
3. Choose New Experiment from the  Experiment menu. For Part I of the experiment, the default data-collection parameters for a microphone will be used (Rate: 10,000 samples per second; Duration: 0.03 seconds). If the microphone is not automatically identified, press  and then Experiment > Advanced Set Up > Configure Sensor > TI-Nspire Lab Cradle:ch1. From there, select the microphone as the sensor.
4. To center the waveform on zero, it is necessary to zero the microphone channel. With the room quiet, choose Set Up Sensor ► Zero from the  Experiment menu. When the process is complete, the reading for the sensor should be close to zero.

Part I Simple Waveforms

5. Produce a sound with a tuning fork or keyboard, and hold it close to the microphone. Start data collection (). When data collection is complete, a graph will be displayed.
6. The data should be sinusoidal in form, similar to the graph in Figure 1. If you are using a tuning fork, strike it against a soft object such as a rubber mallet or the rubber sole of a shoe. Striking it against a hard object can damage it. If you strike it too hard or too softly, the waveform may be rough; collect data again.

*Figure 1*

7. Print or make a sketch of your graph.

8. To examine the data pairs on the displayed graph, click any data point. Use ► and ◀ to record the times for the first and last peaks of the waveform. Count the number of complete cycles that occur between your first measured time and the last. Divide the difference, Δt , by the number of cycles to determine the period of the tuning fork. Record these values in Table 1.
9. The period is the time for one complete cycle. The frequency is the number of cycles per time. Use the period you calculated in Step 8 to now calculate the frequency of the tuning fork. Record this value in Table 1.
10. Examine the graph again to find the maximum and minimum sound values for an adjacent peak and trough. Calculate the amplitude of the wave by taking half of the difference between the maximum and minimum y-values. Record the values in Table 2.
11. To compare your data to the textbook sinusoidal model, $y = A\sin(2\pi f t)$, you will use the model $Y = \mathbf{a} * \sin(\mathbf{b}(x - \mathbf{c})) + \mathbf{d}$. Comparing terms, listing the textbook model's terms first, the amplitude A corresponds to the parameter \mathbf{a} and \mathbf{b} corresponds to $2\pi f$. The parameter \mathbf{c} corresponds to the horizontal shift and \mathbf{d} correspond to the vertical shift. Your value for \mathbf{d} should be zero or very close to that since you zeroed the probe before collecting the data. The variable time (t) is represented by x .

Table 3 allows you to record the transformation for the basic sinusoidal curve.




- a. Enter your value for the amplitude as your value for \mathbf{a} .
- b. Enter your estimate for \mathbf{b} .
- c. Locate the time value at which a sine seems to begin on the time axis, remembering that a sine curve begins at zero and increases. This is the horizontal shift of the graph. Record this value as \mathbf{c} .
- d. Initially use zero for \mathbf{d} .
- e. To check your model with the data, choose Model from the Analyze menu.
- f. Enter the equation, $\mathbf{a} * \sin(\mathbf{b} * (x - \mathbf{c})) + \mathbf{d}$.
- g. Select OK.

Adjust the values in your model to obtain a good match.

- h. The parameter values are located to the left of the graph in the Graph Details box. Adjust each value until you see what each one does and until you have a good match of your model to the data. If your frequency is not matching up, you might want to look at the frequency printed on your tuning fork to try a new value for \mathbf{b} .
- i. After optimizing the four values, record the parameters \mathbf{a} , \mathbf{b} , \mathbf{c} , and \mathbf{d} in your data table.
12. Calculate the frequency of the tuning fork using the curve fit equation's value for \mathbf{b} . Record this value in Table 3.
13. Click the Store Latest Data Set button (☒) to save the first run data. Repeat Steps 5–12 for the second frequency or tuning fork.

DataQuest 32

Part II Beats

14. Two pure tones with different frequencies sounded at once will create the phenomenon known as beats. Sometimes the waves will reinforce one another and other times they will combine to a reduced intensity. This happens on a regular basis because of the fixed frequency of each tone. To listen to beats, strike your tuning forks at the same time (simultaneously) or simultaneously hold down two keys on the keyboard and listen for the combined sound. If the beats are slow enough, you should be able to hear a variation in intensity. When the beats are too rapid to be audible as intensity variations, a single rough-sounding tone is heard. At even greater frequency differences, two separate tones may be heard, as well as various difference tones.
15. To capture the beats, it is necessary to collect data for a longer period of time.
 - a. Insert a new **Problem** into your TI-Nspire document, and add a DataQuest App to the problem. Choose New Experiment from the  Experiment menu.
 - b. Choose Collection Setup from the  Experiment menu. Enter **2500** as the rate (samples/second) and **0.08** as the experiment duration in seconds. The number of points collected should be 201.
 - c. Select OK.
16. Start the two tones sounding, and then start data collection (). When using tuning forks, strike them equally hard and hold them the same distance from the microphone.
17. Note the shape of your waveform graph. You should see a time variation of the sound amplitude. The pattern will be complex, with a slower variation of amplitude on top of a more rapid variation. Ignoring the more rapid variation and concentrating in the overall pattern, count the number of amplitude maxima after the first maximum, and record it in Table 4.
18. Record the times for the first and last amplitude maxima. To do this, click any data point. Divide the difference, Δt , by the number of cycles to determine the period of beats (in s). Calculate the *beat frequency* in Hz from the beat period. Record these values in Table 4.

DATA**Part I Simple Waveforms**

Table 1						
Tuning fork or note	Number of cycles	Time of first max (s)	Time of last max (s)	Δt (s)	Period (s)	Calculated frequency (Hz)

Table 2			
Tuning fork or note	Peak	Trough	Amplitude

Table 3					
Tuning fork or note	Parameter a	Parameter b (s ⁻¹)	Parameter c	Parameter d	Calculated frequency (Hz)

Part II Optional: Beats

Table 4					
Number of cycles	Time of first max (s)	Time of last max (s)	Δt (s)	Beat (s)	Calculated beat frequency (Hz)

DataQuest 32**QUESTIONS****Part I Simple Waveforms**

1. Did your curve fit match the waveform well? In what ways was the curve fit similar to the data, and in what ways was it different?
2. Compare the model frequency calculated in Step 12 to the frequency calculated in Step 9. Which would you expect to be more accurate? Why?
3. Calculate the percent error between the curve fit frequency and the frequency of the tuning fork or keyboard note for both of the notes played.
4. Compare the parameter **a** to the amplitude of the waveform.

Part II Beats

5. Is there any way the two individual frequencies can be combined to give the beat frequency you measured earlier? Compare your conclusion with information given in your textbook.

EXTENSIONS

1. There are commercial products available called *active noise cancellers*, which consist of a set of headphones, microphones, and some electronics. Intended for wearing in noisy environments where the user must still be able to hear (for example, radio communications), the headphones reduce noise far beyond the simple acoustic isolation of the headphones. How does such a product work?

2. The trigonometric identity

$$\sin x + \sin y = 2 \sin\left(\frac{x+y}{2}\right) \cdot \cos\left(\frac{x-y}{2}\right)$$


is useful in modeling beats. Show how the beat frequency you measured above can be predicted using two sinusoidal waves of frequency f_1 and f_2 , whose pressure variations are described by $\sin(2\pi f_1 t)$ and $\sin(2\pi f_2 t)$.

3. Most of the attention in beats is paid to the overall intensity pattern that we hear. Use the analysis tools to determine the frequency of the variation that lies inside the pattern (the one inside the envelope). How is this frequency related to the individual frequencies that generated the beats?
4. Examine the pattern you get when you play two adjacent notes on a keyboard. How does this change as the two notes played get further and further apart? How does it stay the same?


TEACHER INFORMATION

Sound Waves and Beats

1. Editable Microsoft® Word versions of the student pages and pre-configured TI-Nspire™ files can be found on the CD that accompanies this book. See *Appendix A* for more information.
2. This experiment cannot be done with Easy or Go! Products since data collection rates are greater than 200 samples/second. The microphone requires sample rates around 10,000 samples per second. You must use a multi-channel sensor interface for this experiment.
3. In the first part of this lab, the students are investigating pure tones, such as those produced by a tuning fork. It is important to use quality tuning forks with large tines. These tuning forks produce a relatively loud signal. Tuning forks with frequencies from 256 Hz to 512 Hz are recommended. When using tuning forks, they have to be struck by a soft object such as a rubber mallet, rubber sole, or the fleshy part of the hand. When struck with hard objects, the tuning forks produce overtones. It is also important to hold the tuning fork close to the microphone.
4. When using a sinusoidal curve fit on the data from a single sound source, the results might not match the data as expected. To get a better match of the data, adjust the region used for the curve fit by moving the brackets (**[** or **]**) to make the region smaller. See *Appendix B* or *C*.
5. An electronic keyboard also works well, but it needs to be set to a voice which produces as nearly a sine wave as possible. On some keyboards, this is the “flute” sound. Disable any vibrato effects, since they work by varying the frequency of the tone.
6. Since an important part of this lab is observing beats, it is important to make a good choice of frequencies. A good combination for tuning forks is C at 256 Hz and D at 288 Hz. On the keyboard you can use B and G. The difference between the notes should be at least 40 Hz.
7. Collecting a beat pattern with tuning forks is difficult to do. Try to strike each of them equally hard and hold them equidistant from the microphone.
8. The TI-Nspire must be in radian mode for this experiment.

For Handhelds: To verify the mode, hover the cursor over the battery indicator. To change the setting, press  then select Settings ► Settings ► General.

For Computers: To verify the mode, hover the cursor over Settings label along the bottom of the screen. To change the setting select Settings ► Document Settings from the File menu.

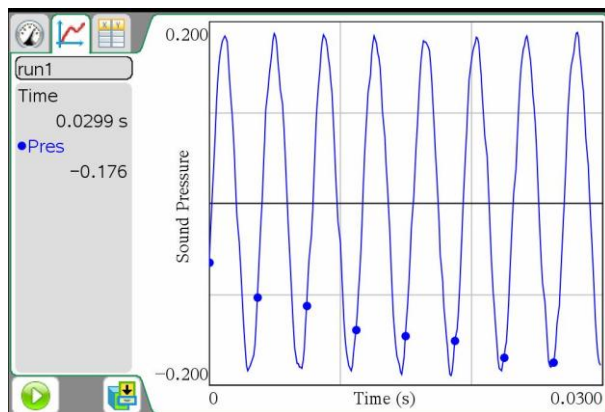
9. You might want to have your students find the sinusoidal regression and compare that equation with the model that they found in the activity. To fit your data using a sinusoidal curve fit, choose Curve Fit ► Sinusoidal from the  Analyze menu. If your model does not fit the data, adjust the region used for the curve fit by moving the brackets (**[** or **]**) to make the region smaller.

ANSWERS TO PRELIMINARY QUESTIONS

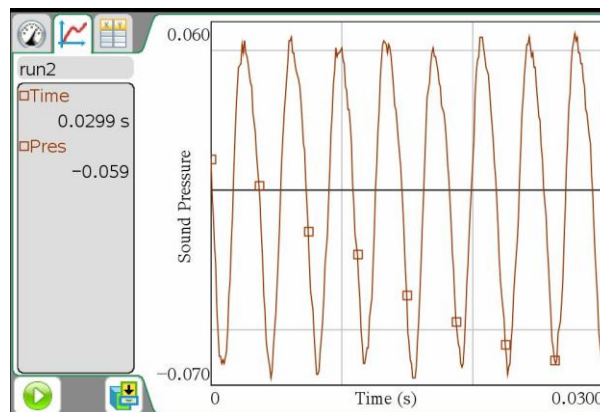
1. If they are not tuned, the sound is unpleasant. If the tuning is particularly bad, beats may be heard.
2. If a pressure increase and a pressure decrease from two different waves were to occur in the same location, the net effect would be a small pressure change or no pressure change.

SAMPLE RESULTS

Part I Simple Waveforms



Frequency of 256 (C) Hz



Frequency of 288 (C) Hz

Tuning fork or note	Number of cycles	First maximum (s)	Last maximum (s)	Δt (s)	Period (s)	Calculated frequency (Hz)
C – 256 Hz	7	0.0026	.0296	0.0270	0.003857	259
D – 288 Hz	8	0.0016	0.0293	0.0277	0.003463	289

Tuning fork or note	Peak	Trough	Amplitude
C – 256 Hz	0.800	-0.810	0.805
D – 288 Hz	0.814	-0.815	0.8145

Tuning fork or note	Parameter a	Parameter b (s ⁻¹)	Parameter c	Parameter d	Calculated frequency (Hz)
C – 256 Hz	.8003	1637	0	0	260
D – 288 Hz	.8159	1813	.002	0	289

Part II Beats

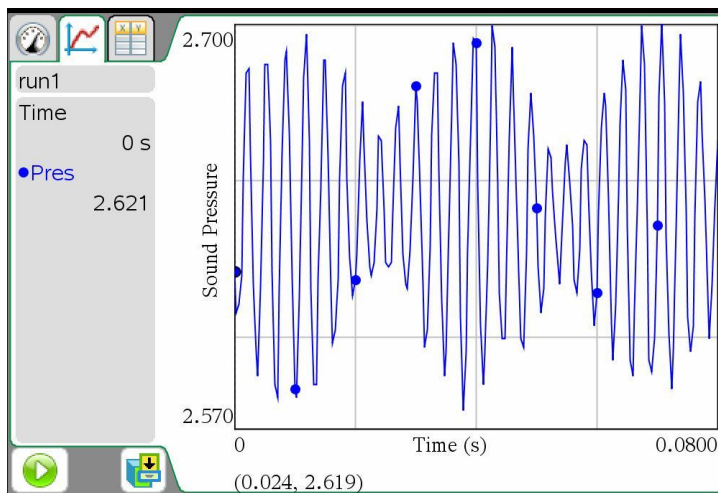


Table 4

Number of cycles	First maximum (s)	Last maximum (s)	Δt (s)	Period (s)	Calculated frequency (Hz)
2	0.010	0.071	0.061	0.0305	32.8

ANSWERS TO QUESTIONS

- The model should match the data. Often there are variations in the amplitude of the collected data while the curve fit will not show any variation. The frequency should be a close match.
- The frequency determined by the curve fit takes into account all the data, while the peak-counting method uses only select parts of the data. As a result, the curve fit frequency should be more accurate.

- The percent error for the note C-256 from the sample data is $\frac{|260 - 256|}{256} \times 100 = 1.6\%$.

The percent error for the note D-288 is $\frac{|289 - 288|}{288} \times 100 = 0.4\%$.

- These values should be close. The amplitude determined by the curve fit takes into account all the data, while the adjacent crest and trough method uses only select parts of the data. As a result, the curve fit amplitude should be more accurate.
- The beat frequency is equal to the difference in frequency of the two individual tones. The expected value for the sample data is 32 Hz. The experimental value was 32.8 Hz.

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About the Activity

- You have seen a number of sources for TI-Nspire™ activities. To allow you to make the most relevant use of the remainder of this workshop, you will have time to explore activities that are of particular interest to you for your classroom use. Some activities are contained in your workshop binder, some are available online through the Teacher Software, or you might have found something on your own that you would like to explore. You will share your findings with the whole group.

Sources for Activity Materials:

- Connecting Science and Mathematics workshop binder
- TI-Nspire Teacher Software Content links

TI-Nspire™ Navigator™ System

- If you want, you can use the workshop set of TI-Nspire Navigator to practice enhancing your activity presentation, engage your fellow participants, and share any TI-Nspire documents you found useful. The T³ Instructor will be happy to help you with the system.

Discussion Points

Please work through an activity or two in the time provided. While completing the activity, consider:

- How does it add new TI-Nspire skills to your repertoire?
- What are some pedagogical implications of the activity and its technology use?
- What is the content relevance?
- How might it engage and motivate your students?
- You are encouraged to work in small groups and discuss as you go.
- Each group will give a short presentation on an activity and the results of the discussions surrounding it.

Tech Tip: Try using any TI-Nspire documents on both the TI-Nspire Teacher Software and the TI-Nspire handheld. Transfer any documents from one to the other and back again.

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Ball Toss

When a juggler tosses a ball straight upward, the ball slows down until it reaches the top of its path. The ball then speeds up on its way back down. A graph of its velocity *vs.* time would show these changes. Is there a mathematical pattern to the changes in velocity? What is the accompanying pattern to the distance *vs.* time graph? What would the acceleration *vs.* time graph look like?

In this experiment, you will use a Motion Detector to collect distance, velocity, and acceleration data for a ball thrown straight upward. Analysis of the graphs of this motion will answer the questions asked above.

OBJECTIVES

- Collect position, velocity, and acceleration data as a ball travels straight up and down.
- Analyze the position *vs.* time, velocity *vs.* time, and acceleration *vs.* time graphs.
- Determine the best-fit equations for the distance *vs.* time and velocity *vs.* time graphs.
- Determine the mean acceleration from the acceleration *vs.* time graph.

MATERIALS

TI-Nspire handheld **or**
computer and TI-Nspire software

CBR 2 **or** Go! Motion **or**
Motion Detector and data-collection interface

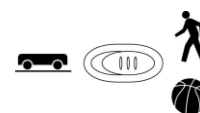
volleyball or basketball

PRE-LAB QUESTIONS



1. Think about the changes in motion a ball will undergo as it travels straight up and down. Make a sketch of your prediction for the position *vs.* time graph. Describe in words what this graph means.
2. Make a sketch of your prediction for the velocity *vs.* time graph. Describe in words what this graph means.
3. Make a sketch of your prediction for the acceleration *vs.* time graph. Describe in words what this graph means.



PROCEDURE


1. Place the Motion Detector on a table or chair, away from other objects.
2. If your Motion Detector has a switch, set it to Normal. Connect the Motion Detector to the data-collection interface. Connect the interface to the TI-Nspire handheld or computer. (If you are using a CBR 2 or Go! Motion, you do not need a data-collection interface.)







DataQuest 27

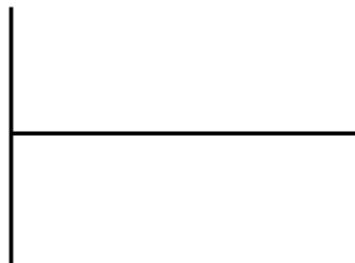
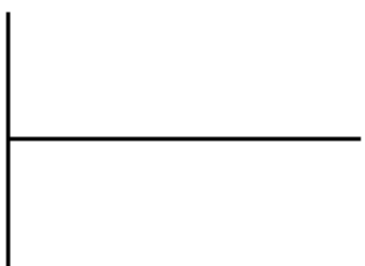
3. Set up data collection.
 - a. Choose New Experiment from the  Experiment menu.
 - b. Choose Collection Setup from the  Experiment menu. Enter **25** as the rate in samples/second. The number of points collected should be 126.
 - c. Select the Strip Chart option
 - d. Select OK.

4. Collect the data.
 - a. *This step may require some practice.* Hold the ball in two hands about 0.5 m above the motion detector. Toss the ball straight upward above the Motion Detector and let it fall back toward the Motion Detector. Be sure to pull your hands away from the ball after it starts moving so they are not picked up by the Motion Detector. A toss that goes to about 1.0 m above the Motion Detector works well.
 - b. Have your partner start data collection (). **Note:** Data will be collected until you stop data collection but only the last 5 seconds of data will be retained.
 - c. Toss the ball as described in Step a. Continue tossing until you have one good toss.
 - d. Have your partner stop data collection () before any of the data from your desired toss is discarded.
 - e. Check with your instructor if you are not sure whether you need to repeat the data collection. If necessary, repeat Steps b–d until you have the desired data.

5. Modify your graph to show only your desired toss.
 - a. From the position vs. time graph, select a region of data that includes the desired toss. The region should be about 1.5 seconds in duration and included points both before and after the toss.
 - b. Choose Strike Data from the  Data menu, then select the Outside Selected Region option.
 - c. Check with your instructor if you are not sure if your selected region is appropriate for the analysis of the data. If necessary, restore your data and select the region again.


6. Use Data Markers to identify the following points on your position vs. time graph.
 - The point where you started to toss the ball.
 - The point where the ball leaves your hand.
 - The point where the ball reaches its maximum height.
 - The point where the ball is first caught.
 - The point where the ball comes to rest in your hands.
 - a. To add a data marker, click on the graph and use  and  to locate the points.
 - b. Move your cursor over the Graph View details box and launch the contextual menu (handheld –  ; computer – right-click). Select the Add Data Marker option.
 - c. Add a brief description of the point in the text field.

7. Either print or sketch the three motion graphs. To display an acceleration vs. time graph, change the y-axis of the velocity or position graph to Acceleration.

DATA**Position vs. Time****Velocity vs. Time****Acceleration vs. Time****PROCESSING THE DATA**

1. Label these points directly on the printed or sketched graphs.
 - a. Identify the region when the ball was being tossed but still in your hands.
 - Label this region on the velocity vs. time graph.
 - Label this same region on the acceleration vs. time graph.
 - b. Identify the region where the ball is in free fall.
 - Label the region on each graph where the ball was in free fall and moving upward.
 - Label the region on each graph where the ball was in free fall and moving downward.
 - c. Determine the position, velocity, and acceleration at these specific points.
 - On the velocity vs. time graph, locate where the ball had its maximum velocity, after the ball was released. Mark the spot and record the value on the graph.
 - On the position vs. time graph, locate the maximum height of the ball during free fall. Mark the spot and record the value on the graph.
2. The motion of an object in free fall is modeled by $y = v_0t + \frac{1}{2}gt^2$, where y is the vertical position, v_0 is the initial velocity, t is time, and g is the acceleration due to gravity (9.8 m/s^2). This is a quadratic equation whose graph is a parabola.

Examine the position vs. time graph to see if it is a parabola in the region where the ball was in freefall. Now fit a quadratic equation to your data.

- a. If the data are not already selected, select the data points in the region where the ball was in freefall. Choose Curve Fit ► Position ► Quadratic from the  Analyze menu.
- b. Record the parameters of the curve fit in the data table.

DataQuest 27

3. Display a graph of velocity vs. time. This graph should be linear in the region where the ball was in freefall. Fit a linear equation to your data in this region.
 - a. Select the data points in the region that corresponds to when the ball was in freefall.
 - b. Choose Curve Fit ► Velocity ► Linear from the \mathbb{A} Analyze menu.
 - c. Record the parameters of the curve fit in the data table.
4. Examine the graph of acceleration vs. time. During free fall, the acceleration graph should appear to be more or less constant. Note that because the graph is automatically scaled to fill the screen vertically, small variations may appear large. A good way to analyze the acceleration data is to find the mean (average) of these data points.
 - a. If the data are not already selected, select the data points in the region where the ball was in freefall. Choose Statistics ► Acceleration from the \mathbb{A} Analyze menu.
 - b. Record the mean acceleration value in your data table.

	Analysis Parameters		
	A or M or Average	B	C
Distance ($Ax^2 + Bx + C$)			
Velocity ($Mx + B$)			
Average acceleration			

QUESTIONS

1. Based on your graphs, what was the velocity of the ball at the top of its motion? What was the acceleration of the ball at the top of its motion?
2. How closely does the coefficient of the x^2 term of the Quadratic fit of the position data compare to $\frac{1}{2}g$?
3. How closely does the coefficient of the x term of the linear fit of the velocity data compare to the accepted value of g ?
4. How closely does the average acceleration of the free fall motion data compare to the accepted value for g ?
5. List some reasons why your three measured values for the ball's acceleration may be different from the accepted value for g .

EXTENSIONS

1. Determine the consistency of your acceleration values and compare your measurement of g to the accepted value of g . Do this by repeating the ball toss experiment five more times. Each time, fit a straight line to the free-fall portion of the velocity graph and record the slope of that line. Average your six slopes to find a final value for your measurement of g . Does the variation in your six measurements explain any discrepancy between your average value and the accepted value of g ?

Ball Toss

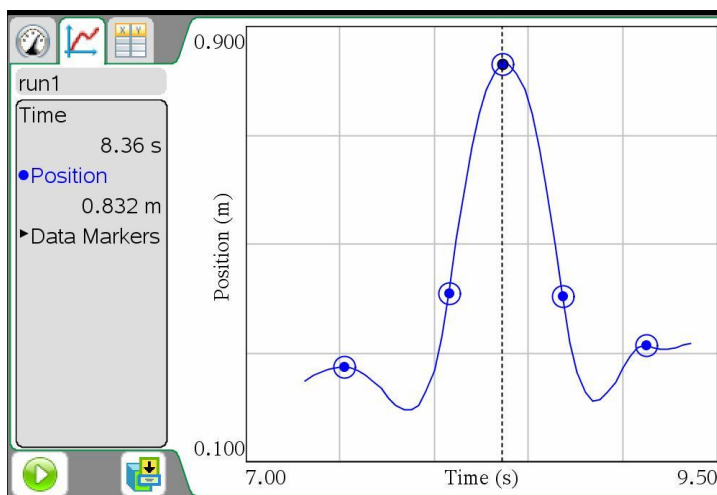
2. The ball used in this lab is large enough and light enough that a buoyant force and air resistance may affect the acceleration. Perform the same curve fitting and statistical analysis techniques, but this time analyze each half of the motion separately. How do the fitted curves for the upward motion compare to the downward motion? Explain any differences.
3. Perform the same lab using a beach ball or other very light, large ball. See the questions in Extension 2 above.
4. Use a smaller, denser ball where buoyant force and air resistance will not be a factor. Compare the results to your results with the larger, less dense ball.
5. Instead of throwing a ball upward, drop a ball and have it bounce on the ground. (Position the Motion Detector above the ball.) Predict what the three graphs will look like, then analyze the resulting graphs using the same techniques as this lab.

TEACHER INFORMATION**Ball Toss**

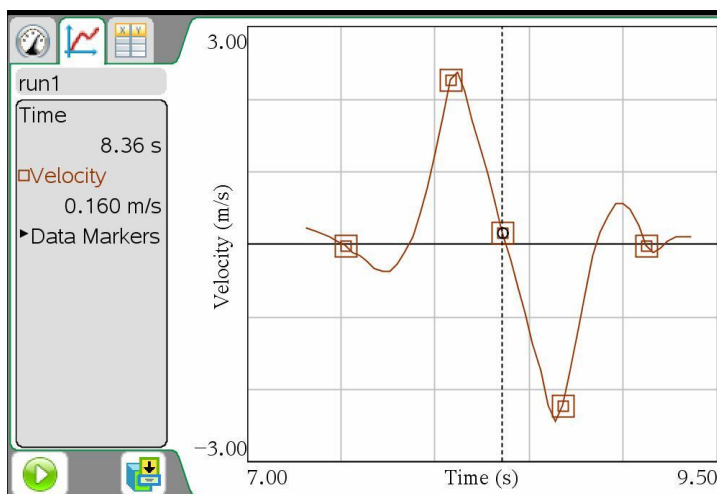
1. Editable Microsoft Word versions of the student pages and pre-configured TI-Nspire files can be found on the CD that accompanies this book. See *Appendix A* for more information.
2. A volleyball or a basketball works well in this lab. Since these are rather large, a buoyant force and air resistance will affect the acceleration. The students will probably not get 9.8 m/s^2 , but the shapes of the curves will be correct. Smaller objects that yield better g values are difficult to use because they do not reflect the ultrasound well. Do not use a light ball such as a beach ball, since air resistance is too large compared to the gravitational force. The analysis of the motion of a beach ball is suggested as an extension.
3. Using a beach ball will yield more air resistance and buoyant force effects, while using a baseball or dense rubber ball will do the opposite. Careful analysis may show some small differences between the dense balls and the others. Over a short distance and with the velocities relatively low, air resistance does not become a major factor, except for the beach ball. Nerf[®] or foam balls do not work well for this experiment.
4. There are several keys to collecting good data. It will help if you demonstrate the toss before the students begin. Here are some tips:
 - Hold the ball with your hands on the sides of it. After you release the ball, get your hands out of the way.
 - Do not toss the ball using one hand underneath the ball. Your hand will interfere with the data collection.
 - It is not necessary to toss the ball high. A height of 0.5 to 1.0 m above the release point works well.
 - The ball must stay directly above the Motion Detector during its motion.
5. Motion detectors without a mode switch do not properly detect objects closer than 0.5 m. As a result, such motion detectors must be farther away from the experiment than described in the student notes. In contrast, Motion detectors *with* a mode switch will detect objects as close as 0.15 m. Ideally, an experiment will be set up so that the target is nearly this close at the point of closest approach, giving the best possible data.
6. This activity makes use of the Strip Chart feature in DataQuest. Based on the setup, only the last five seconds of data will be retained after stopping data collection. It is strongly recommend that students work in pairs when collecting data where one person throws the ball and the other person starts and stops data collection.

Experiment 27

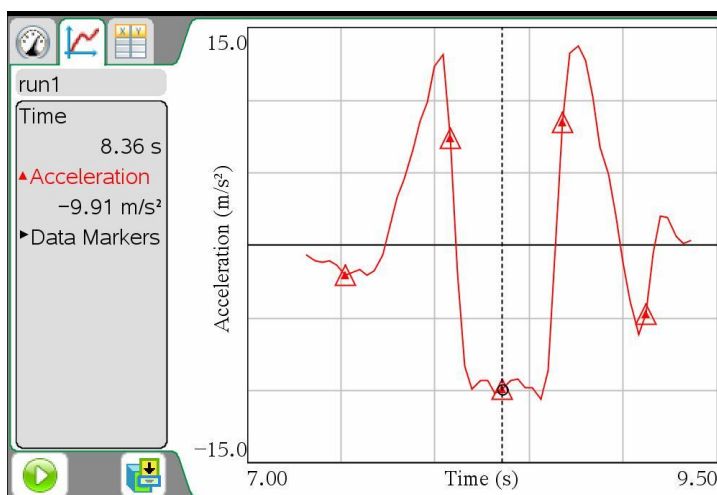
SAMPLE RESULTS



Typical position vs. time graph.



Typical velocity vs. time graph.



Typical acceleration vs. time graph.

	Analysis Parameters		
	A or M or Average	B	C
Distance ($Ax^2 + Bx + C$)	- 4.79	80.38	- 335.9
Velocity ($Mx + B$)	- 9.67	81.02	
Average acceleration	- 9.58		

ANSWERS TO QUESTIONS

1. The velocity when the ball is at the top should be close to 0 m/s. The acceleration when the ball is at the top should be close to -9.80 m/s^2 .
2. In this example, the coefficient of the x^2 term is -4.79 . For free fall without air resistance, $1/2 g$ should be -4.90 .
3. When a straight line is fit to the velocity graph, the slope of the line is -9.67 m/s^2 , compared to the acceleration due to gravity of -9.80 m/s^2 .
4. The mean acceleration from the acceleration graph is -9.58 m/s^2 , compared to the acceleration due to gravity of -9.80 m/s^2 .
5. The acceleration of the ball was consistently smaller than the accepted acceleration due to gravity. This is largely due to air resistance and the buoyancy of the surrounding air.

EXTENSIONS

1. Since the balls used in this lab are rather large, a buoyant force and air resistance will affect the acceleration. The students will probably not get 9.8 m/s^2 , but the shapes of the curves will be correct. Smaller objects that yield better g values are difficult to use because they do not reflect the ultrasound well. Variations in your measurements will indicate that there is error in determining the distance that will affect your results.
2. For the half-trip up, the net force on the ball is affected by the upward-directed buoyant force and the downward-directed air resistance. For the half-trip down, the net force on the ball is affected by the upward-directed buoyant force and air resistance.
3. Using a beach ball will yield more air resistance and buoyant force effects. You should expect a lower value for g in this case.
4. Using a baseball or dense rubber ball will yield less air resistance and buoyant force effects. Careful analysis may show some small differences between the dense balls and the others.



Boyle's Law

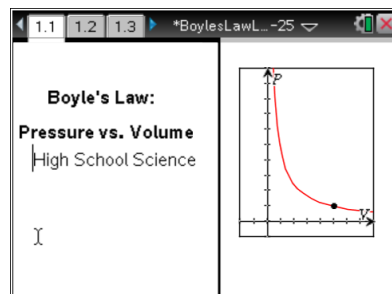
Student Activity

Name _____

Class _____

Open the TI-Nspire document *Boyles Law.tns*.

In this activity, you will use a Gas Pressure Sensor to measure the pressure of an air sample inside a syringe. Using graphs, you will apply your results to real-world examples.

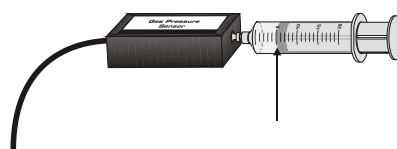


What is the mathematical relation between volume and pressure for a confined gas? To answer this question, you will perform an experiment with air in a syringe connected to a Gas Pressure Sensor. When the volume of the syringe is changed by moving the piston, the change in the pressure will be measured. It is assumed that temperature and moles of gas will be constant throughout the experiment. Pressure and volume data pairs will be collected during this experiment and then analyzed. Using the data and the graph, the type of mathematical relationship between pressure and volume of the confined gas can be determined. Historically, this relationship was first established by Robert Boyle in 1662 and has since been known as Boyle's law.

Move to page 1.6.

Press **ctrl** **▶** and **ctrl** **◀** to navigate through the lesson.

- As volume increases, pressure:
 - increases
 - decreases
 - remains the same
- With the syringe disconnected from the Gas Pressure Sensor, move the piston of the syringe until the front edge of the inside black ring (indicated by the arrow in the picture to the right) is positioned at the 10.0 mL mark.
- Turn on your TI-Nspire handheld, and close any documents that are open.
- Attach the syringe to the probe as shown to the right. (Do not twist too tightly—the syringe just needs to be secure.)
- Plug the pressure probe into the EasyLink™, and plug the EasyLink into the USB port in the top of the handheld. The DataQuest APP should open automatically.
 - What is the default unit for collection with this sensor?
- Select **MENU > Experiment > Collection Mode > Events with Entry**.
- Type in **volume** for Name, press **tab**, and type **mL** for Units.
- Press **enter**.





9. Click the green start arrow to initiate data collection.
Time to collect pressure and volume data. It is best for one person to take care of the syringe and for another to operate the handheld.
10. To collect your first data reading, click on the “camera” icon in the lower left of the screen (“Keep current reading”). Enter a value of 10, since you set the syringe at 10 mL earlier. Click on OK, or press .
11. Depress and hold the plunger to the 9 mL mark. When the pressure value on the left side of the screen has stabilized, keep this reading, type in 9, and press .
12. Continue this procedure, collecting data at 8, 7, 6, and 5 mL. After you have collected data for 5 mL, click on the stop button in the lower left corner of your TI-Nspire screen.
- Your pressure/volume graph should now be displayed.
13. Explore the various regression models to determine the best mathematical relationship for your data set.
14. Based on the graph of pressure vs. volume, decide what kind of relationship exists between these two variables—direct or inverse.
- While on the DataQuest app page, select **MENU > Analyze > CurveFit > Power**.
 - Scroll down to see the curve fit statistics for the equation in the form $y = Ax^B$, where x is volume, y is Pressure, A is a proportionality constant, and B is the exponent of x (Volume).

Note: The relationship between pressure and volume can be determined from the value and sign of the exponent, B .

- If the mathematical relationship has been correctly determined, the regression line should closely fit the points on the graph (that is, pass through or near all of the plotted points).

Move to page 2.3.

15. Which variable is considered to remain constant during a Boyle's Law Experiment?
- A. pressure B. volume C. temperature D. all of these



Boyle's Law

Student Activity

Name _____

Class _____

16. To linearize the data and confirm that an inverse relationship exists between pressure and volume, plot a graph of pressure vs. reciprocal of volume ($1/\text{Volume}$) in DataQuest:
- Select **MENU > Data > New Calculated Column**.
 - Type **InverseV** for Name.
 - Short Name: **1/V**
 - Units: **1/mL**
 - Expression: **1/Volume**
 - Click OK, or press .
 - Select **MENU > Graph > Select X-axis > InverseV**.
17. Calculate the regression line $y = mx + b$ where x is $1/\text{volume}$, y is pressure, m is a proportionality constant, and b is the y -intercept. On the DataQuest page, select **MENU > Analyze > Curve Fit > Linear**.

Move to page 3.2.

18. If the volume is doubled from 5 to 10 mL, what does the data show happens to the pressure?
- A. increases B. decreases C. doubles D. cut in half
19. If the volume is halved from 20 to 10 mL, what does the data show happens to the pressure?
- A. increases B. decreases C. doubles D. cut in half
20. Based on the data, what would be expected to happen to the pressure if the volume in the syringe were increased from 10 to 40 mL?
- A. increase B. decrease C. quadruple D. cut to 1/4th
21. From the answers to the above three questions and from the shape of the curve of the plot, of pressure vs. volume, what is the relationship between the pressure and volume of a confined gas?
- A. inverse B. direct C. quadratic D. impossible to determine



Boyle's Law

Student Activity

Name _____

Class _____

22. Based on the data, what would be expected to happen to the pressure if the volume in the syringe were increased from 10 to 40 mL?
- A. increase B. decrease C. quadruple D. cut to 1/4th
23. What two experimental factors are assumed to be constant during this experiment? (select two)
- A. pressure B. volume C. moles of the gas D. temperature
24. Using P, V, and k, write an equation representing Boyle's Law.
25. Which of the following produced a constant value?
- A. pressure x volume B. pressure/volume C. volume/pressure D. none of these
26. Summarize what you have learned about the relationship between pressure and volume.

Move to page 4.1.

Extension: Effect of Temperature on Boyle's Law

Follow the instructions on Pages 4.1-4.3 for the simulation, and then answer the following questions from Pages 4.4 and 4.5:

1. When the temperature is doubled, how does the pressure change?
- A. The pressure doubles B. The pressure is reduced by $\frac{1}{2}$
C. The pressure is 4X larger D. The pressure does not change
2. At a higher temperature, the relationship between pressure and volume is a(an) _____ relationship.
- A. direct B. inverse C. quadratic D. impossible to determine



Science Objectives

- Use a Gas Pressure Sensor and a gas syringe to measure the pressure of an air sample at several different volumes.
- Determine the relationship between gas pressure and volume.
- Use the results to predict the pressure at other volumes.

Math Objectives

- Mathematically describe the relationship between gas pressure and volume.
- Evaluate an inverse mathematical relationship.
- Generate and analyze a power regression model.
- Linearize an inverse relation.

Materials Needed

- TI-Nspire or TI-Nspire CAS unit for each student
- Vernier® EasyLink™
- Vernier Gas Pressure Sensor
- 20 ml syringe

Vocabulary

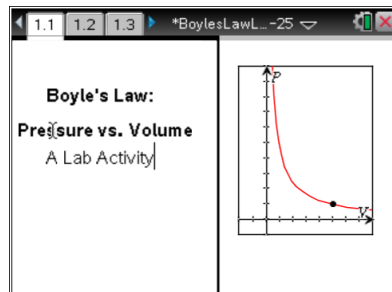
- pressure
- volume
- inverse

About the Lesson

- This activity makes use of the Gas Pressure Sensor in an inquiry activity that enables the student to understand Boyle's Law through experimentation and data collection.
- As a result, students will:
 - Built a mathematical model to show the inverse relationship between gas pressure and gas volume.
 - Analyze that mathematical model, and make predictions from the model through interpolation and extrapolation.
 - Apply Boyle's Law to the real-life situation of human respiration.

TI-Nspire™ Navigator™ System






- Screen Capture to monitor student progress.
- Live Presenter allows students to show their graphs to the class.



TI-Nspire™ Technology Skills:

- Download a TI-Nspire document
- Open a document
- Move between pages
- Entering and graphing data
- Tracing and interpolating

Tech Tips:

- Make sure the font size on your TI-Nspire handhelds is set to Medium.
 - You can bring up the data collection console at any time by pressing ctrl D
 - You can hide the function entry line by pressing 
-    

Lesson Materials:

Student Activity

- Boyle's Law.pdf
- Boyle's Law.doc

TI-Nspire document

- Boyle's Law.tns

Visit www.mathnspired.com for lesson updates and tech tip videos.



Discussion Points and Possible Answers

Boyles Law PreLab.tns

Page 1.5

Answer: decreases

1.3 1.4 1.5 ▶ BoylesLawP... 3.2

As volume decreases the pressure

decreases.

increases.

remains the same.

Boyles Law Lab.tns

Page 2.10

Answer: temperature

2.8 2.9 2.10 ▶ BoylesLawLab3.2

Which variable is considered to remain constant during a Boyle's Law experiment?

pressure

volume

temperature

all of the above

Page 2.11

Answer: increase

2.9 2.10 2.11 ▶ BoylesLawLab3.2

When a quantity of gas is compressed, the pressure of the gas is expected to _____.

decrease

remain the same

increase

double

Page 2.12

Answer: inverse

2.10 2.11 2.12 ▶ BoylesLawLab3.2

The expected mathematical relationship between pressure and volume is _____.

direct

inverse

indirect

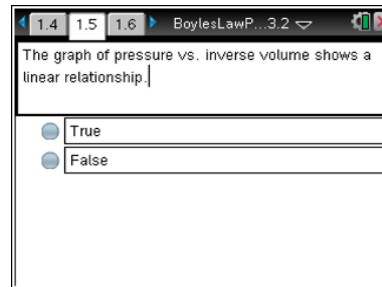
impossible to determine



Boyles Law PostLab.tns

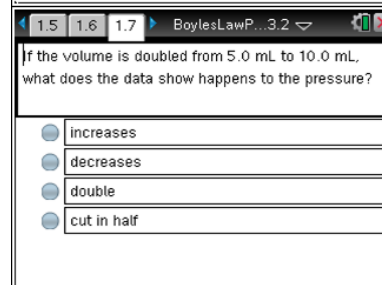
Page 1.5

Answer: false



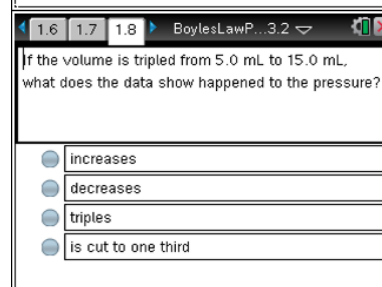
Page 1.7

Answer: cut in half



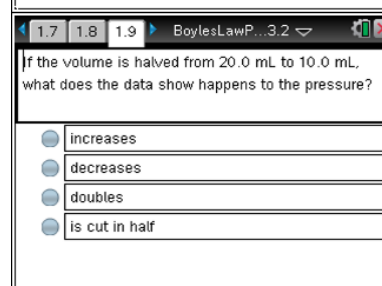
Page 1.8

Answer: is cut by one-third



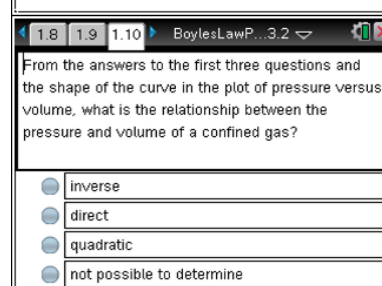
Page 1.9

Answer: doubles



Page 1.10

Answer: inverse





Page 1.11

Answer: cut into one-fourth

1.9 1.10 1.11 BoyleLawP... 3.2

Based on the data, what would be expected to happen to the pressure if the volume of the syringe was increased from 10.0 mL to 40.0 mL.

- increase
- decrease
- quadruple
- cut into one fourth

Page 1.12

Answer: moles of gas and temperature

1.10 1.11 1.12 BoyleLawP... 3.2

What TWO experimental factors are assumed to be constant in this experiment?

- pressure
- volume
- moles of gas
- temperature

Page 1.13

Answer: $P = k/V$

1.11 1.12 1.13 BoyleLawP... 3.2

Using P, V, and k, write an equation representing Boyle's law

Student: type response here

Page 1.14

Answer: pressure times volume

1.12 1.13 1.14 BoyleLawP... 3.2

Which of the following produced a constant?

- pressure times volume
- pressure divided by volume
- volume divided by pressure
- none of the above

Page 1.15

Sample Answers: Answers will vary. Students should indicate the inverse relationship between pressure and volume.

1.13 1.14 1.15 BoyleLawP... 3.2

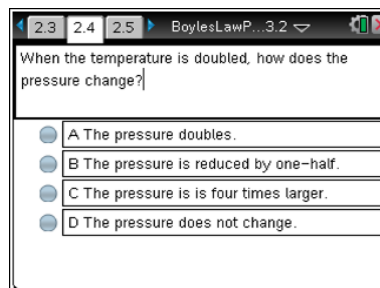
Summarize what you have learned about the relationship between pressure and volume.

Student: type response here



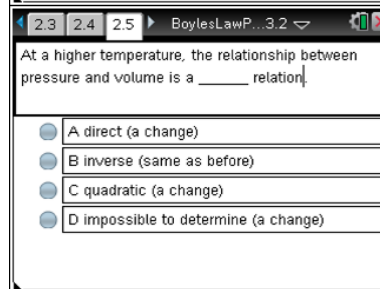
Page 2.4

Answer: The pressure doubles.



Page 2.5

Answer: inverse (same as before)



TI-Nspire Navigator Opportunity: Screen Capture

See Note 1 at the end of this lesson.

Wrap Up

Use Boyle's Law to offer a practical application such as human breathing.

Assessment

Formative assessment will consist of questions embedded in the pre-lab .tns file. Summative assessment questions are found in the lab and post-lab .tns files. The questions will be graded when the .tns files are retrieved. The Slide Show can be utilized to give students immediate feedback on their assessment.

TI-Nspire Navigator Notes

Note 1 Screen Capture

Screen Capture can be used to monitor students.

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Dew Point Temperature

On hot summer days, you may notice water droplets forming on the outside of a glass of ice water. It is commonly said that the glass is “sweating.” Since the glass cannot actually sweat, the liquid on the glass must come from the air outside the glass. This liquid forms by the condensation of water vapor that is near the surface of the glass. The air next to the cold glass has been cooled to the *dew point* or *dew point temperature*. The dew point temperature is the temperature to which air would have to be cooled to become saturated. Once the air is saturated, the water vapor condenses to form a liquid. The same process occurs when dew forms on the lawn.

In this experiment, you will use a temperature probe to make two investigations. In the first, you will measure the temperature of air next to a can of ice water to see if it is colder than room temperature. In the second investigation, you will determine the dew point temperature of the air in the classroom. You will do this by slowly adding ice to water and watching for condensation to form on the outside of the container. Throughout this process, you will continuously record the temperature of the water. When condensation first forms on the container, the temperature of the water is the dew point temperature.

OBJECTIVES

In this experiment, you will

- Compare room temperature to the temperature of air next to a can of ice water.
- Record the temperature of water while ice is slowly added.
- Observe the formation of condensation.
- Determine the dew point temperature.

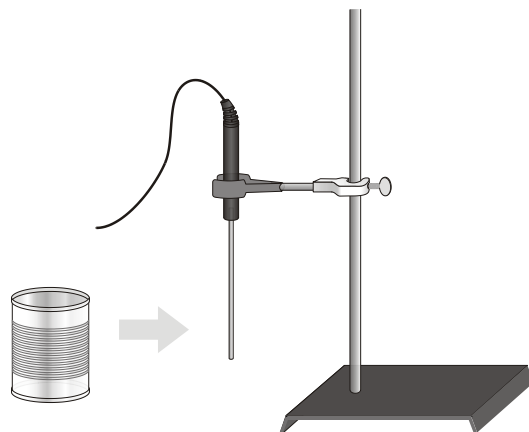
MATERIALS






TI-Nspire handheld **or**
computer and TI-Nspire software
EasyTemp **or** Go!Temp **or**
Temperature Probe and data-collection interface
room temperature water

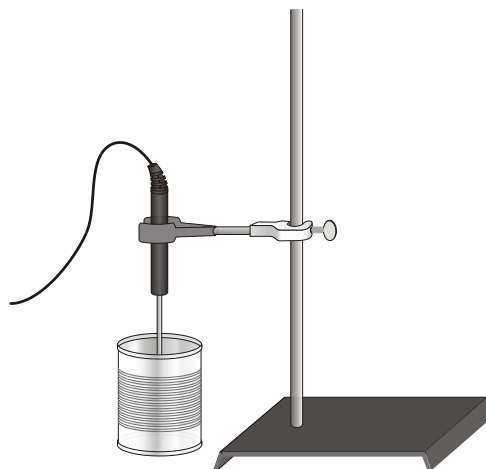
plastic spoon
ice cubes and ice chips
ring stand
utility clamp
paper towels

PRE-LAB QUESTIONS

1. To determine the dew point temperature, you will slowly add small pieces of ice to room temperature water. After each piece is added, you will wait for the ice to melt. Throughout this process, you will graph the temperature of the water. Draw a rough sketch of what the temperature *vs.* time graph will look like while the ice melts.
2. In the experiment, you will continue to collect temperature data after the small pieces of ice have melted. Draw a rough sketch of what the temperature *vs.* time graph will look like after the ice has melted.

DataQuest 7*Figure 1***PROCEDURE****Part I Measure the Temperature of the Air Next to a Can of Ice Water**

1. Use a utility clamp to suspend the Temperature Probe on a ring stand as shown in Figure 1. The end of the Temperature Probe should be about 1 cm above the tabletop.
2. Connect the Temperature Probe to the data-collection interface. Connect the interface to the TI-Nspire handheld or computer. (If you are using an EasyTemp or Go!Temp, you do not need a data-collection interface.)
3. Choose New Experiment from the  Experiment menu. Choose Collection Setup from the  Experiment menu. Enter **1** as the rate (samples/second) and **900** as the experiment duration in seconds. The number of points collected should be 901. Choose the Data Marker option and select OK.
4. Read the room temperature displayed on the screen. Record it in the data table.
5. Place 5 or 6 ice cubes in the metal can, fill it with water, and place it away from the Temperature Probe.
6. Start data collection () . Wait 30 seconds and then place the can about 1 mm from the tip of the Temperature Probe. Do not touch the probe to the can.
7. Watch the outside of the can. When condensation forms on the can, click the Add Data Marker button () to mark the dew point temperature. Stop data collection () .
8. A graph of temperature vs. time will be displayed. The temperature you marked with the Data Marker will be highlighted in the graph with a large point icon. Double-click on this point, label it **Dew Point**, and then select OK. The point label is displayed in the Graph View Details box. Record the dew point temperature in the data table.
9. Print or sketch copies of the graph as directed by your instructor.
10. Empty the can and dry the outside.

*Figure 2***Part II Determine the Dew Point Temperature**

11. Fill the dry can half full with room temperature water.
12. Lower the Temperature Probe into the water (to about 1 cm from the bottom) as shown in Figure 2. Click the Store Latest Data Set button (☰) to save the first run data.
13. Click the Meter View tab (📊). Monitor the temperature of the water. Once the temperature is stable, go to Step 14.
14. Start data collection (▶). Wait about 30 seconds and then add a spoonful of ice chips to the water. Stir the water while the ice melts. After the ice has melted, continue to stir the water for about 10 seconds.
15. Add another spoonful of ice chips and again stir the water until it melts. Again wait about 10 seconds after the ice has melted. Observe the can to see if water has condensed on the outside.
16. Repeat Step 15 until you observe condensation. When condensation forms on the can, click the Add Data Marker button (📌) to identify the dew point temperature. Stop data collection (◻).
17. A graph of temperature *vs.* time will be displayed. The temperature you marked with the Data Marker will be highlighted in the graph with a large point icon. Click on this point, label it **Dew Point**, and then select OK. Record the dew point temperature in the data table.
18. Print or sketch copies of the graphs as directed by your instructor.

DataQuest 7

DATA

Part I	
Room temperature (°C)	
Air temperature close to the can of ice water (°C)	

Part II	
Dew point temperature (°C)	

QUESTIONS

1. Compare the room temperature to the temperature of the air next to the can of ice water. How much colder was this air than room temperature?
2. Compare the room temperature, the temperature of the air next to the can, and the dew point temperature.

EXTENSIONS

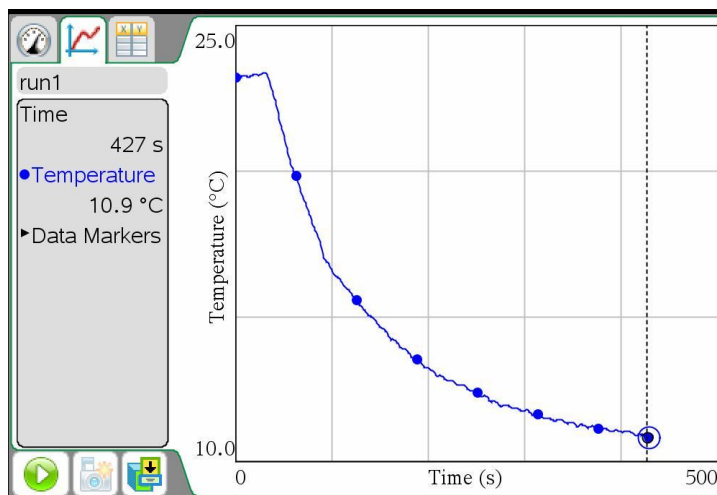
1. Repeat Part II of this experiment four more times and determine the average dew point temperature.
2. Collect results from other lab groups and determine the average dew point temperature.
3. Repeat the experiment outside and compare the dew point temperature of the outside air to that of the inside air. Explain any differences.

TEACHER INFORMATION

Dew Point Temperature

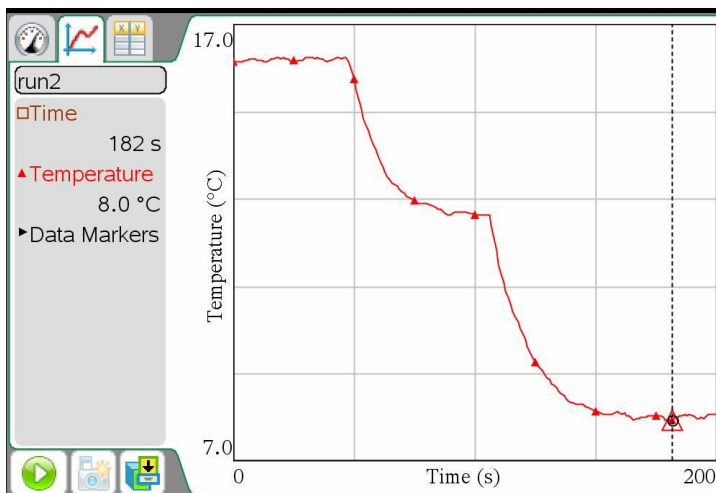
1. Editable Microsoft Word versions of the student pages and pre-configured TI-Nspire files can be found on the CD that accompanies this book. See *Appendix A* for more information.
2. This experiment is relatively easy to perform. The key is to carefully watch for the formation of condensation on the can. The initial condensation will be extremely small water droplets. The surface of the can will actually look dull instead of shiny.
3. A shiny, metal soup can works well for this lab. Be sure to remove any sharp edges on the can.
4. In Part 1 use enough ice cubes to produce an ice bath.
5. In Part 2 use crushed ice instead of whole ice cubes. The crushed ice allows the students to slowly add the ice and allow each addition to melt. This process provides time for the condensation to form.

SAMPLE RESULTS



Typical graph for Part 1

Part 1	
Room temperature (°C)	23.4
Air temperature close to the can of ice water (°C)	10.9

Experiment 7*Typical graph for Part 2*

Part 2	
Dew point temperature (°C)	8.0

ANSWERS TO QUESTIONS

1. Answers will vary. See the Sample Results.
2. Answers will vary. See the Sample Results.

Freezing and Melting of Water

Freezing temperature, the temperature at which a substance turns from liquid to solid, and melting temperature, the temperature at which a substance turns from a solid to a liquid, are characteristic physical properties. In this experiment, the cooling and warming behavior of a familiar substance, water, will be investigated. By examining graphs of the data, the freezing and melting temperatures of water will be determined and compared.

OBJECTIVES

In this experiment, you will

- Collect temperature data during the freezing and melting of water.
- Analyze graphs to determine the freezing and melting temperatures of water.
- Determine the relationship between the freezing and melting temperatures of water.

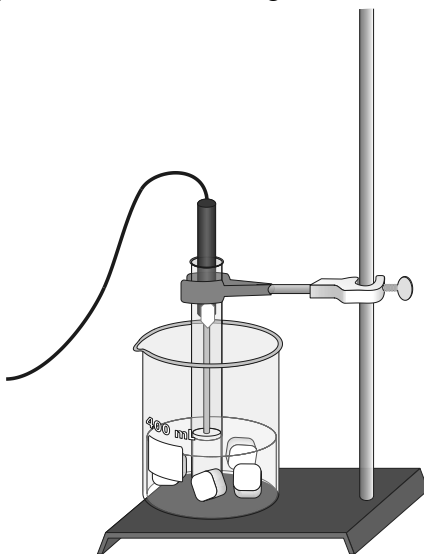


Figure 1





MATERIALS

TI-Nspire handheld **or**
computer and TI-Nspire software
EasyTemp **or** Go!Temp **or**
Temperature Probe and data-collection interface
ring stand with utility clamp
stirring rod



400 mL beaker
10 mL graduated cylinder
test tube (25 x 150 mm)
salt
ice
water


DataQuest 18

PROCEDURE**Part I Freezing**

1. Put about 100 mL of water and 6 ice cubes into a 400 mL beaker.
2. Put 5 mL of water into a test tube and use a utility clamp to fasten the test tube to a ring stand. The test tube should be situated above the water bath. Place the Temperature Probe into the water inside the test tube.
3. Connect the Temperature Probe to the data-collection interface. Connect the interface to the TI-Nspire handheld or computer. (If you are using an EasyTemp or Go!Temp, you do not need a data-collection interface.)
4. Choose New Experiment from the  Experiment menu. Choose Collection Setup from the  Experiment menu. Enter **0.2** as the rate (samples/second) and **900** as the experiment duration in seconds (15 minutes). The number of points collected should be 181. Select OK.
5. When everything is ready, start data collection (). Lower the test tube into the ice-water bath.
6. Soon after lowering the test tube, add 5 spoons of salt to the beaker and stir with a stirring rod. Continue to stir the ice-water bath throughout the remainder of Part I.
7. Slightly, but continuously, move the Temperature Probe during the first 10 minutes of Part I. Be careful to keep the probe in, and not above, the ice as it forms. When 10 minutes have gone by, stop moving the probe and allow it to freeze into the ice. Add more ice cubes to the beaker as the original ice cubes get smaller.
8. Data collection will stop after 900 seconds. Keep the test tube *submerged* in the ice-water bath until Step 11.
9. Analyze the flat part of the graph to determine the freezing temperature of water.
 - a. Identify the flat portion of the graph that represents freezing. Select the data in the flat portion of the graph.
 - b. Choose Statistics from the  Analyze menu.
 - c. Record the mean (average) temperature. This is your value for the freezing temperature of water.

Part II Melting

10. Click the Store Latest Data Set button () to store data from the first run.
11. Start data collection () , then raise the test tube and fasten it in a position above the ice-water bath. Do not move the Temperature Probe during Part II.
12. Dispose of the ice water as directed by your teacher. Obtain 250 mL of warm tap water in the beaker. When 12 minutes have passed, lower the test tube and its contents into this warm-water bath.

13. Data collection will stop after 900 seconds. Analyze the flat part of the graph to determine the melting temperature of water.
 - a. Identify a flat portion of the graph that represents melting. Select a region of data in the flat portion of the graph.
 - b. Choose Statistics from the  Analyze menu.
 - c. Record the mean (average) temperature. This is your value for the melting temperature of ice.
14. A good way to compare the freezing and melting curves is to view both sets of data on one graph. Click **run2** and select All. Both runs will now be displayed on the same graph. Sketch or print this graph.

DATA

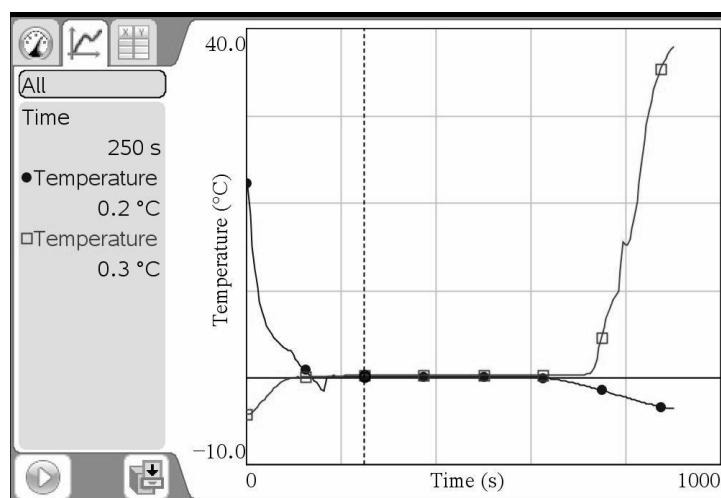
Freezing temperature of water (°C)	
Melting temperature of ice (°C)	

QUESTIONS

1. What happened to the water temperature during freezing? During melting?
2. According to your data and graph, what is the freezing temperature of water? The melting temperature? Express your answers to the nearest 0.1°C.
3. How does the freezing temperature of water compare to the melting temperature of ice?
4. Tell if the *kinetic energy* of the water in the test tube increases, decreases, or remains the same in each of these time segments during the experiment when:
 - a. the temperature is changing before and after the water reaches its freezing point in Part I.
 - b. the temperature remains constant in Part I.
 - c. the temperature is changing before and after the ice reaches its melting point in Part II.
 - d. the temperature remains constant in Part II.
5. In those parts of Question 4 in which there was no kinetic energy change, tell if *potential energy* increased or decreased.

TEACHER INFORMATION**Freezing and Melting of Water**

1. Editable Microsoft Word versions of the student pages and pre-configured TI-Nspire files can be found on the CD that accompanies this book. See *Appendix A* for more information.
2. This entire experiment requires a full 45–50 minute period.
3. The freezing and melting temperatures of water should be within $0^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$ using sensors.
4. Test tubes size 20×150 mm work well. Sizes 25×150 mm and 18×150 mm work, too.
5. A water sample size of 5 mL works well. Larger samples will take more time than is recommended in this procedure.
6. As shown in the first graph in the Sample Results, many of the samples will supercool. Stirring will bring the super-cooled water to the melting temperature plateau.

SAMPLE RESULTS

Typical graph for freezing (●) and melting (□) of water.

Freezing temperature of water ($^{\circ}\text{C}$)	0.02 $^{\circ}\text{C}$
Melting temperature of water ($^{\circ}\text{C}$)	0.03 $^{\circ}\text{C}$

ANSWERS TO QUESTIONS

1. The water temperature stayed constant near 0°C during freezing and melting.

Experiment 18

2. The expected value is 0°C for both the freezing and melting temperatures, but answers may vary slightly.
3. The freezing temperature of water and melting temperature of ice are about the same.
4.
 - a. Average kinetic energy decreases with the temperature decrease at the beginning and end of Part I.
 - b. Since there is no temperature change during freezing, average kinetic energy remains constant.
 - c. Average kinetic energy increases with the temperature increase at the beginning and end of Part II.
 - d. Since there is no temperature change during melting, average kinetic energy is constant.
5. Potential energy decreased during freezing. Potential energy increased during melting.

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Science Objectives

- Students will set up a data collection experiment.
- Students will zero a sensor.
- Students will collect, evaluate, and interpret data.
- Students will determine the coefficient of dynamic friction.
- Students will consider applications of friction.
- Students will see and discuss some of the variabilities of friction.

Math Objectives

- Students will interpret the data they collect.
- Students will use a zero slope line to estimate mean values of data.
- Students will use measured values in a formula with units.
- Students will compare results from a table and from a summary bar graph.

Materials & Advance Preparation

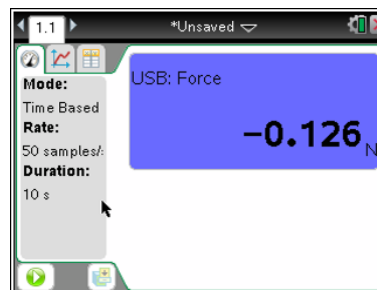
- Friction – A Sticky Subject (student handout activity sheet)
- Dual Range Force Sensor and EasyLink™
- Pieces of string or cord: about 40 cm
- Masses up to 0.5 kg per group (sand, water, rice, mass set)
- Bags to seal mass as needed

About the Lesson

- This lesson involves students investigating friction by measuring the force of friction as a shoe is pulled across a surface.
- As a result, students will:
 - Weigh the shoe and use their data to calculate the coefficient of friction for that case (their “Shoe μ ”).
 - Repeat the experiment with added mass in their shoe and again determine the coefficient of dynamic friction.

TI-Nspire™ Navigator™ System

- Use Screen Capture to show results from different groups.



TI-Nspire™ Technology Skills:

- Open a new document
- Set up a data collection experiment
- Zero a sensor
- Collect data with a sensor
- Use Scratchpad for calculations

Tech Tips:

- Data collection occurs in the Vernier DataQuest™ application, which can be viewed as a meter, a graph, or as a data table.

Lesson Materials:

Student Activity

- Friction – A Sticky Subject_Student.doc
- Friction – A Sticky Subject_Student.pdf



Discussion Points and Possible Answers

Tech Tip: Ensure that the sensor reads zero before each run. Start with a little slack and pull slowly and evenly until the shoe moves at uniform speed.

Begin the lesson by having students show a variety of different styles of shoes they are wearing. Ask how they differ in use. Consider different sport shoes and the surfaces they are designed to be used on: basketball, soccer, hiking, running, dancing, curling, etc. Assign half the groups to perform the data collection on a smooth surface such as a table top or linoleum-covered floor, and the rest to perform the data collection on a rougher surface such as a carpet floor or a clean outdoor sidewalk (or grass or packed snow).

1. When opening a new document, the system might give a warning message about saving the previous document. Decide ahead of time what might have been open on the handheld, and whether it should be saved or discarded.
2. What happens to your handheld?

Answer: The handheld automatically detects the force sensor and opens the Vernier DataQuest™ application.

Tech Tip: If a student does not automatically see the Vernier DataQuest™ application, make sure the force sensor and the EasyLink™ are completely plugged in and that a New Document was created. Choose New Experiment from the Experiment menu if old sensor information appears.

3. Pushing and pulling will give negative and positive force readings. Make sure students zero the sensor in the orientation that it will be used: vertical or horizontal.
4. The second part of the experiment requires students to add some mass to the shoe. You might decide to use known lab masses, in which case their weight can be calculated by $m \times g$. If you are using some other convenient material such as sand, water, or rice, students will need to seal it well in a bag. Hang another larger bag from the sensor and put the mass bag in it. Weigh it all, and put it all in the shoe when needed.



5. Have students discuss and make a prediction of what the graph of force vs. time will look like before beginning to pull the shoe. Prediction is a valuable learning process as it gives the students ownership of what they do and motivation to follow through to find out how well they did in their prediction. There is no right or wrong prediction; it is the process that is important.
6. Students need to run several trials and look at their data critically before storing or overwriting. Some students might have difficulty pulling the shoe consistently; adjusting the direction of the shoe helps. This is a time when interesting results might occur, so encourage students to share what they get and ask questions about what they see. Use some of their examples to illustrate static friction, good data, poor data, chatter, etc.

TI-Nspire Navigator Opportunity: *Screen Captures*

See Note 1 at the end of this lesson.

7. Students might have a blank run (the last one which was not run) or have stored a poor one. They should look at them all, and then display only the good ones.
8. Help the students understand that the model function with a slope of zero is a horizontal line and represents one method of estimating an average value for the force of friction. This is not a statistical calculation but is good enough in this case because friction is quite variable in this scenario.
9. Students can perform their calculations on Scratchpad and write the results in the table provided. Exit Scratchpad by pressing `[esc]`. The calculation will remain in Scratchpad and can be viewed again just by returning to Scratchpad.

Tech Tip: The results will be saved in a spreadsheet on student handhelds. With TI-Nspire Navigator, it is possible to collect and aggregate these results and send them back to the students' handhelds. This is beyond the scope of this workshop.

10. Students will enter all their results from each problem into the spreadsheet they create as Page 1.2, and will manually write them in the worksheet results table. At this point everyone will have an individual copy of their results. Later, they will add other groups' results to the spreadsheet for comparison.



11. Plan ahead for how you want the students to add mass to the shoe. Any convenient mass will do; approximately 1 kg is adequate. If the mass changes the shoe contact area or profile by even a small amount, then the coefficient of friction will probably change as well.

Teacher Tip: It is unlikely that the second value of the coefficient of friction will be the same as the first because the added mass will likely bend the shoe a little and change the contact area with the surface.

12. As time permits, have students experiment with a completely different type of shoe on the same surface, or share results with other groups using the same surface.
13. Discuss with students why it is important to share data from the same surface type. They may then compare their summary charts with those from different surfaces.

Teacher Tip: There will likely be a number of interesting results which can lead to more in-depth discussion of friction: wide variation in the value of Shoe μ , an initial peak for static friction, and highly variable periodic data indicating chatter.

TI-Nspire Navigator Opportunity: Screen Captures

See Note 2 at the end of this lesson.

Tech Tip: The default order of the bars in the summary chart is alphabetical. It can be changed to value order or list order by pressing **ctrl** **Menu** and selecting an option from **Sort**. Colors and labels can be added.

Questions:

1. What is the meaning of the coefficient of friction?

Answer: The coefficient of friction is a measure of how hard it is to slide an object on a surface. The lower the coefficient of friction, the slipperier the situation.

2. What are the units of the coefficient of friction? Why?

Answer: The coefficient of friction is a dimensionless quantity; it has no units. This



is because it is a ratio of two forces and the units divide out, or it is just a comparison number between how hard it is to slide an object compared to the force between the object and surface (normal force).

3. Do all the shoes have the same coefficient of friction on all surfaces? What does this mean?

Answer: Different shoes might have different coefficients of friction on the same surface, and the same shoe might have different coefficients on different surfaces. You should choose the shoes for a particular situation based on how much friction you need.

4. Does adding mass to the shoe change its coefficient of friction? How? Why?

Answer: Adding mass will likely increase the apparent value of the coefficient of friction for most shoes because it will change the contact area or contact profile with the surface. Very stiff boots, like ski boots, would not likely show this effect.

5. Why would you want different types of shoes with different coefficients of friction? Where would you use A or B?

Answer: Shoes are designed to have a certain amount of friction on a particular type of surface. Sometimes you might want your feet to be able to slide easily so you don't trip; other times you want your footwear to have a really good grip so you don't slip.

6. Give several pairings of shoe types to the surface in which they are meant to perform best. Are they meant to be sticky (lots of grip) or is sliding important?

Answer: You would want relatively low friction for dancing shoes on a wooden floor to slide easily, but you wouldn't want to wear them playing soccer on a grass pitch. You want high friction for court shoes to play basketball, but you would probably stumble around if you were to try wearing them while learning some ballroom dance steps.



7. Can you think of any extreme shoe designs (to be very slippery or sticky)? Can you try them?

Answer: Curlers wear one shoe (the slider) that has very low friction to slide easily on ice; rock climbers have shoes with very high friction to get a good grip on rock faces.

8. Research some values of coefficient of friction for your extreme situations. How large and how small can the value of μ be? What would that mean?

Answer: μ can be very low – close to zero – in very slippery situations. Some types of polybutylated rubber can have values in the thousands on some surfaces, for example the old “sticky hand” toy that you throw at the wall and it would just slowly flop down the wall and not slip.

Wrap Up

This activity provides students with an opportunity to think, talk, and work with experimental design issues while learning some basic concepts about friction and its applications. Discussion around different situations relating to friction engage students and provide reinforcement for vocabulary and concept understanding.

Assessment

Students can self-asses their understanding of their experimental set-up and data quality by sharing in their group and with other groups. Students should also be given the opportunity to show and explain their results to the class, another group, or the teacher.

TI-Nspire Navigator

Note 1

Step 5, *Screen Capture*

Here is an ideal place to display screen captures to focus student attention and discussion. Screen captures can be displayed with or without student names. Decide whether you want to praise someone’s work, or just display some representative work anonymously.

Note 2

Step 12, *Screen Capture*

Showing the class comparable summary charts from different surfaces is a good focus for discussion.



This activity promotes the following **Common Core State Standards Mathematical Practices:**

2. Reason abstractly and quantitatively
4. Model with mathematics
5. Use appropriate tools strategically
7. Look for and make use of structure

And the following **Constructivist 5-E's Processes:**

- Engagement
- Explorations
- Explanation
- Elaboration

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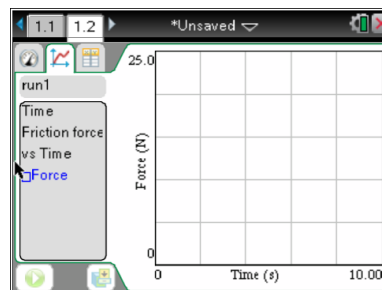
Friction—A Sticky Subject

Student Activity

Name _____

Class _____

In this activity, you will explore the concept of friction as it applies to different types of shoes. You will collect data using a force sensor and share results with your class. Different groups will use different types of shoes on different surfaces and consider the impact of friction in different situations.



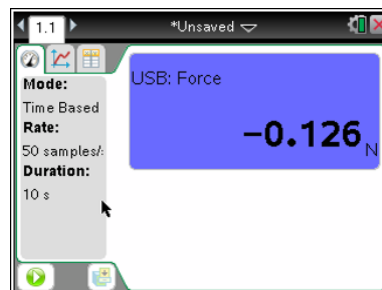
- How many different types of shoes can you name?
- Why are they designed differently?
- What different types of surfaces are they designed for?

Begin this activity by choosing two different types of shoes and obtaining a mass for each as directed by your teacher.

Problem 1

Turn on your TI-Nspire™.

1. Open a new document by pressing and selecting **New Document**. A Save message box might appear. Press to save, or press and to not save; ask your teacher which you should do.
2. Obtain a Dual Range Force Sensor and EasyLink™ adaptor. Set the switch on the force sensor to the 50 N range. Connect the sensor cable to the EasyLink and the EasyLink to your TI-Nspire handheld. Make sure the cables are pushed in securely.
 - What happens to your handheld?



Note the force reading on the meter display on the screen. Gently pull and push on the hook of the force sensor. What happens to the readings? Note the sensor reading when it is placed flat on a table and again when you hold the sensor with the hook vertically down. Because of these differences, the sensor needs to be zeroed for the position in which it is being used.

3. Hold the sensor vertically with the hook down. Press **Menu > Experiment > Set Up Sensors > Zero**.
4. Hang a shoe from the sensor, and note its weight in the table below (or on Scratchpad) (Press to exit Scratchpad.) Repeat with the other shoe. Weigh the mass as



Friction—A Sticky Subject

Student Activity

Name _____

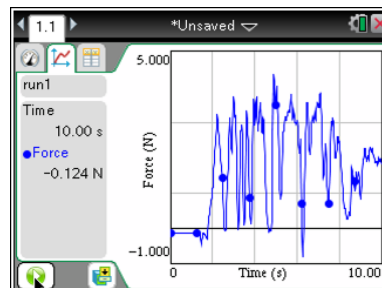
Class _____

directed by your teacher, and record the weight.



5. Next, you will pull your shoe across a horizontal surface. With some slack in the string, you will gradually increase your pull until the shoe starts to move uniformly.
 - What do you think the graph of force vs. time will look like? Sketch your ideal graph in the screen at the top of the first page of this worksheet.

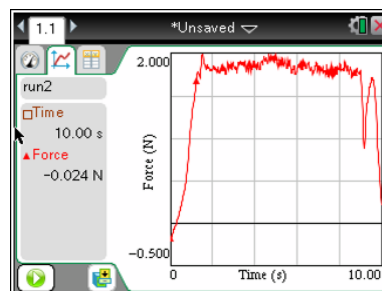
6. Place the force sensor flat on a horizontal surface as assigned by your teacher and again zero the sensor. Place shoe A on the surface, and loop the string on the shoe so that you can pull the shoe horizontally. Loop the other end of the string over the hook of the force sensor with a little slack in the string.

Note the information on your handheld screen. The default settings for the force sensor are to collect time-based data at a rate of 50 samples per second for 10 seconds. This is suitable for this experiment.




Don't store this data. Click start to overwrite.

7. When you are ready to pull the shoe, move your cursor to the Start button  and click  on it. Slowly take up the slack, and gently increase force until you are pulling the shoe at a slow, constant speed across the surface. Data will collect automatically for 10 seconds, and then stop. Look at the data that is displayed in the graphing window.



Store this data and then complete another run.

- If you do not think your trial was suitable (too fast, too rough, ran out of time...) then just click the start button again and redo the trial.
- If your data seems reasonable, press **tab** to highlight the Store button  (file cabinet), and press **enter** to store the data (or just click the Store button).

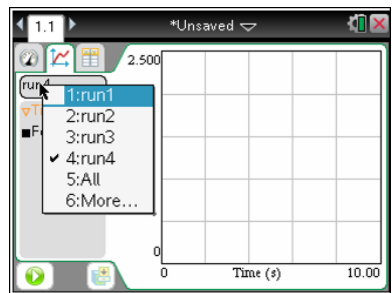
8. Repeat by clicking the Start button and then storing until you have collected at least three good runs with that shoe.

Friction—A Sticky Subject
Student Activity

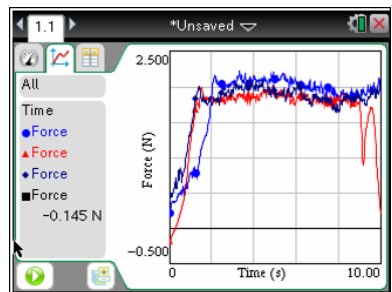
Name _____
 Class _____

9. Move your cursor, and click on the small window near the top left of your screen that says “run4” (or run5 or run6 depending on how many you did). Select **All**, and all your stored runs will be displayed. You might see an initial peak force.

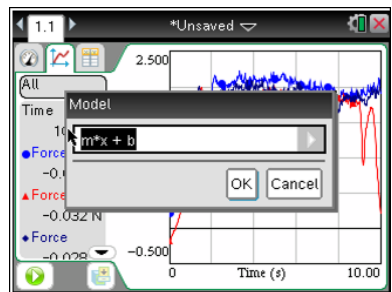
- What does this represent?



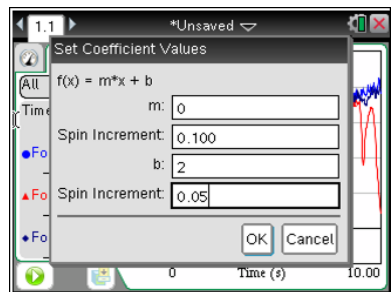
- There will also be a section of relatively constant data values representing the dynamic friction of that shoe sliding on that surface. Estimate a reasonable average value for this data.



10. Press **Menu > Analyze > Model**. A linear model ($m1*x+b1$) is the default. Press **enter**.

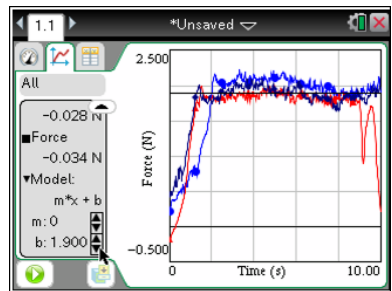


11. Tab through the field cells to make $m1 = 0$, $b1 =$ your estimate, and the bottom Spin Increment = 0.05, and again press **enter**.



12. In the Graph Details window on the left, use your cursor to scroll down to the Model1 info and click on the up or down arrows to change the value of $b1$. When your model line on the graph best matches the linear portion of the data, note the value of $b1$.

- What is your best value of dynamic friction for this shoe on this surface ($b1$)?







Friction—A Sticky Subject

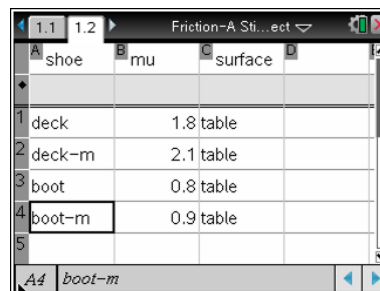
Student Activity

Name _____

Class _____


13. The coefficient of friction between an object and surface (μ) is defined as the force of friction divided by the normal force (the weight of the object). Press  to open the Scratchpad and calculate your “shoe μ ”.

14. Add a new Lists & Spreadsheet page by pressing  > **Insert > Lists & Spreadsheet**. Label Column A **shoe**, Column B **mu**, and Column C **surface**. Enter your information for shoe type, the value of the coefficient of friction, and the surface into the spreadsheet and into the table at the end of this worksheet.




shoe	mu	surface
deck	1.8	table
deck-m	2.1	table
boot	0.8	table
boot-m	0.9	table

Problem 2

15. Start a new problem by pressing  > **Insert > Problem > Add Vernier DataQuest**.
16. Add the extra mass to the shoe according to your teacher's directions, and repeat steps 5 – 8 with the same shoe on the same surface to find the coefficient of dynamic friction for the shoe with some weight in it. Don't forget to use the total weight of the shoe and mass for the final calculation.
17. Enter your values into the table at the end of this activity and into the spreadsheet on Page 1.2 of the .tns file. Use the same shoe name with **-m** appended to it to indicate the shoe had mass in it. (e.g., boot and boot-m).

Problem 3 & 4

18. Start a new problem by pressing  > **Insert > Problem > Add Vernier DataQuest**. Repeat steps 3 – 12 for a different shoe on the same surface. When you are finished, enter your information into the table below and on Page 1.2. Gather results from other groups using the same surface and enter that data into your spreadsheet as well.



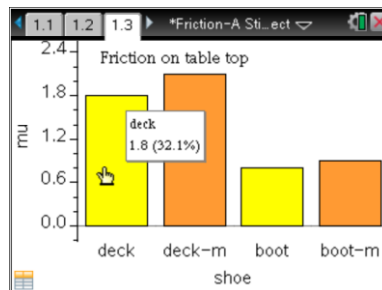
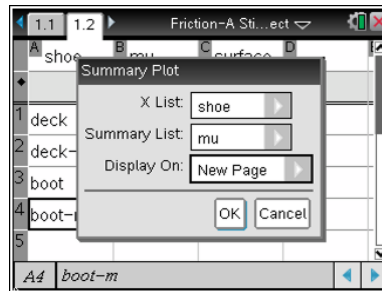
Friction—A Sticky Subject

Student Activity

Name _____

Class _____

13. Go to your results spreadsheet on Page 1.2. Press **MENU > Data > Summary Chart**. For X List, choose *shoe*; for Summary List, choose *mu*; and for Display On, choose *New Page*. Click OK. Discuss and compare results with other groups before answering the questions below.



Results Table

Shoe	Mu (μ)	Surface



Friction—A Sticky Subject

Student Activity

Name _____

Class _____

Questions:

1. What is the meaning of the coefficient of friction?
2. What are the units of the coefficient of friction? Why?
3. Do all the shoes have the same coefficient of friction on all surfaces? What does this mean?
4. Does adding mass to the shoe change its coefficient of friction? How? Why?
5. Why would you want different types of shoes with different coefficients of friction? Where would you use A or B?
6. Give several pairings of shoe types to the surface in which they are meant to perform best. Are they meant to be sticky (lots of grip) or is sliding important?
7. Can you think of any extreme shoe designs (to be very slippery or sticky)? Can you try them?
8. Research some values of coefficient of friction for your extreme situations. How large and how small can the value of μ be? What would that mean?



Activity Overview

This activity demonstrates the data aggregation features of the TI-Nspire™ Navigator™ Teacher Software. You will answer a **Quick Poll** question, and the instructor will aggregate the data. You will then find a line of best fit for the data, and the instructor will collect participants' responses with a **Quick Poll**.

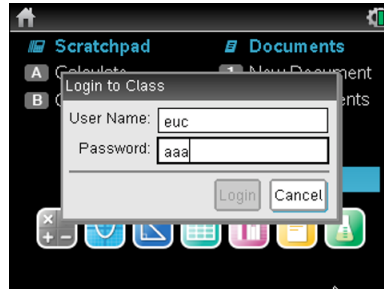
Step 1:

Login to the TI-Nspire™ Navigator™ class.

Turn the handheld on. If the **Login to Class** window is not open, press **on** and select **Settings > Login**. Type the user name. Tab to the **Password** field by pressing **tab**, type the password, and press **enter**.

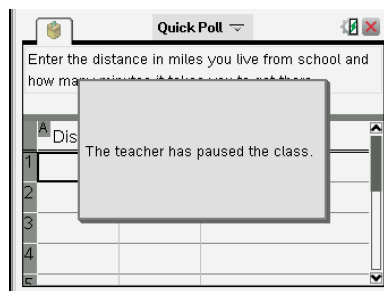
A message appears indicating that you are logged in to class. Close the **Login Successful** window by pressing **enter**.

Go to the **My Documents** folder on the handheld by pressing **on** > **My Documents**. Locate the **Class** folder and open **Aggregating_Data_1**.



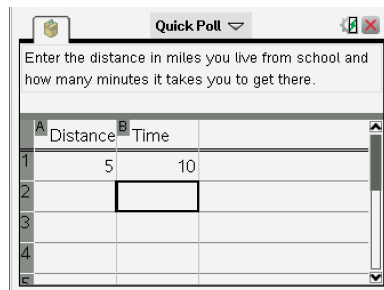
Step 2:

The instructor will send a **Quick Poll** question, and the class will be immediately paused. This gives the instructor the opportunity to discuss the **Quick Poll**.



Step 3:

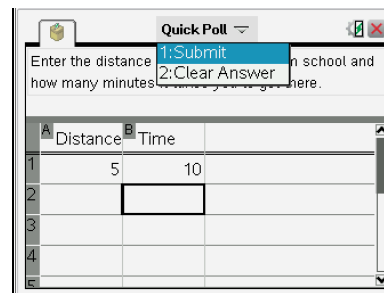
Once class is resumed, enter the appropriate data into the given lists. Type a value for **Distance** and move to the **Time** cell by pressing **tab**. Type a value for **Time** and press **enter**.



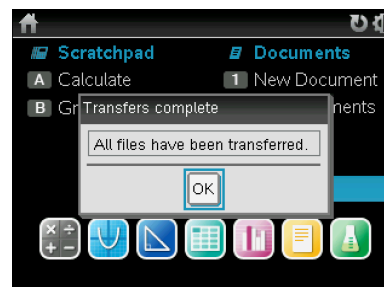
**Step 4:**

Submit your answer to the **Quick Poll**. Use your Touchpad and cursor to access the **Quick Poll** drop-down menu and select **Submit**.

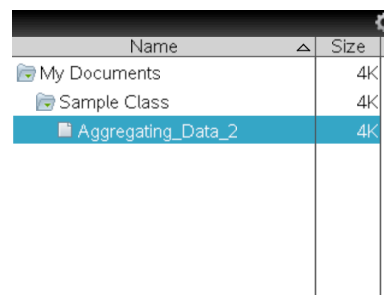
Note: The **Quick Poll** drop-down menu can also be accessed by pressing **[doc]**, and the answer can be submitted by pressing **[1]**.

**Step 5:**

The instructor will aggregate the data and send a TI-Nspire™ document to the class. Once the **Transfers Complete** window appears, press **[enter]**.

**Step 6:**

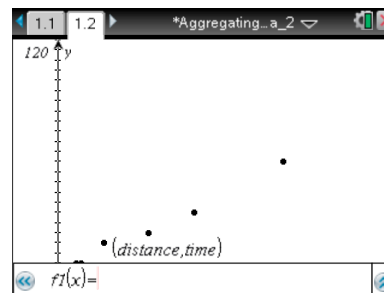
Go to the **My Documents** folder on the handheld by pressing **[home]** > **My Documents**. Locate the Class folder and open **Aggregating_Data_2**.



Note: If a window appears that asks “Do you want to save ‘Unsaved Document’?,” press **[tab]** to select **No** and then press **[enter]**.

Step 7:


The aggregated data is on page 1.1. Move to page 1.2 by pressing **[ctrl]** ▶. Open the entry line by pressing **[tab]**.


**Step 8:**

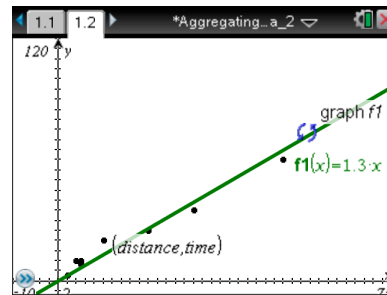
Graph an initial line of best fit by typing an expression and pressing **[enter]**.




Step 9:

Transform the line of best fit to best model the given data. Rotate the line by hovering the cursor over either “end” of the line. When the rotational cursor  appears, rotate the line by clicking and dragging it.

Translate the line by hovering the cursor over the line near the “middle.” When the translational cursor  appears, translate the line up and down by clicking and dragging it.



Step 10:

The instructor will send a **Quick Poll** that asks you enter the equation of your line of best fit. After you type your equation, submit it by clicking the **Quick Poll** drop-down menu and selecting **Submit** or pressing  and selecting **Submit**.

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Activity Overview:

In this activity, you will create a new self-check document with the *Question* application of the TI-Nspire™ Teacher Software. As you create this document, you will explore the properties of each of the four question types: Multiple Choice, Open Response, Equations, and Coordinate Points & Lists. Students can use this self-check document on their handhelds to answer questions and check their responses.

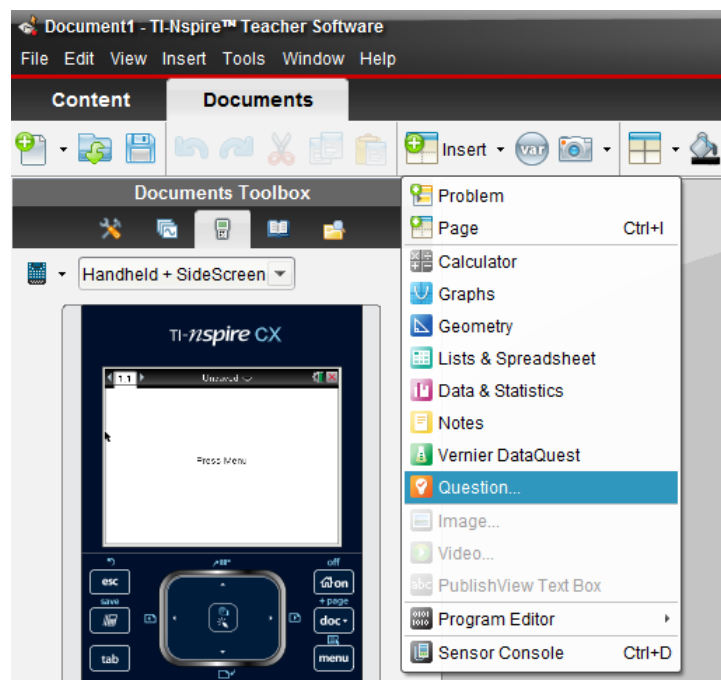
Materials

- TI-Nspire™ Teacher Software

Step 1:

Open the TI-Nspire™ Teacher Software. If the **Welcome Screen** appears when the software is opened, click  to create a new document with a *Question* application as the first page. Otherwise, insert a *Question* application by clicking **Insert** >  **Question**.

Note: TI-Nspire™ documents with *Question* applications can be created only with TI-Nspire™ Teacher Software. Documents with *Question* applications cannot be created with the handheld or Student Software. Therefore, when the Teacher Software is in Handheld view and **Menu** is pressed, the *Question* application does not appear on the handheld screen or in TI-SmartView's list of applications.

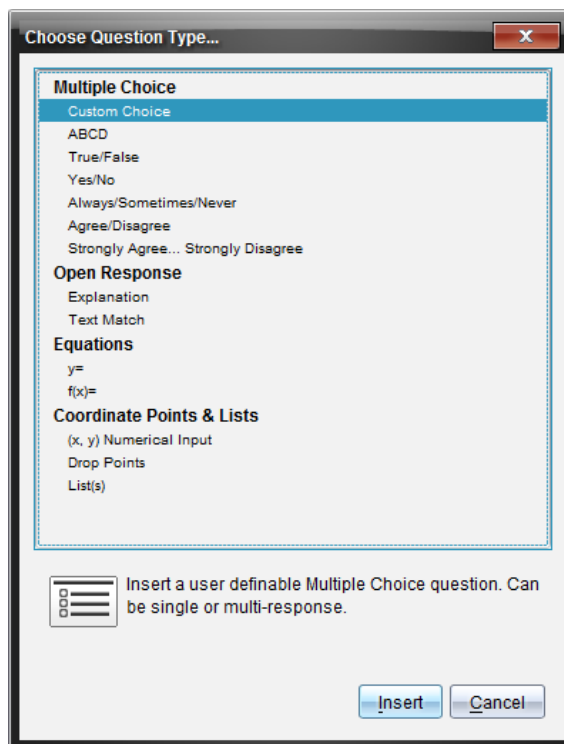




Step 2:

The **Choose Question Type** window appears. Select **Custom Choice** and click **Insert**.

Note: A brief description of the highlighted question type appears at the bottom of the window.

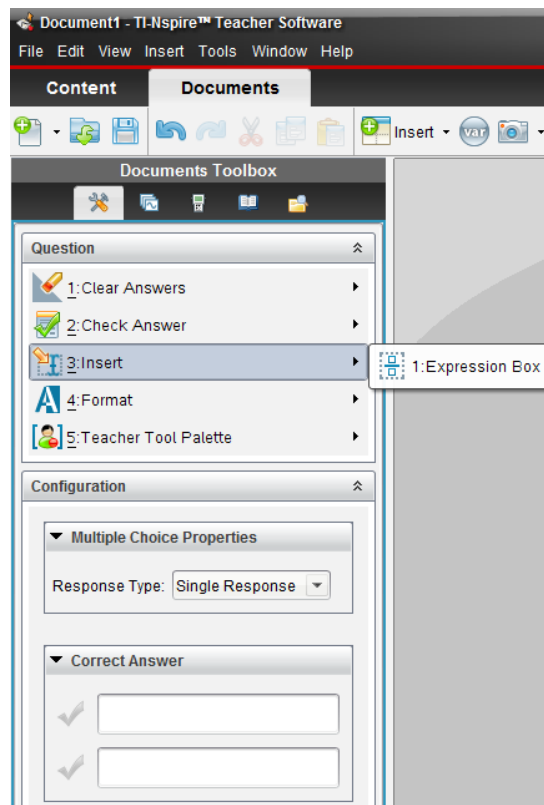


Step 3:

Enter the prompt given below. To type the equation into an Expression Box, go to the **Documents Toolbox**, select the **Document Tools** pane, and select **Insert > Expression Box**.

Solve for x: $\frac{9}{5}x + 32 = 212$

Note: An Expression Box can also be inserted by pressing **ctrl** **M**. A variety of math templates can be accessed in the **Documents Toolbox** by selecting the **Utilities** pane.





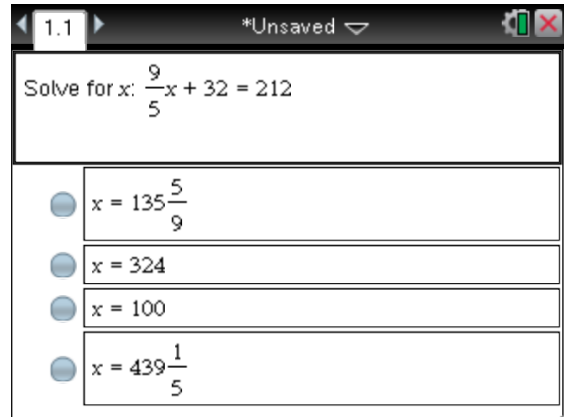
Step 4:

Type the first answer choice into the first field by clicking it and inserting an **Expression Box**. To move to the next field, click in the next field or press .

Type the following answer choices:

$$x = 135\frac{5}{9}, x = 324, x = 100, x = 439\frac{1}{5}$$

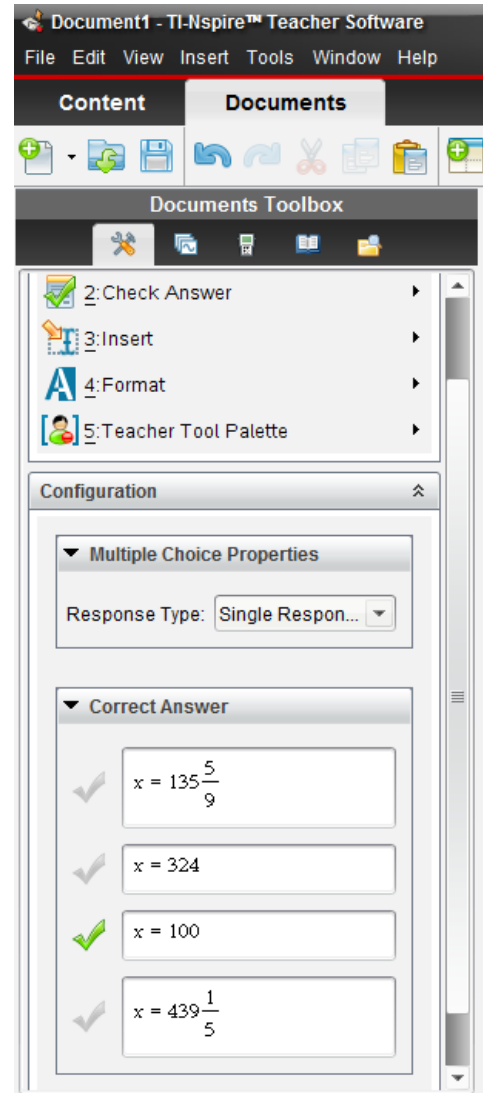
Note: To remove an empty answer field, click in that field and press the **Backspace** key.



Step 5:

As you type answer choices, they automatically appear in the **Correct Answer** fields in the **Configuration** panel. Select the correct answer by clicking the check mark in front of the answer choice.

Note: In the **Configuration** panel, the **Multiple Choice Properties** can be changed to allow a different **Response Type**. **Single Response** allows for one correct answer, while **Multiple Response** allows for multiple correct answers. The **Multiple Choice Properties** and **Correct Answer** fields can be collapsed by clicking ▼ and expanded by clicking ►.



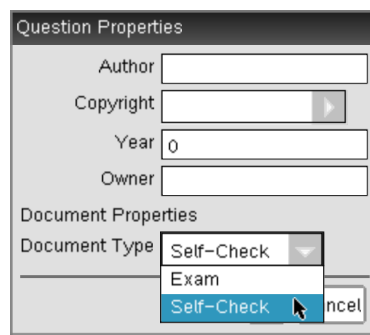


Step 6:

To allow students to check their answers, select Teacher Tool Palette > Question Properties. Change the Document Type to Self-Check and click OK.

Note: The **Document Type** applies to all questions in the current document. Therefore, all questions in the document will become **Self-Check**.

After students answer a question, they can check their answers by pressing and selecting **Check Answer**. A message (“Your current answer is correct.” or “Your current answer is incorrect.”) is displayed. If the answer is incorrect, two options appear: **Show Correct Answer** and **Try Again**.



Step 7:

Insert a new question by clicking on the **Insert** menu and selecting **Question > Open Response > Text Match**. Inserting an **Expression Box** for the equation, type the following into the question field:

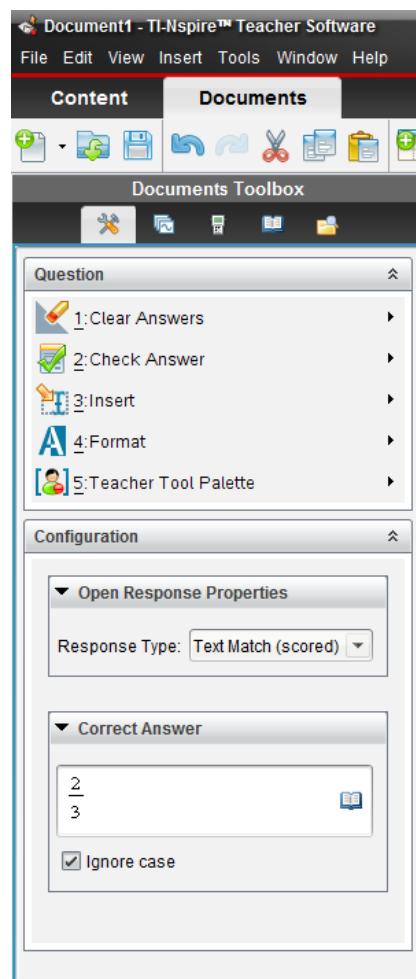
What is the slope of the line $2x - 3y = 12$?

Step 8:

Using an **Expression Box**, type $\frac{2}{3}$ into the **Correct Answer** field. To access math templates and symbols, click the **Utilities** icon in the **Correct Answer** field. Double-click the **Fraction** template, and close the window by clicking **Cancel**.

Note: The **Explanation** response type (not scored) allows students to give answers that closely match the correct answer. When students select **Check Answer**, the correct or incorrect answer message will not be displayed. However, any suggested response entered by the teacher will be displayed.

The **Text Match** response type (scored) requires students to exactly match the correct answer, including templates (if applicable). When students select **Check Answer**, the correct or incorrect answer message will be displayed.





Step 9:

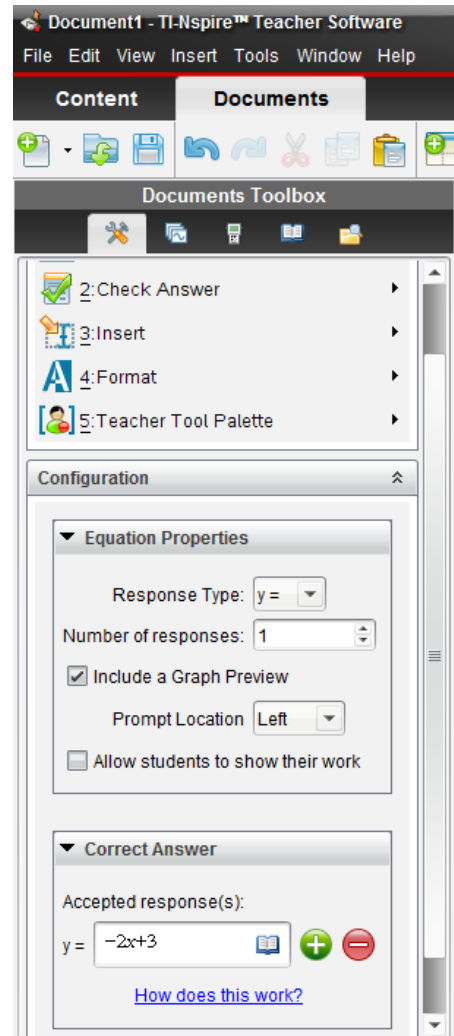
Insert a new question by clicking the **Insert** menu and selecting **Question > Equation > $y =$** . Type the following into the question field:

Write the equation of a line whose slope is -2 and whose y -intercept is 3 .

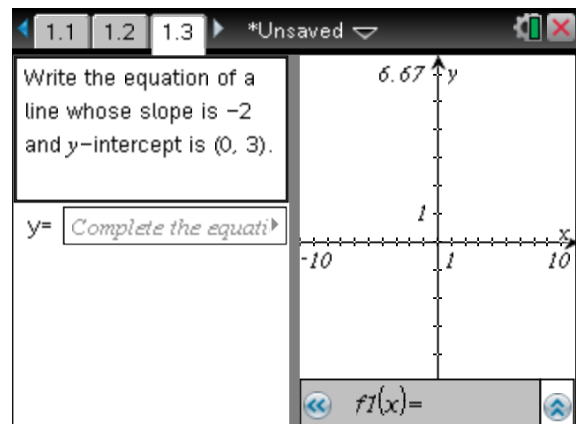
Step 10:

In the **Configuration** panel, choose **Equation Properties** and check the box for **Include a Graph Preview**. In the **Correct Answer** field, type $-2x + 3$ as an accepted response.


Note: In the **Configuration** panel, the **Equation Properties** can be changed to allow **Response Type** in $y =$ or $f(x) =$ notation. The number of responses and prompt location can be changed, and students can be allowed to show their work in a series of blank fields.



Note: By changing the **Equation Properties** to **Include a Graph Preview**, the page layout of the question is automatically changed and a *Graphs* application is inserted on the right. When an expression is typed into the $y =$ field, it automatically appears on the graph. If **enter** is pressed, another $y =$ field appears.



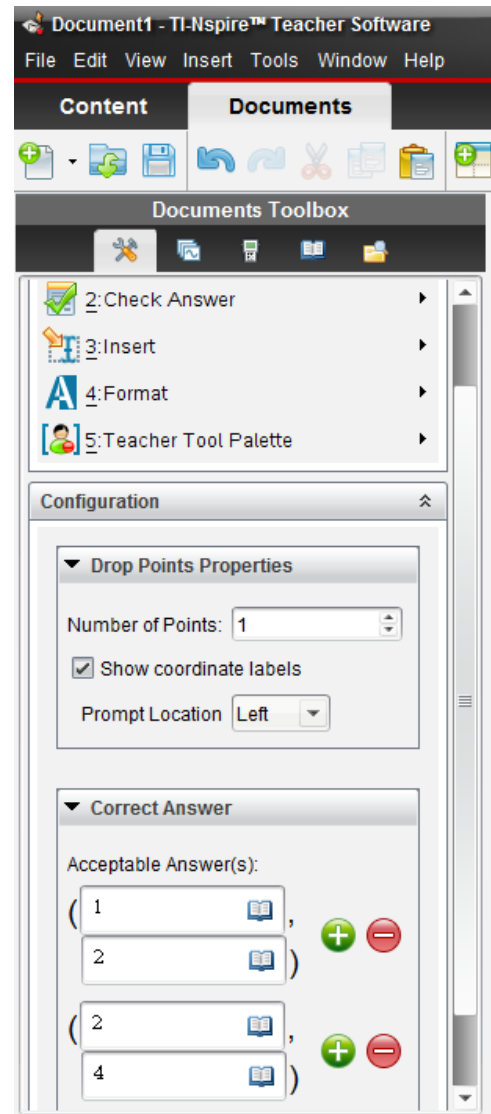
**Step 11:**

Insert a new question by clicking the **Insert** menu and selecting  **Question > Coordinate Points & Lists > Drop Points**. Type the following into the question field:

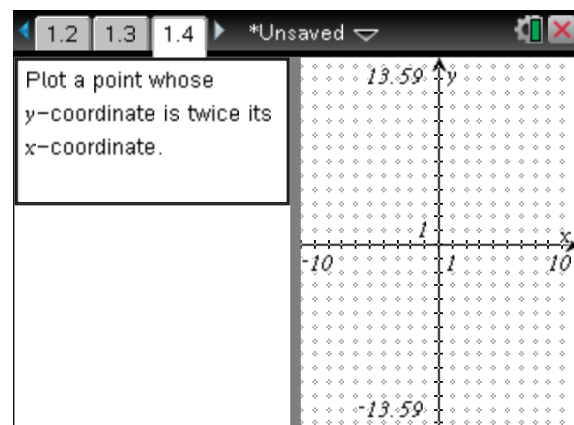
Plot a point whose y-coordinate is twice its x-coordinate.

Step 12:

In the **Correct Answer** field, enter (1, 2) as an acceptable answer. Add an additional acceptable answer field by clicking the green addition icon. Enter (2, 4) as an acceptable answer.



Note: The **Drop Points** question type automatically includes a *Graphs* application with a grid.





Activity Overview:

In this activity, you will learn how to insert images into *Graphs*, *Geometry*, and *Question* applications. You will also learn how to move, resize, compress, and stretch an image, as well as make it appear more transparent.

Materials

- TI-Nspire™ Teacher Software

Step 1: Open the TI-Nspire™ Teacher Software. If the **Welcome Screen** appears when the software is opened, click to create a new document with a *Graphs* application as its first page. Otherwise, insert a *Graphs* application by clicking **Insert** > **Graphs**.

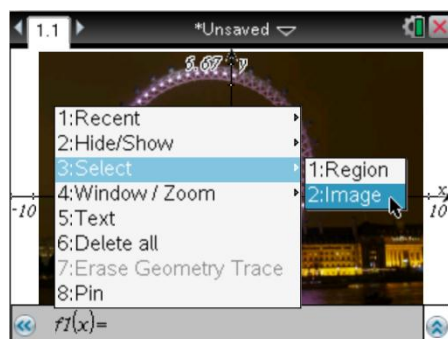
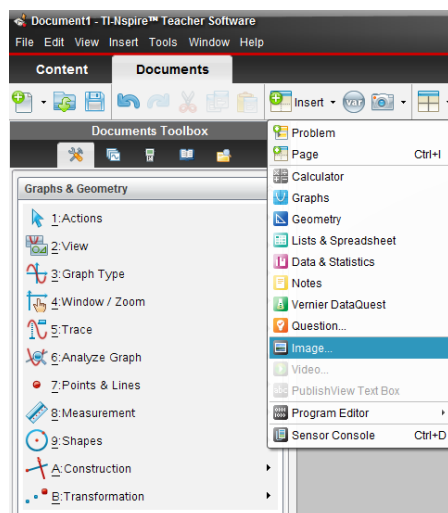
Note: Images can be inserted into *Graphs*, *Geometry*, *Data & Statistics*, *Notes*, and *Question* applications.

Step 2: Insert an image into the *Graphs* application by clicking **Insert** > **Image**. A selection of images is preloaded in the **My Documents > TI-Nspire > Images** folder. Select **Ferris Wheel.jpg** and click **Open**.

Note: Although the TI-Nspire™ Teacher Software comes with a selection of preloaded images, all .jpg, .jpeg, .bmp, and .png images are supported. The optimal format for images is .jpeg 560×240. Images substantially larger than this may take the document longer to load on the handheld. Images appear in grayscale for TI-Nspire™ Touchpad and Clickpad handhelds updated to the latest operating system.

Step 3: Images can be moved, resized, and vertically or horizontally stretched or compressed. To select an image in the *Graphs*, *Geometry*, or *Question* application, right-click the image and choose **Select > Image**. To select an image in the *Notes* application, click the image. To move the image, grab and move its interior. To resize the image, grab and move a corner. To vertically stretch or compress the image, grab and move the top or bottom edge. To horizontally stretch or compress the image, grab and move the left or right edge.

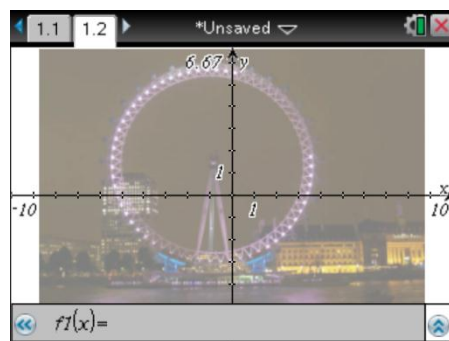
Note: To right-click on a handheld, press **ctrl** . To grab an object, press **ctrl** . To let go of an object, press **esc**.





Step 4: To make an image appear more transparent, insert it in a *Geometry* application and then change the page to a *Graphs* application.

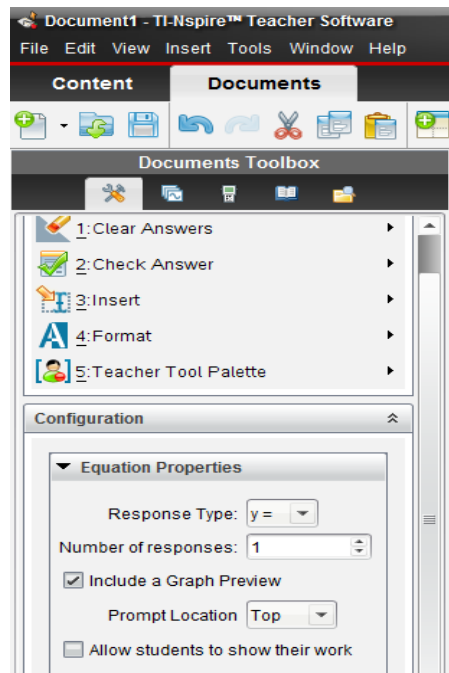
Insert a *Geometry* application by clicking **Insert** > **Geometry**. Then insert an image by selecting **Insert** > **Image**. Again, choose **Ferris Wheel.jpg**. Change the *Geometry* application to a *Graphs* application by selecting **View** > **Graphing**.



Step 5: Insert a *Question* application by clicking **Insert** > **Question**. The **Choose Question Type** window appears. There are four general question types: **Multiple Choice**, **Open Response**, **Equations**, and **Coordinate Points & Lists**. Images can be inserted into each question type. Select **Equation** > **y =**.

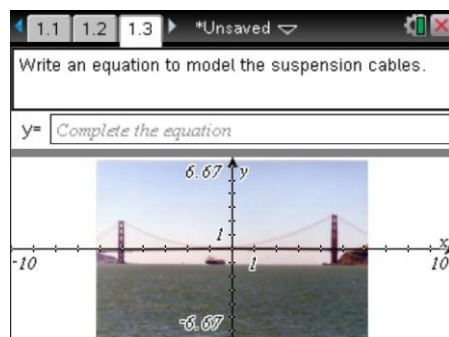
Step 6: To change the question properties in the **Document Tools** pane, go to the **Configuration** panel. In the **Equation Properties** panel, select **Include a Graph Preview** and change the **Prompt Location** to **Top**.

Note: To maximize the area of the **Graph Preview**, grab and move the gray bar separating the question and answer fields from the **Graph Preview**.



Step 7: Insert an image into the **Graph Preview** by clicking the graph and selecting **Insert** > **Image**. Choose **Bridge1.jpg** and click **Open**. Type the following into the question field:

Write an equation to model the suspension cables.





Activity Overview:

The **Press-to-Test** feature enables you to quickly prepare student handhelds for exams by temporarily disabling folders, documents, and select features and commands. In this activity, you will learn how to enable and disable **Press-to-Test**.




Materials

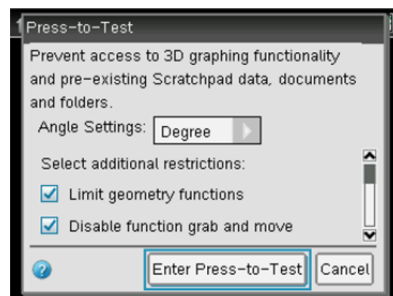
- TI-Nspire™ handheld-to-handheld or handheld-to-computer USB connection cable

Step 1: To enable **Press-to-Test** on TI-Nspire™ with Touchpad and TI-Nspire CX™, first ensure that the handheld is turned off. Press and hold  and  until the **Press-to-Test** screen appears.



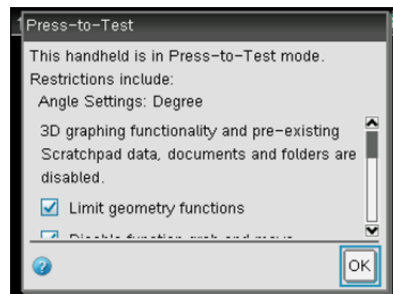
Note: To enable **Press-to-Test** on TI-Nspire™ with Clickpad, press and hold , , and .

Step 2: By default, **Press-to-Test** disables 3D graphing and pre-existing **Scratchpad** data, documents, and folders. The angle settings can be changed by pressing , selecting the appropriate setting, and pressing  or .



By default, all of the commands and features listed are disabled. To enable a feature or command, uncheck its box. Keep all boxes checked and enable **Press-to-Test** mode by selecting **Enter Press-to-Test**.

Step 3: Once **Press-to-Test** is enabled, the handheld reboots. A dialog box confirms that the handheld is in **Press-to-Test** mode and the restrictions are listed. Click **OK**.



Step 4: When **Press-to-Test** is enabled, the LED at the top of the handheld begins blinking. Green indicates that all restrictions are selected (default), while yellow indicates that one or more restrictions are unselected. During the initial reboot, the LED alternates between red and, depending on the restrictions, either green or yellow.





Step 5: Create a new document, add a *Graphs* page, and press **menu**. Since geometry functions are limited, observe that the **Graph Type**, **Analyze Graph**, **Measurement**, **Construction**, and **Transformation** menus are not accessible.

Note: The lock icon at the top of the handheld screen indicates that **Press-to-Test** is enabled.

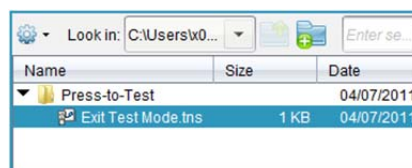
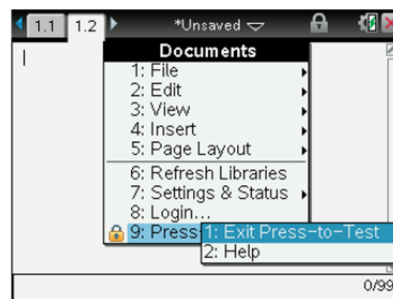
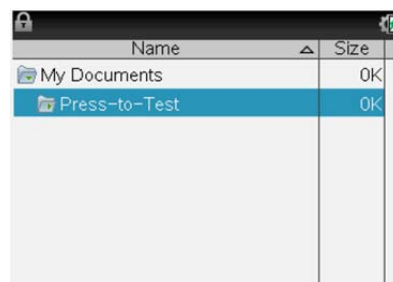
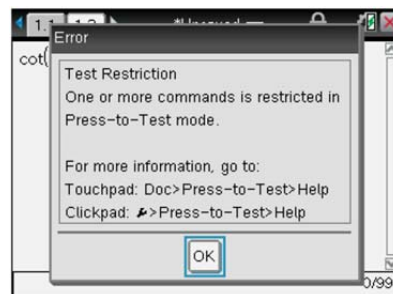
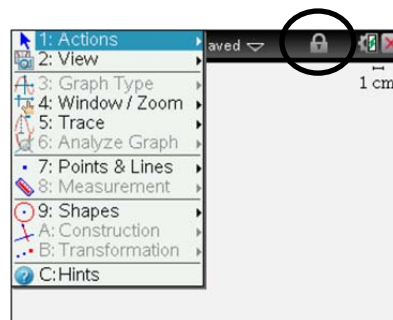
Step 6: Add a *Calculator* application by pressing **doc** and selecting **Insert > Calculator**. Type $\cot(\pi/2)$ and press **enter**. Since trigonometric functions are limited, an error message appears. The dialog box tells students how to access additional information about the restrictions. Select **OK**.

Step 7: Go to **My Documents** by pressing **on** > **My Documents**. When **Press-to-Test** is enabled, a **Press-to-Test** folder is created in **My Documents**. All other folders and documents present on the handheld before **Press-to-Test** mode was entered are inaccessible.

Step 8: **Press-to-Test** can be disabled by connecting two handhelds using the handheld-to-handheld USB connection cable. While the handhelds are connected, press **doc** and select **Press-to-Test > Exit Press-to-Test**. A handheld in **Press-to-Test** mode can be disabled regardless of whether the other handheld is in **Press-to-Test** mode.

Press-to-Test can also be disabled with the TI-Nspire™ Navigator™ system. Begin a class in the TI-Nspire™ Navigator™ Teacher Software. Students can then press **doc** and select **Press-to-Test > Exit Press-to-Test**.

Step 9: Alternatively, **Press-to-Test** can be disabled with TI-Nspire™ Teacher Software or TI-Nspire™ Navigator Teacher Software by creating a document named **Exit Test Mode.tns** and transferring it to connected handhelds. Go to the **Tools** menu and select **Transfer Tool**. Click **Add to Transfer List** and select the document **Exit Test Mode.tns**. In the Transfer List, select **Exit Test Mode.tns**. In the **Edit Destination Folder** field, select the **Press-to-Test** folder and click **Change**. Then click **Start Transfer**.

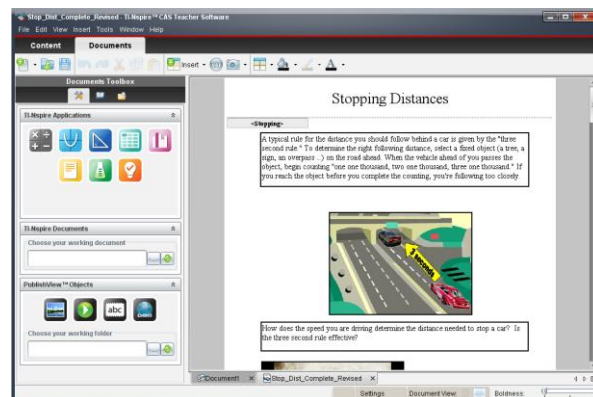


Objectives

- Demonstrate features of PublishView™ documents
- Create a PublishView™ document like the sample provided
- Provide an opportunity for individual exploration of the PublishView™ feature

Activity Materials

- Computer with software
- PublishView™-specific files



Part 1: TI-Nspire™ Teacher Software and PublishView™ (≈ 10 minutes)

The Instructor will do a brief overview of PublishView™ features using pre-made files.

Part 2: Creating a PublishView™ document (≈ 45 minutes)

The instructor will guide participants through the steps needed to create a PublishView™ document like the one shown in the PDF file:

Stop_Dist_Create.pdf

Part 3: Exploring PublishView™ on your own (≈20 minutes)

PublishView™ Technology Skills:

- Insert TI-Nspire™ applications
- Insert PublishView™ objects
- Insert TI-Nspire™ document pages
- Convert a PublishView™ document to a TI-Nspire™ document
- Apply color appropriately

Activity Files:

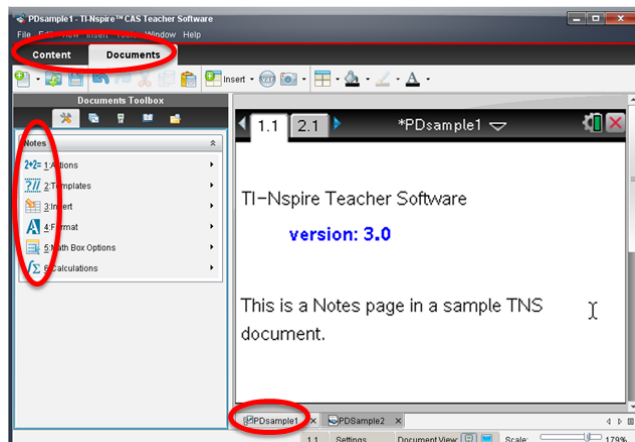
3_second_rule.jpg
StoppingDistance.flv
StopDistData.jpg
React_time.tns
Vehicle_Type.tns
React_and_Vehicle.tns

Useful links:

<http://www.teachersdomain.org/>
<http://www.ortrucking.org/stopping.htm>
<http://www.visualexpert.com/Resources/reactiontime.html>
[http://www.hayshighindians.com/academics/classes/csadams/tapestry/Relevant%20coursework/Reaction times and distances.htm](http://www.hayshighindians.com/academics/classes/csadams/tapestry/Relevant%20coursework/Reaction%20times%20and%20distances.htm)

Part 1: TI-Nspire™ Teacher Software

The TI-Nspire™ Teacher Software allows you to work with two types of documents—TI-Nspire™ documents and PublishView™ documents.



A TI-Nspire™ Document

When working on an application page of a TI-Nspire™ document, the menu icons are arranged vertically in the panel on the left. As in previous versions of the software, you can work on the document in Computer View or in Handheld View.

A TI-Nspire™ document consists of problems and pages.



A PublishView™ Document

This is a different type of document—it is not a different view of a TI-Nspire™ document.


A PublishView™ document consists of problems and sheets.

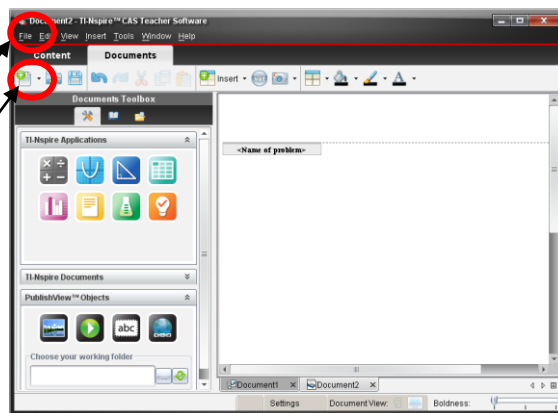
- You can use PublishView™ to create lesson plans and student documents (used in software). PublishView™ documents can also be converted into TI-Nspire™ documents for use on the handheld or in the Student or Teacher Software.
- Image files which can be inserted: .jpg .jpeg, .bmp, .png format
- Only videos in Flash Video format (.flv) can be inserted. If you have a video in a different file format (.mov, for example), insert a hyperlink to the file rather than inserting the file.
- When a PublishView™ document is converted to a TI-Nspire™ document, PublishView™ objects will not convert to become part of the TI-Nspire™ document. If you wish for text or images to convert, use an appropriate TI-Nspire™ application.
- View → PublishView™ Layout Options:
 Show Object Borders shows all borders. Hide Object Borders hides all borders.
 Show Problem Breaks shows all breaks. Hide Problem Breaks hides all brakes.

Part 2: Creating a PublishView™ document

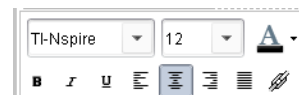
The instructor will guide you through the steps needed to create a basic PublishView™ document.



Instructions for creating the PublishView™ document about Stopping Distances.



1. Launch the TI-Nspire™ Teacher Software and be sure to be in the Documents workspace.
2. Start a new PublishView™ document: Use File ▶ New PublishView™ Document or click the icon .
3. Move the cursor around the software and hover over icons to view their functionality.



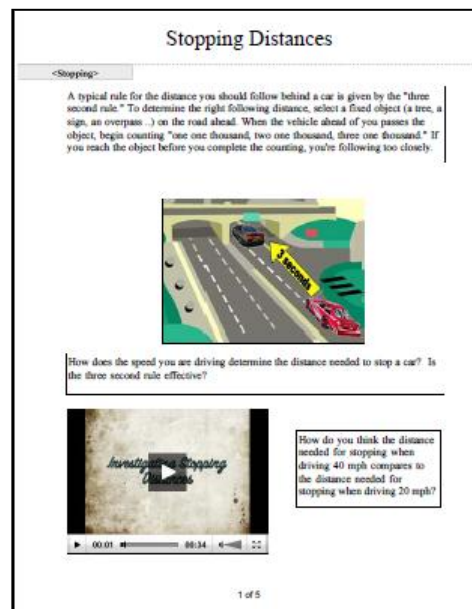
4. Click at the top of the sheet to type the name **Stopping Distance** in the header. Note that a Text toolbox appears. Click outside the text box to make the toolbox disappear. (When you click inside a Text box, the text tools will appear.)



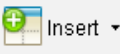
5. Click in the box for <Name the Problem> and type “Stopping.”
6. To insert a PublishView™ Text Box, use the  Insert ▾ menu. Alternatively, you could click and drag the text icon  from the PublishView™ Objects of the Documents Toolbox on the left. Type something about the Three-Second Rule for driving such as: “A typical rule for the distance you should follow behind a car is given by the three-second rule.” Click on the border of the text box and resize it to fit the text.


7. To insert an image, use the  Insert ▾ menu. Alternatively, you could click and drag the image  from the PublishView™ Objects of the Documents Toolbox on the left. Choose the file: 3_second_rule.jpg. Click on the border of the image to move or resize the image as desired.

8. Insert a PublishView™ Text Box and type some text such as: How does the speed you are driving determine the distance needed to stop a car? Is the three-second rule effective? Watch the video to view some stopping distances.



Sheet 1

9. Insert a Video using the file: StoppingDistance.flv. Position and resize as desired.
(You may wish to explore other related videos available at educational websites such as www.teachersdomain.org.)
10. Insert a PublishView™ Text Box near the video. Pose questions about the apparent stopping distance when driving 40 mph compared to the apparent stopping distance when driving 20 mph. Position and resize as desired.
11. Insert a PublishView™ sheet using  or Ctrl I.
12. Insert a TI-Nspire™ Graphs application. Resize it to increase its size. Hide the Entry Line, hide the Chevron, and hide the Axes.
13. With the Graphs application still selected, insert the image StopDistData.jpg
14. Insert a TI-Nspire™ Lists & Spreadsheet application. Name the lists as follows:
Column A is **speed_mph**, Column B is **react_ft**, Column C is **brake_ft**.

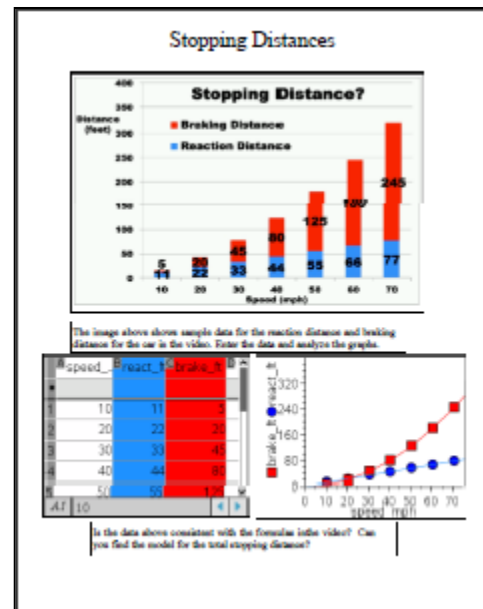
15. To select a color for Column B, first arrow up in Column B (react_ft) until the entire list is selected. Click on the Fill icon  on the icon toolbar of the software and choose dodger blue for the fill color of Column B. Arrow up in Column C (brake_ft) until the list is selected and choose red for the fill color.

16. Enter the data values for row 1: speed_mph = 10, react_ft = 11, brake_ft=5.

17. Insert a TI-Nspire™ Data & Statistics application.

18. Click to add the variable **speed_mph** along the horizontal axis and click to add **react_ft** along the vertical axis.

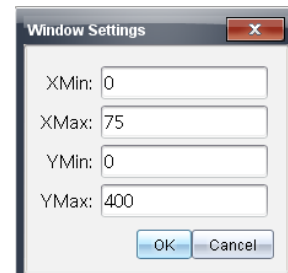
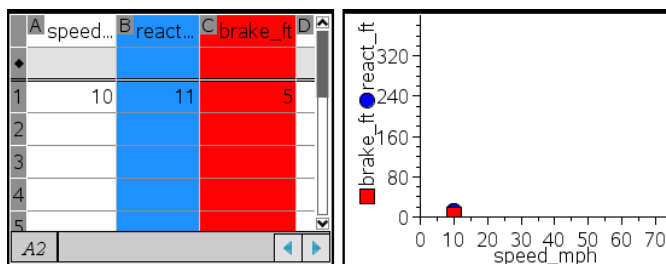
19. When the Data & Statistics application is selected (click inside the APP), you can see its menu in the Documents Tools panel of the Document Toolbox. **Choose Plot Properties > Add Y Variable** and choose **brake_ft**.



Sheet 2

20. Change the plot colors to match the column colors. Right click on the data point (10, 11) and change the color to blue to match the column for **react_ft**. Right click on the data point (10, 5) and change the color to red.

21. With the Data & Statistics application selected, choose **Window/Zoom > Window Settings** in the Documents Tools panel and change the settings as shown in the figure at the right.



22. Insert a PublishView™ Text Box and type the text: “Can you find a model for the total stopping distance?”


23. Save this file as Stopping_Distance. It will be a TI-Nspire PublishView™ document and is saved with a .tnsp extension.

24. With the document open, click on the File menu. Choose Convert to ► TI-Nspire™ Document. This is a new TI-Nspire™ document that has not been named or saved.

(The remaining steps are optional as time permits)

25. Insert a Problem. (Insert a sheet first, if needed.)

26. Click in the box for <Name the Problem> and type Reaction Time.

27. In the TI-Nspire™ Documents space on the left, click on the  to browse and find the file React_time.tns. Open the file.

28. The pages of the TI-Nspire™ document will appear in the left panel. Click, drag, and drop each page of the TI-Nspire™ document onto the PublishView™ Sheet. Resize and reposition as desired.

29. Repeat steps 25 – 28 but name the problem Vehicle Type and add pages from Vehicle_Type.tns.



30. Repeat steps 25 – 28 but name the problem Reaction and Vehicle Type and add pages from React_and_Vehicle.tns.

Transferring Documents Using the TI-Nspire™ Teacher Software

TI PROFESSIONAL DEVELOPMENT

TEACHER NOTES

Activity Overview:

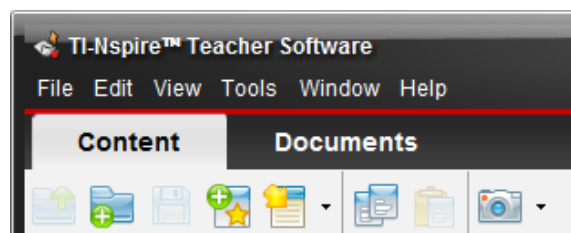
In this activity, you will use the **Content** and **Documents** Workspaces of the TI-Nspire™ Teacher Software to transfer files between the computer and the handheld. You will view information about a connected handheld, send a document from the computer to the handheld, and preview the contents of a document. You will also learn how to transfer files using the **Content Explorer** in the **Documents Workspace**.

Materials

- TI-Nspire™ Teacher Software
- TI-Nspire™ handheld
- TI-Nspire™ USB connection cable

Step 1:

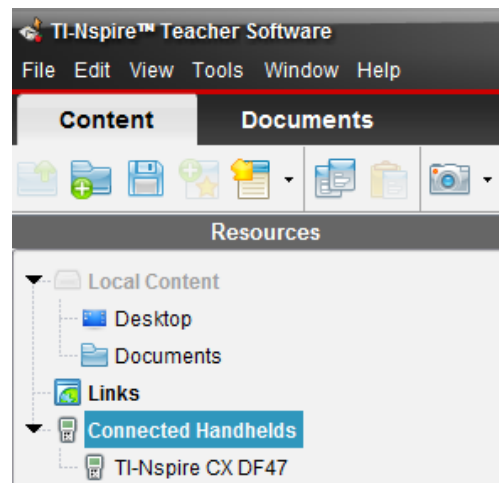
Open the TI-Nspire™ Teacher Software. If the **Welcome Screen** appears when the software is opened, go to the **Content Workspace** by clicking **View Content**. Otherwise, go to the **Content Workspace** by clicking the **Content** tab.



Step 2:

Connect a TI-Nspire™ handheld to the computer using the USB connection cable. In the **Resources** panel, click **Connected Handhelds**.

Note: Multiple handhelds can be connected to the computer using multiple USB ports, USB hubs, or the TI-Nspire™ Docking Station. If multiple handhelds are connected to the computer, then multiple handhelds appear in the list of **Connected Handhelds**.



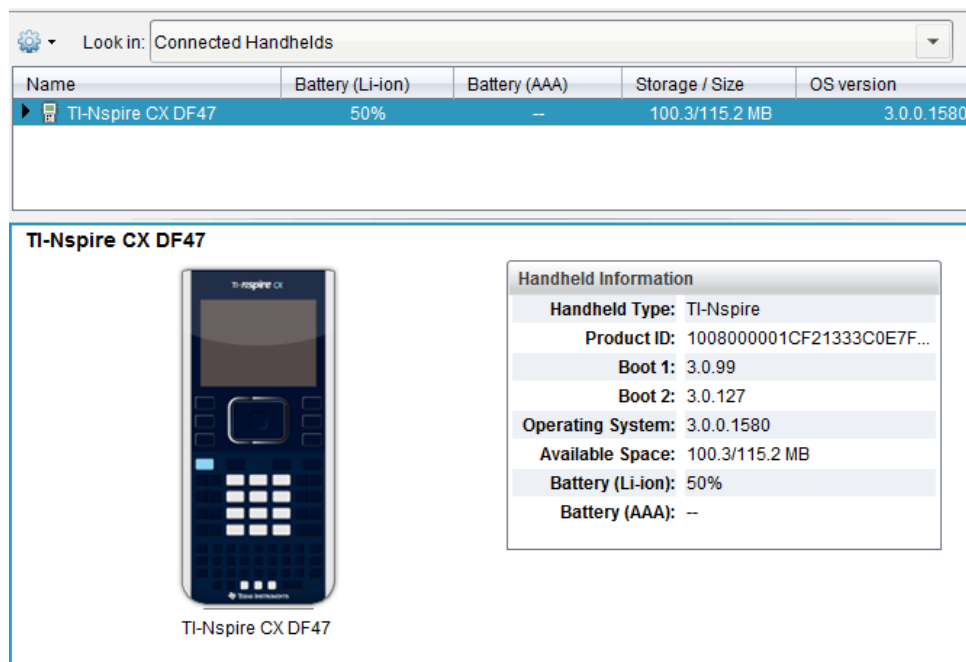


Transferring Documents Using the TI-Nspire™ Teacher Software

TI PROFESSIONAL DEVELOPMENT

Step 3:

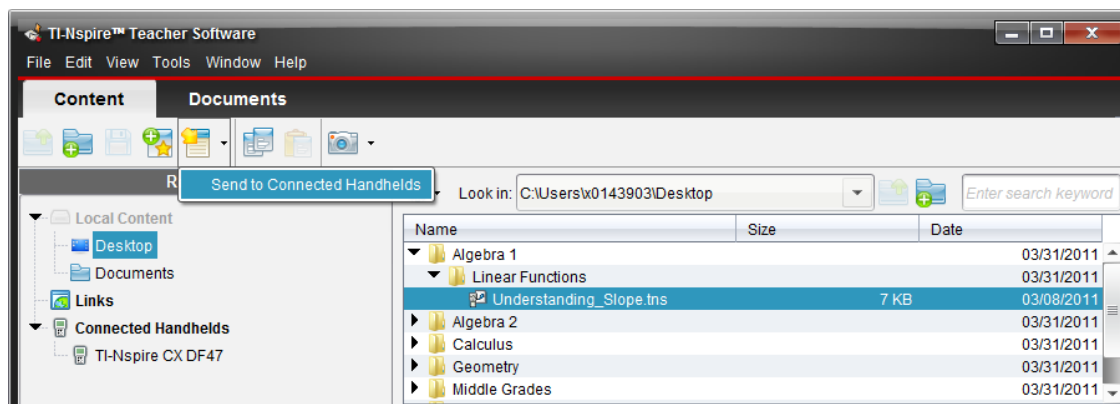
The connected handheld appears in the **Content Window**, along with battery, storage, and OS information. More detailed information appears in the **Handheld Information** window.



Step 4:

Locate a TI-Nspire™ document on your computer by going to the **Resources** panel and accessing **Local Content**. To locate a file on the desktop, click **Desktop**. To locate a file in the **My Documents** folder, click **Documents**. Send the TI-Nspire™ document to the connected handheld by clicking the file and selecting **Send to Connected Handhelds**.

Note: The TI-Nspire document can also be sent to the connected handheld by right-clicking the file and selecting **Send to Connected Handhelds**.



Transferring Documents Using the TI-Nspire™ Teacher Software

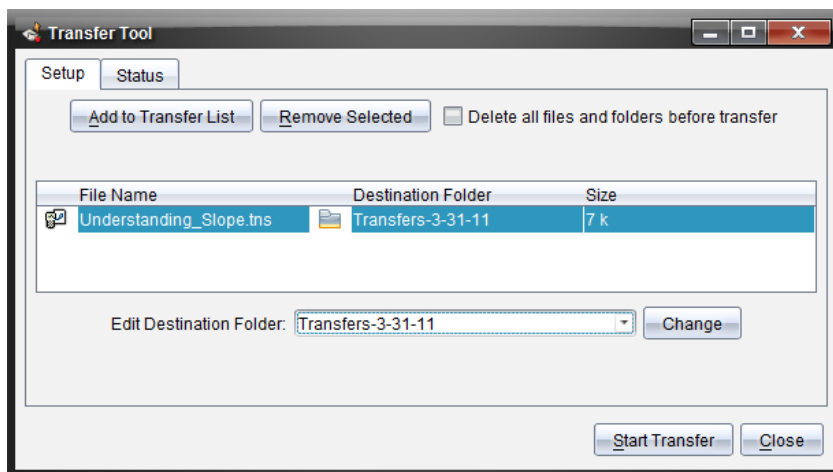
TI PROFESSIONAL DEVELOPMENT

TEACHER NOTES

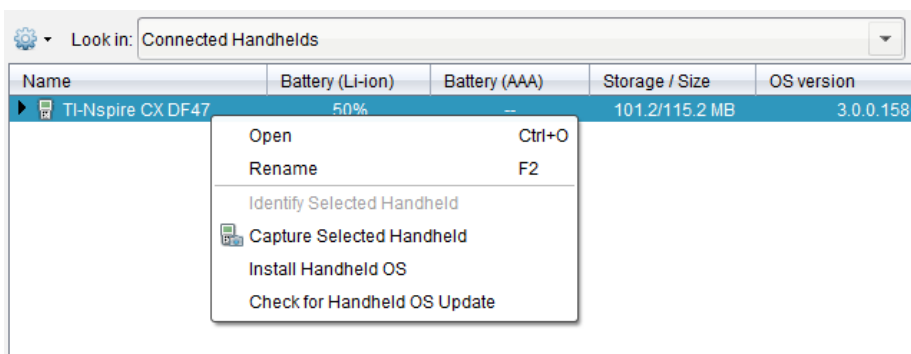
Step 5:

Upon selecting **Send to Connected Handhelds**, the **Transfer Tool** window appears, the **Setup** tab is active, and the current TI-Nspire™ document is listed. To add an additional file to the transfer list, select **Add to Transfer List** and locate the additional file. To remove a file from the transfer list, select the file and click **Remove Selected**.

The **Destination Folder** is the folder on the handheld where the file will be placed. To change the **Destination Folder**, select the file and go to the **Edit Destination Folder** field. To select an existing folder, select it from the drop-down menu and click **Change**. To create a new folder, type its name into the field and click **Change**. To send the file to the handheld, click **Start Transfer**. Once the **Status** tab indicates that the transfer is complete, click **Stop Transfer**

**Step 6:**

To view the files and folders on a connected handheld, right-click the handheld and select **Open**. From the right-click menu, the selected handheld can be renamed, its current screen can be captured, the OS can be checked, and an updated OS can be installed.



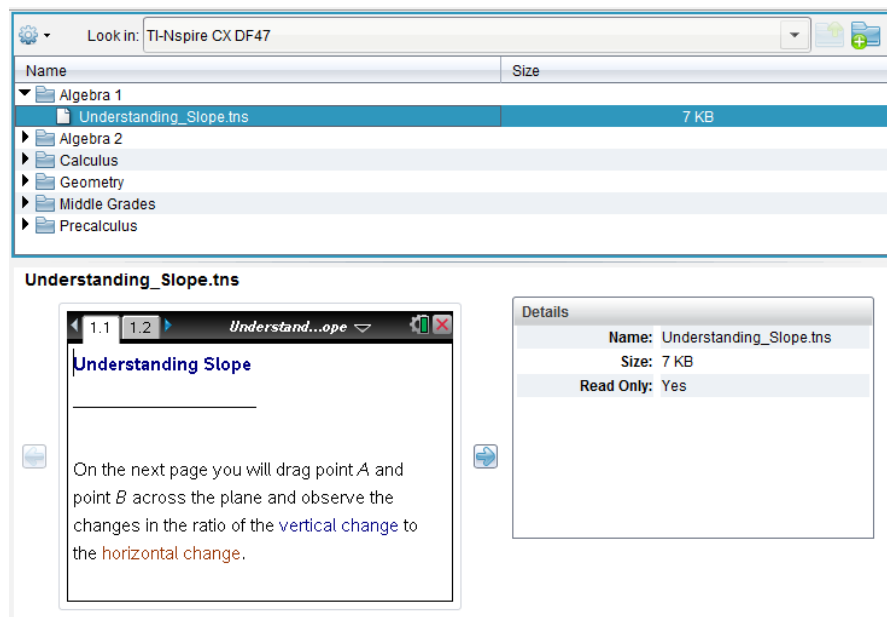


Transferring Documents Using the TI-Nspire™ Teacher Software

TI PROFESSIONAL DEVELOPMENT

Step 7:

The files and folders on a connected handheld can also be viewed by going to the **Resources** panel and selecting from the list of **Connected Handhelds**. When a TI-Nspire™ document is selected, an icon appears labeled **Click here to preview document**. Click the icon to preview the first page of the TI-Nspire™ document. Double-click the file to open it in the **Documents Workspace**.

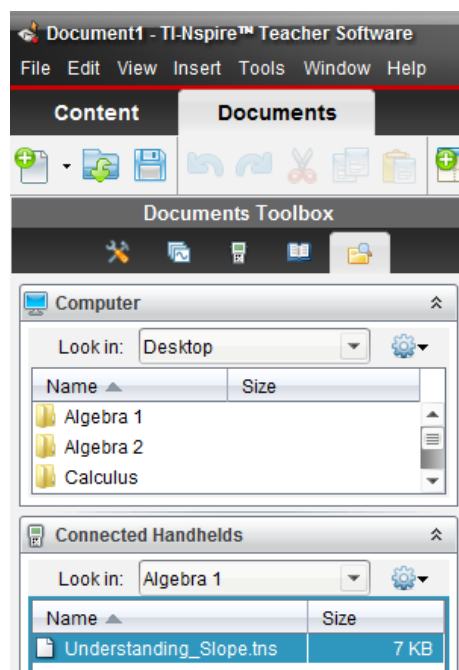


Step 8:

Files can also be transferred between the computer and connected handhelds using the **Content Explorer** in the **Documents Workspace**.

To transfer a TI-Nspire™ document from the computer to the connected handheld, locate the file in the **Computer** panel. Click, drag, and drop it into the desired handheld or folder in the **Connected Handhelds** panel.

To transfer a TI-Nspire™ document from the connected handheld to the computer, locate the file in the **Connected Handhelds** panel. Click, drag, and drop it into the desired folder in the **Computer** panel.



Activity Overview:

In this activity, you will learn how to check the operating system (OS) on a handheld and update it using the Content Workspace of the TI-Nspire™ Teacher Software.

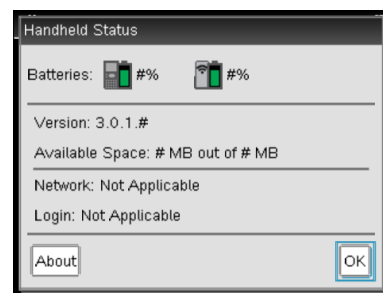
Materials

- TI-Nspire™ Teacher Software and USB connection cable

Viewing handheld status

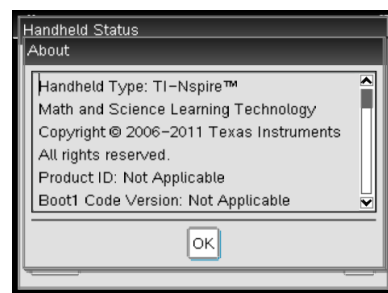
The **Handheld Status** screen displays the battery status, OS version, available space, network (if any), and your student login name and whether you are logged in.

To view the **Handheld Status**, press **on** and select **Settings > Status**. The **Handheld Status** dialog box opens.



Viewing handheld details on the About screen

The **About** screen displays the handheld type and product ID. To view the **About** screen from the **Handheld Status** screen, click **About**. To return to the home screen, press **enter**.



Updating the handheld OS

You can update the OS on your TI-Nspire™ handheld using your computer and TI-Nspire™ Teacher Software or by transferring the OS from one handheld to another. OS upgrade operations do not delete user documents. If there is not enough room on the receiving handheld for the upgrade, the sending handheld is notified. The only time documents can be affected by an OS installation is if the receiving handheld has a corrupted OS. In this situation, documents may be affected by OS restoration. It is a good practice to back up your important documents and folders before installing an updated operating system.

Important OS download information

The OS for the TI-Nspire CX™ handheld has the file extension *.tco*; the OS for the TI-Nspire CX CAS™ has the file extension *.tcc*; the OS for the TI-Nspire™ with Touchpad or Clickpad has the file extension *.tno*; and the OS for the TI-Nspire CAS™ with Touchpad or Clickpad has the file extension *.tnc*. Always install new batteries before beginning an OS download. When in OS download mode, the APD™ (Automatic Power Down) feature does not function. If you leave your handheld in download mode for an extended time before you begin the downloading process, your batteries may become depleted. You will then need to install new batteries before downloading the OS.

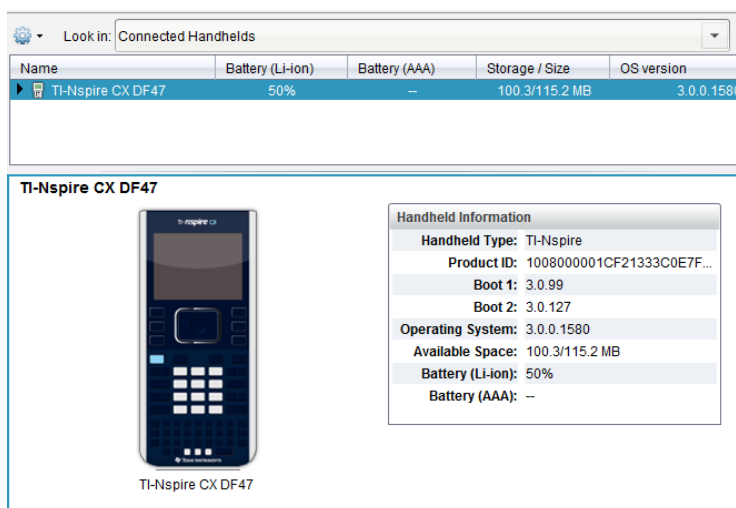
Finding operating system upgrades

Your TI-Nspire™ Teacher Software has convenient links to a number of useful Texas Instruments websites, including those with handheld OS updates. You will need an Internet connection and the appropriate USB cable to download and install the updates.

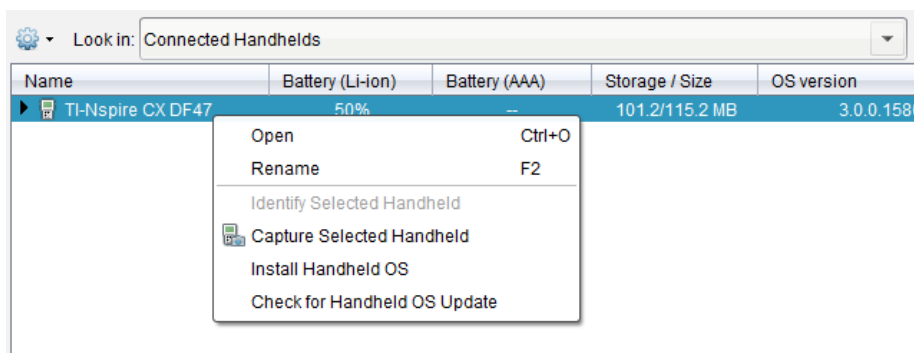
Using TI-Nspire™ Teacher Software to update the handheld OS

Open the TI-Nspire™ Teacher Software and connect a TI-Nspire™ handheld to the computer using the USB connection cable. Go to the Document Workspace, select the **Content Explorer** tab, and click **Connected Handhelds**. Multiple handhelds can be connected to the computer using multiple USB ports, USB hubs, or the TI-Nspire™ Docking Station. If multiple handhelds are connected to the computer, then multiple handhelds appear in the list of **Connected Handhelds**.

The connected handheld appears in the **Content** window, along with battery, storage, and OS information. More detailed information appears in the **Handheld Information** window.



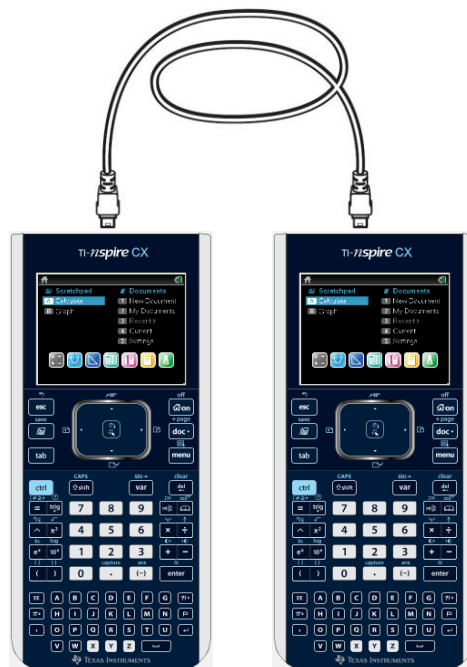
To see if a new OS is available, right-click the handheld and select **Check for Handheld OS Update**. To update the OS, right-click the handheld and select **Install Handheld OS**. A window appears that asks you to select the handheld OS file. Select the OS file and click **Install OS**. A window appears informing you that any unsaved data will be lost and asking if you want to continue. Click **Yes**.



Connecting two TI-Nspire™ handhelds with the USB handheld-to-handheld cable

You can share documents between two TI-Nspire™ handhelds by connecting them with the handheld-to-handheld USB cable. The TI-Nspire™ handheld USB A port is located at the center of the top of the handheld.

1. Firmly insert either end of the USB unit-to-unit cable into the USB A port.
2. Insert the other end of the cable into the receiving unit's USB A port.



Sending a document

1. Open **My Documents** on the sending unit.
2. Press the ▲ and ▼ keys to highlight the document you want to send.
3. Select **Send** from the document menu.
4. When the file transfer is complete, a message displays on the receiving unit.

Rules for sending files or folders

The rules for sending files apply also to those files within folders that you send.

- If you send a document with the same name as an existing document on the receiving TI-Nspire™ handheld, the system renames the sent document by appending a number to the name. For example, if you send a document named **Mydata** to another TI-Nspire™ handheld that already contains a document named **Mydata**, the document you send will be renamed **Mydata(2)**. Both the sending and receiving units display a message that shows the new name.



Transferring Documents Between Handhelds

TI Professional Development

- There is a 255-character maximum length for a file name, including the entire path. If a transmitted file has the same name as an existing file on the receiving unit and the file names contain 255 characters, then the name of the transmitted file will be truncated to allow the software to follow the renaming scheme described in the previous bullet.
- All variables associated with the document being transmitted are transferred with the document.
- Transmissions will time out after 30 seconds.

Receiving a document

No action is required by the user of the receiving TI-Nspire™ handheld. Units are automatically powered on when the cable is attached.

Sending a folder

When you send a folder from one handheld to another, the file structure in the sending folder is retained. If the folder does not exist on the receiving handheld, it will be created. If the folder does exist, files will be copied into it, with appended names added to any duplicate files that may be there.

To send a folder:

1. Open **My Documents**. Press **2**.
2. Using the touchpad, point to the folder you want to send.
3. Select **Send** from the **My Documents** menu. Press **6**.
4. The file transfer begins. A progress bar displays to allow you to follow the transfer. There is a **Cancel** button on the **Sending...** dialog that allows you to cancel the transmission while it is in progress. When the transfer is complete, a message displays. If the file was renamed on the receiving handheld, the new file name displays.

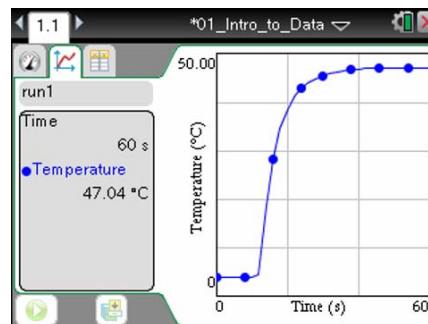
Canceling a transfer

1. To cancel a transmission in progress, press **Cancel** on the dialog of the sending unit.
Note: To cancel a file transfer from the receiving handheld, press . The receiving handheld cannot cancel a transfer of folders, however.
2. A link transmission error message displays.
3. Press or to cancel the transmission error message.

Using DataQuest on a Handheld

This appendix gives an overview of using the Vernier DataQuest application on a TI-Nspire handheld. It includes information on accessing the common tools in the DataQuest Application.

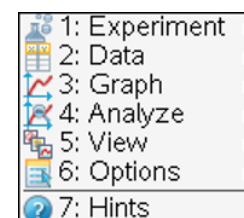
DataQuest is included in TI-Nspire handheld software versions 3.0 and newer. If you have an older version of TI-Nspire software, you can get updates at education.ti.com.



The TI-Nspire Software

Access Menus

DataQuest can be used to collect, display, and analyze data. Most features can be accessed using the application menus. To access the menus, press **menu**.



Access Context Menus

To access context menus, move the cursor over the object using the touchpad or arrow keys, and press **ctrl** **menu**. Meters, View details boxes, graphs, and the table all have contextual menus.

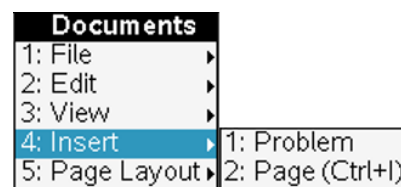
Open a New Document

To open a new document, press **ctrl** **on** then select New Document. Having only one TI-Nspire document opened when using DataQuest is recommended.



Add a Page or Problem

To add a new page or problem to your TI-Nspire document, press **doc** (or **ctrl** **on** for clickpad handhelds) and choose Problem or Page from the Insert menu. For touchpad handhelds, you can also add a page by pressing **ctrl** **doc**.



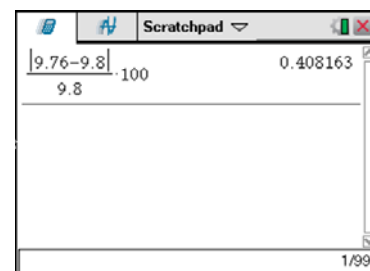
Save a document

To save your TI-Nspire document, press **doc** (or **ctrl** **on** for clickpad handhelds) and choose Save from the File menu or press **ctrl** **S**.



Scratch Pad Calculator

The Scratch Pad Calculator is a built-in calculator that can be used to perform calculations while you are conducting an experiment. To use the Scratch Pad Calculator, press **calc**. (On a click pad handheld, press **on** then select the Scratchpad Calculate option.)



Start DataQuest

DataQuest should automatically start when you connect a TI-Nspire Lab Cradle, EasyLink interface, EasyTemp temperature probe, or Texas Instruments CBR 2™ motion detector to your handheld.



Manually Launch DataQuest

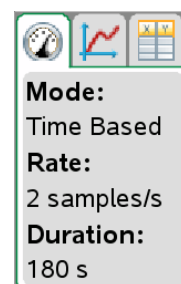
To start DataQuest manually, press **[on]** then select **[A]**. You can also press **[doc]** (**[ctrl]** **[on]** for clickpad handhelds) and choose Vernier DataQuest from the Insert menu.



Views in DataQuest

There are three views in the DataQuest application: Meter, Graph, and Table. Click a tab to change views or press **[menu]** then choose the desired view from the **[View]** menu.

On the left side of the screen in each view, you will see the View details box. The Meter View details box shows the data-collection settings. The Graph View details box shows graph trace and analysis information. The Table View details box shows data set variable information.



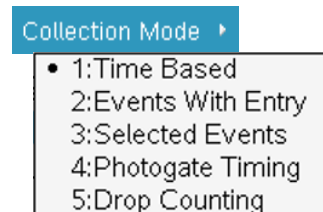
Data Collection Settings

Change the Data-Collection Mode

1. Press **[menu]** then choose Collection Mode from the **[Experiment]** menu.
2. Select the data-collection mode you want to use.

Note: Changing modes will require you to discard any collected data. To avoid losing data, save the current document and open a new document, or insert a new problem in the current document.

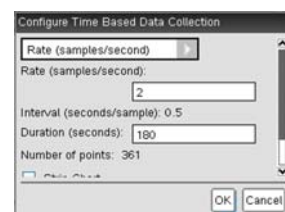
3. A dialog showing the data-collection settings for the mode you have selected will be displayed. Adjust the settings as desired for your experiment. Use **[tab]** to move between entry lines.
4. When you are done setting up the data collection, select OK.



Change Data-Collection Settings

When you have already set up the data-collection mode and want to make changes to the settings, you can change the values you have entered.


1. Press **[menu]** then choose Collection Setup from the **[Experiment]** menu.
2. Make the necessary changes and select OK.

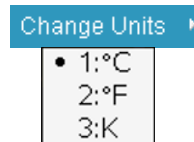


Appendix B

Sensor Settings


Change Units

1. Press **[menu]** then choose Set Up Sensors ► Change Units from the  Experiment menu.
2. Select the unit you want to use. The readings from the sensor and any collected data will be displayed in the new unit.

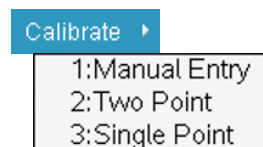


Calibrate a Sensor

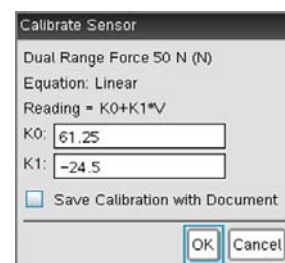
Not all sensors can be calibrated. Check the sensor booklet for specific information about your sensor. For most experiments, the sensor's stored calibration is recommended. In some instances, you may want to calibrate a sensor to get readings that are even more accurate.

1. Press **[menu]** then choose Set Up Sensors ► Calibrate from the  Experiment menu. Select the appropriate calibration option for your situation:

- Manual Entry – Use Manual Entry when you know the calibration equation and want to enter the coefficients directly.
- Two Point – Use Two Point for most calibrations.
- Single Point – Use Single Point when only one known calibration value is attainable (for example, calibrating a Barometer to match the current atmospheric pressure). Single Point calibration will only affect the intercept of the calibration equation.



2. Perform a live calibration (Two Point or Single Point).
 - a. Place the sensor in the desired calibration environment, enter the reference value, wait for the voltage readings to stabilize, and select Keep.
 - b. Two Point only – place the sensor in a second calibration environment, enter the reference value, wait for the voltage readings to stabilize, and select Keep.
3. Note the updated calibration equation, modify if necessary (Manual Entry), and select OK.



Zero a Sensor

Not all sensors can be zeroed. Check the sensor booklet for specific information about your sensor.

ch1: Force 0N

To zero a sensor, press **[menu]** then select Set Up Sensors ► Zero from the  Experiment menu.


Note: When you have more than one sensor you want to zero, select the All Sensors option.

Reverse a Sensor


Not all sensors can be reversed. Check the sensor booklet for specific information about your sensor.

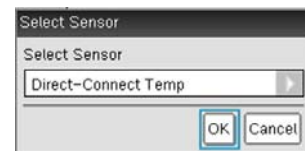
ch1: Force 1N

ch1: Force(↓) -1N

Press **[menu]** then choose Set Up Sensors ► Reverse from the  Experiment menu. The sign of the sensor reading is changed as noted in the example.

Non-AutoID Sensors


The DataQuest Application supports older, non-AutoID sensors. To manually set up a sensor, connect the sensor to the interface and the interface to your handheld. Press **[menu]** then choose Advanced Set Up ► Configure Sensor from the  Experiment menu, and select the interface and channel your sensor is connected to. Select your sensor from the drop down list and click OK.



Non-AutoID sensors must be set up everytime they are used and will not be indentified by the software when opening a saved file.

Data Collection

Start Data Collection

To start data collection, click the Start Collection button or press **[menu]** then choose Start Collection from the  Experiment menu.



Keep Data Points (Event Based Data Collection)

To store a data point during Events with Entry or Selected Events experiments, click the Keep button or press **[menu]** then choose Keep from the  Experiment menu.




Stop Data Collection

To stop data collection, click the Stop Collection button or press **[menu]** then select Stop Collection from the  Experiment menu.



Extend Data Collection (Time Graph Collection)

To extend a time graph experiment to one and one-half times the current duration, press **[menu]** then choose Extend Collection from the  Experiment menu before or during a collection. The time listed in the menu will be the new duration for the experiment.

Extend Collection (270 s)

Store Data Sets

To store a data set, click the Store Latest Data Set button or press **[menu]** then choose Store Data Set from the  Experiment menu.

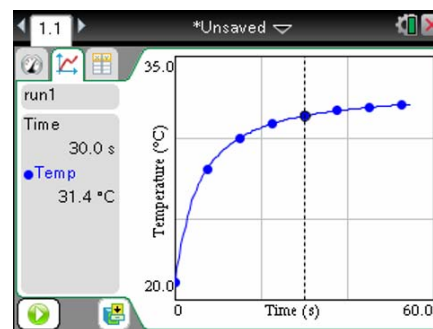


Graphical Display of the Data

By default, DataQuest will graph the most recent (latest) data set on the graph. When two or more of the same type of sensor are connected, data from those sensors will be plotted on the same graph.

When you have two different types of sensors connected, data from the different sensors will be plotted on two separate graphs.

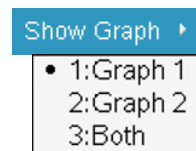
When a Motion Detector is connected, two graphs will be displayed – position and velocity.



Appendix B

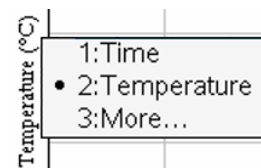
Show Graphs

To change the graph displayed, press **[menu]** then select Show Graph from the **[Graph]** menu. You can select Graph 1, Graph 2, or Both. The two graphs can have different dependent (y-axis) data with different ranges; however, they must have the same independent data and range.



Change what is graphed on the axes

To change the data columns plotted on a graph, move the cursor to the axis label and press **[ctrl]** **[F5]**, or press **[menu]** then select X-Axis Column or Y-Axis Columns from the **[Graph]** menu. Select from the available columns. Use the More option to plot multiple columns on the same axes.

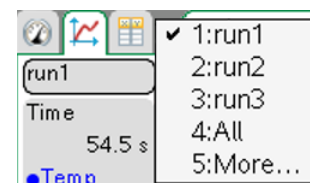


Change which data set is graphed

To plot a different data set or multiple data sets on the same graph, click the run indicator or press **[menu]** then choose Select Run from the **[Graph]** menu.

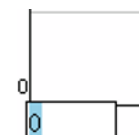
Select All to display all data sets.

Select More to display any combination of stored data sets.



Adjust the Graph Window Settings

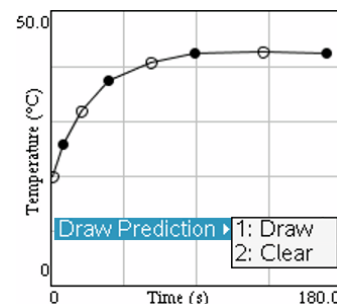
To manually adjust the window settings, click the axis labels or press **[menu]** then choose Window Settings from the **[Graph]** menu.



Draw Prediction

Use the draw prediction feature before data collection to predict the outcome of the data collection. To add a prediction to a graph, press **[menu]**, choose Draw Prediction from the **[Analyze]** menu, then select Draw. Click the graph in the desired locations. When finished press **[esc]**.

To remove a prediction, press **[menu]** then choose Draw Prediction from the **[Analyze]** menu, and select Clear.

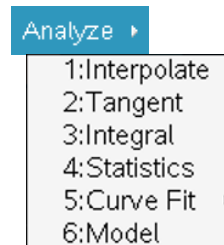


Analyze Data

You can perform multiple types of analysis on your data. For most analysis options, the results will apply to all data points unless a region of data is selected first. Press **[menu]** then choose your desired analysis option from the **[Analyze]** menu.

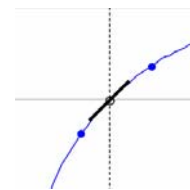
Interpolate

Use Interpolate to examine a graph trace between and beyond the graphed data points. The examine line will move from pixel to pixel instead of data point to data point. This is recommended when examining curve fits.



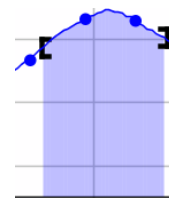
Tangent

Use Tangent to get a measure of the rate of change of the data at a specific point. A segment is drawn on the graph to help visualize the rate and the rate of change (labeled slope) is displayed in the Graph View details box.



Integral

Use Integral to get a measure of the area between your data and the x-axis. Find the area under all data points or under a selected region of the data. You can adjust the region used by clicking and dragging the brackets. The integral region is shaded on the graph and the area is displayed in the Graph View details box.



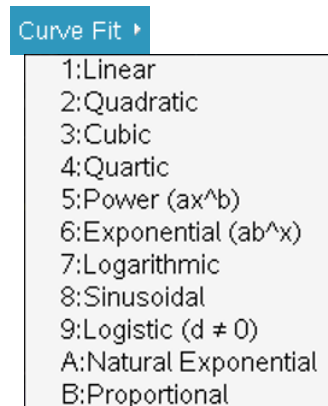
Statistics

Use Statistics to find minimum, maximum, mean, and standard deviation of your data. Find these values for all data points or a selected region of the data. You can adjust the region used by clicking and dragging the brackets. The statistical values are displayed in the Graph View details box.

Samples: 101
min: 0.163
max: 0.593
mean: 0.394
dev: 0.127

Curve Fits

Use Curve Fits to find the best-fit equation of a curve fit function. Curve fit all data points or a selected region of the data. You can adjust the region used by clicking and dragging the brackets. The curve fit equation is graphed on the axes and the equation values are displayed in the Graph View details box.

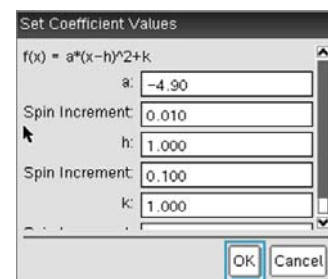


Model

Use Model to manually fit a mathematical equation to your data. A model differs from a Curve Fit in that there are no statistical or iterative processes used to determine the best fit. You can define your models using any function of the variable x .

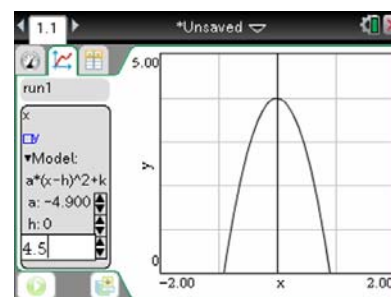
To enter a model:

1. Press **[menu]**, then choose Model from the **[Analyze]** menu.
2. Select one of the predefined equations or enter your own. The model must be a function of the variable x .
3. Enter your estimates for the coefficient values.
4. Modify the spin increment value if desired.
5. Select OK.



You can adjust the coefficients in your model to obtain a good match of your data.

- Click **[spin]** on the spin increment buttons **[spin]**.
- Click **[spin]** on the coefficient and type a new value.
- Move the cursor to the Graph View Details, press **[ctrl]** **[menu]** then select the Modify Model option.



Appendix B

Remove an analysis feature from a graph

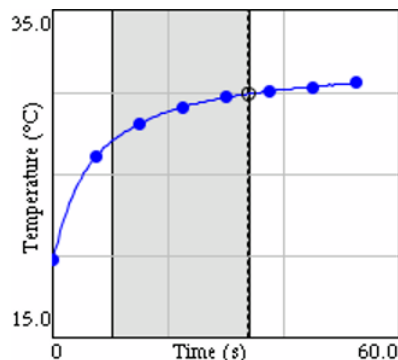
Use the remove option to remove an analysis (integral, statistics, curve fit, or model) from a graph. To do this, press **[menu]** then choose Remove from the **[Analysis]** Analyse Menu. If there are more than one, the analysis options will be listed in the order in which they were created.

Select a Region on a Graph

Select a region when you want to look more closely at a specific region of data or analyze only a portion of the data.

To select a region:

1. Move the cursor to the place you want to start the selected region.
2. Press **[ctrl]** **[graph]** to start the selection.
3. Move the cursor to select the region.
4. Press **[graph]** or **[esc]** to end the selection.

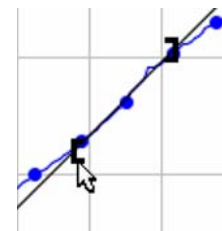


The selected region is indicated by shading. Once a region is selected, you can:

- Zoom in on the region (Press **[menu]** then choose Zoom In from the **[Graph]** Graph menu).
- Analyze the region (see above).
- Strike the data within or outside the selected region (see below).

Modify the range of an analysis

Once you have used one of the analysis tools, you can modify the range over which the analysis will apply. To do this directly on the graph, move the cursor over one of the brackets, when the cursor changes to a white arrow, press **[ctrl]** **[graph]** to grab the bracket, then use the touch pad or arrow keys to move the bracket. Press **[esc]** to release the bracket.



To do this from a menu, move the cursor over the Graph View details box, press **[ctrl]** **[menu]**, then choose the Modify Range option. If you have more than one analysis, choose the one you want to adjust or choose the Modify All option to apply the change to all of the existing ranges.

Strike Data

When there are data points that you wish not to have considered in the graphing or analysis of your data, you can “strike” that data. Striking data does not delete the data; rather, data is displayed in the data table with a single line drawn through it and calculated column cells based on struck data will be blank. Struck data is not displayed on the graph.

	Time	Temp
3	1.0	20.9
4	1.5	21.6

To strike data, select a region, press **[menu]**, then choose Strike Data from the **[Data]** Data menu. Select whether to strike through data inside or outside the selected region.

Strike Data ▾

1: In Selected Region
2: Outside Selected Region

Restore Data

Use this option to restore struck data. Select a region (optional), press **[menu]** then choose Restore Data from the **[Data]** Data menu. Select whether to restore data In Selected Region, Outside Selected Region, or Restore All Data.

Restore Data ▾

Tabular Display of the Data

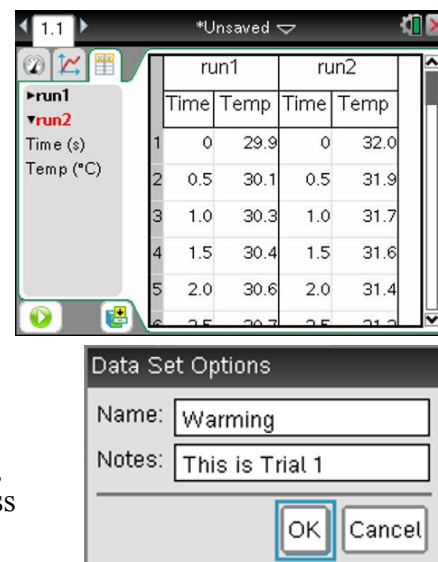
DataQuest also displays data in a data table. In addition to viewing collected sensor data, you can enter data manually and perform column calculations. Use the scroll bar and scroll buttons to view the data.

Data collected will populate the Latest Data Set in the table. This data set is identified with **red, bolded text** on CX handhelds (**bolded text** on other handhelds) in the Table View Details box. Storing a Data Set will change the data set

identified as the Latest.

Data Set Options

To change the name of a run or to add notes about the data set, double-click the run name or move the cursor to the table, press **ctrl** **menu** then select Data Set Options.



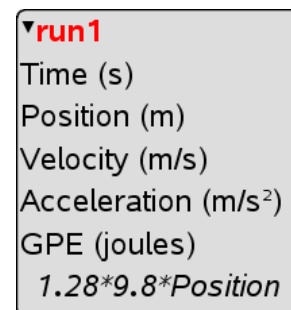
Column Options

Use the column options to change the name of the column and to modify the display precision of any column. Press **menu**, choose Column Options from the **Data** menu, then select the column you wish to modify.

Calculated Columns

Calculated columns are used to generate data based on existing columns in a data set. For example, you may want to calculate gravitational potential energy from height measurements or you may want to linearize pressure-volume data by plotting pressure vs. the reciprocal of the volume data.

To add a calculated column, press **menu** then choose New Calculated Column from the **Data** menu. The equation you enter must use one of the data columns in the data set.



Manually Entered Data

For experiments that require hand-entered data, launch DataQuest in a new document or problem without any sensors connected. Use the default *x* and *y* columns to manually enter data values. You can use the Column Options to rename your columns if desired (see above).

To add additional manual columns, press **menu** then choose New Manual Column from the **Data** menu.

	run1	
	x	y
1	5.00	18.60
2	10.00	5.8
3	15.00	-22.50

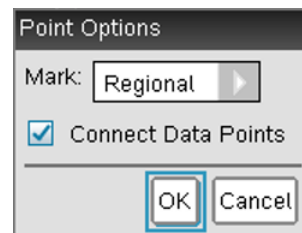
Appendix B

DataQuest Options

Points Options

Use the point options to determine how the data are drawn on the graph. To access the Point options, press **[menu]** then choose Point Options from the **[Options]** menu.

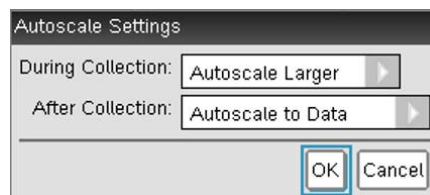
Mark refers to the symbol used to distinguish the different traces on a graph. The Mark options are None, Regional, or All. You can also choose whether to have the data points drawn connected.



Regional/Connected is the default for Time Graph data collection. All/Not Connected is the default for Event based data collection.

Autoscale Settings

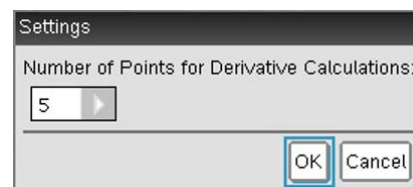
Use the Autoscale Settings to set the scaling behavior of the application during and after data collection. To access Autoscale Settings, press **[menu]** then choose Autoscale Settings from the **[Options]** menu.



- Autoscale Larger – expands the graph range when needed to ensure each data point appears on the graph. This is the default setting and only applies while collecting data.
- Autoscale From Zero – adjusts the graph range to ensure all data points and the origin (0,0) are displayed with little or no extra space. This only applies after collection is complete.
- Autoscale to Data – adjusts the graph range to show all data points with little or no extra space around the points. This is the default setting and only applies after data collection.
- Do Not Auto Scale – maintains the current window range regardless of the collected data. This can be applied either during or after collection.

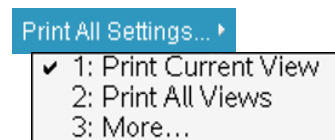
Derivative Settings

Use the derivative settings to set the number of points used in derivative calculation. The default value is five. To access this setting, press **[menu]** then choose Derivative Setting from the **[Options]** menu.



Print All Settings

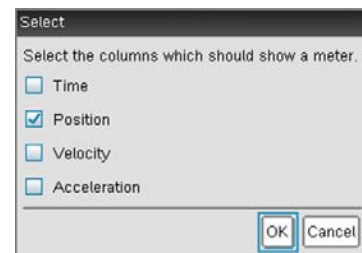
Use the Print All settings to determine which DataQuest views are printed when the Print All printing option is used. Choose from Print Current View (default), Print All Views, or select any one or combination of views to print. The Print All Settings are specific to each DataQuest App so multiple instances of the app must be set up separately.



To access Print All Settings, press **[menu]** then choose Print All Settings from the **[Options]** menu. **Note:** You cannot print a document directly from a handheld. You can only print from the TI-Nspire computer software.

Show/Hide Meters

You can display (or hide) a meter for any column of data. This is useful for calculated columns of data. To select which meters to display, press **[menu]** then choose Show/Hide Meters from the **[Options]** menu. **Note:** Meters for calculated columns will only show live values during data collection.

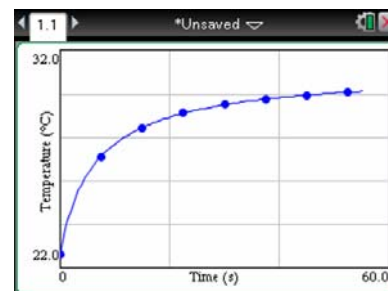


Hide View Details (Show View Details)

The View details boxes, tabs, and collection buttons can be hidden if desired. To hide the View details, press **[menu]** then choose Hide View Details from the **[Options]** menu. When the details are hidden, use the menus to change views and control data collection.

Note: View details will automatically be hidden in some split screen views and when the application window gets too small.

To show View details when they are hidden, press **[menu]** then choose Show View Details from the **[Options]** menu.



Print a Document

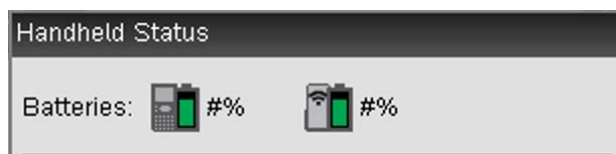
You cannot print a document directly from a handheld. You can only print from the TI-Nspire computer software. See *Appendix C* for more details regarding printing.

Battery Level

The battery icon located in the upper right portion of the screen will display the current battery level available to the handheld. Move your cursor over the battery icon to get an approximate percent of battery life remaining. The level is a combination of all battery types that apply – handheld AAA, handheld rechargeable, and Lab Cradle rechargeable.

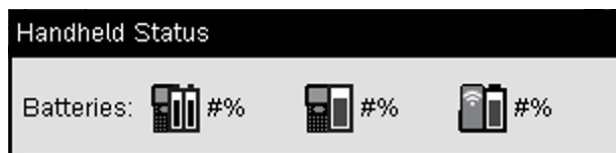


For more detailed information regarding the charge level of the different battery types, press **[on]**, choose Settings, then select Status.



We recommend not letting your battery level go below 25% as this can affect the identification of your sensors.












The TI-Nspire Lab Cradle can be used to collect data on a handheld while powered using the AC adaptor that comes with the Lab Cradle.







DataQuest Cursors

The DataQuest application uses several different cursors to help identify when there is some special feature available to you through mouse interaction (clicking, right-clicking, clicking and dragging, etc.). The table below will give you a brief explanation of the different cursors used.

Appendix B

Cursor	Description
	Pointer – The standard cursor you see when using DataQuest.
	<p>Horizontal Resize Cursor – This cursor is shown when you are over the location of an object that can be resized in a horizontal direction. The locations where the Horizontal Resize cursor appears are:</p> <ul style="list-style-type: none"> ▶ The right edge of and View Details box in Meter, Graph and Table View. This will allow you to resize the details box. ▶ The left one-third of the horizontal (x-) axis. This allows you to dynamically adjust the x-min window-setting value without changing the x-max value. ▶ The right one-third of the horizontal (x-) axis. This allows you to dynamically adjust the x-max window-setting value without changing the x-min value. ▶ The left edge of a table cell. This allows you to adjust the width of the column to the left of the cursor. <p>Press ctrl  to grab the object and resize it. After the object has been grabbed, the cursor changes to . Move the cursor left or right to resize the object. Press esc to release the object.</p>
	<p>Vertical Resize Cursor – This cursor is shown when you are over the location of an object that can be resized in a vertical direction. The locations where the Vertical Resize cursor appears are:</p> <ul style="list-style-type: none"> ▶ The space between two DataQuest graphs when both graphs are shown. This will allow you to resize the two graphs as desired. The default is to show both graphs the same height. ▶ The top one-third of the vertical (y-) axis. This allows you to dynamically adjust the y-max window-setting value without changing the y-min value. ▶ The bottom one-third of the vertical (y-) axis. This allows you to dynamically adjust the y-min window-setting value without changing the y-max value. <p>Press ctrl  to grab the object and resize it. After the object has been grabbed, the cursor changes to . Move the cursor left or right to resize the object. Press esc to release the object.</p>
	<p>Translation Cursor – This cursor is shown when you are over the location of an object that can be repositioned up-and-down or left-and-right. The locations where the Translation cursor appears are:</p> <ul style="list-style-type: none"> ▶ The middle one-third of the horizontal (x-) axis. This allows you to dynamically adjust the x-min and x-max window setting values by the same amount, simultaneously. The graph will appear to move left or right. ▶ The middle one-third of the vertical (y-) axis. This allows you to dynamically adjust the y-min and y-max window setting values by the same amount, simultaneously. The graph will appear to move up and down. <p>Press ctrl  to grab the object and resize it. Move the cursor to resize the object. When you move the object, the cursor changes to . Press esc to release the object.</p>
	<p>Text Edit Cursor – This cursor is shown when you are over the numeric graph-axis labels. Press edit to edit the value. Press enter to save the change. Press esc to exit without making a change.</p>

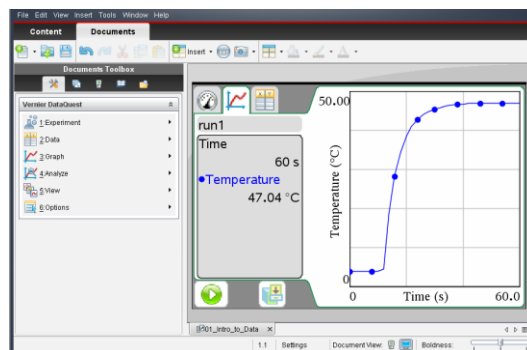
Cursor	Description
	<p>Hollow Pointer – This cursor is shown when the object underneath is selectable in some way. The locations where the Hollow Pointer appears are:</p> <ul style="list-style-type: none"> ▶ The graph-axes text label. Press ctrl menu to change what is graphed on the axis. ▶ The analysis selected-region brackets ([or]). Press ctrl  to grab a bracket. Move the cursor left or right to adjust the region used in the analysis calculation. Press esc to release the bracket.
	<p>Pencil Cursor – This cursor is shown when Draw Prediction is active. Move the cursor to the desired location and press  to add a point. Repeat as necessary. Press esc to end your prediction.</p>

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Using DataQuest on a Computer

This appendix gives an overview of using the Vernier DataQuest application on a computer running the TI-Nspire software. It includes information on accessing the common tools in the DataQuest Application.

DataQuest is included in TI-Nspire computer software versions 3.0 and newer. If you have an older version of TI-Nspire software, you can get updates at education.ti.com.



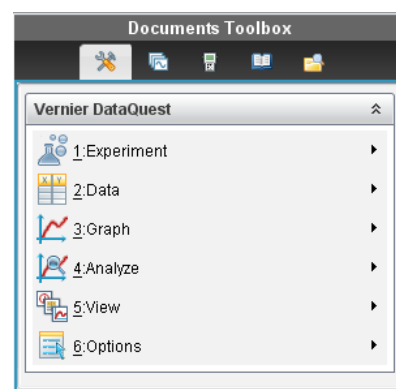
The TI-Nspire Software

Access Menus

DataQuest can be used to collect, display, and analyze data. Most features can be accessed using the application menus found in the Document Tools shown in the Documents Toolbox. If the Documents Toolbox is not displayed, you can show the menus by selecting **Document Tools** from the Window menu.

Access Context Menus

To access context menus on a Windows[®] computer, right-click the object. To access context menus on a Macintosh[®] computer, control-click the object. (In this document, right-click is synonymous with control-click on a Mac.)



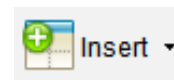
Open a New Document

To open a new document, choose New TI-Nspire Document from the File menu. Having only one TI-Nspire document opened when using DataQuest is recommended.



Add a Page or Problem

To add a new page or problem to your TI-Nspire document, choose Page or Problem from the Insert menu.




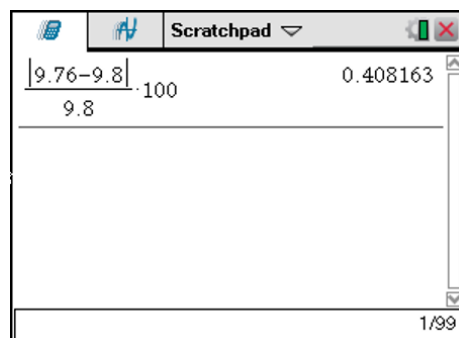
Save a document

To save your TI-Nspire document, choose Save Document from the File menu.



Scratch Pad Calculator

The Scratch Pad Calculator is a built-in calculator that can be used to perform calculations while you are conducting an experiment. To use the Scratch Pad Calculator, choose Keypad (student software) or TI-SmartView™ Emulator (teacher software) from the Window menu. Press  on the keypad to access the Scratch Pad Calculator.




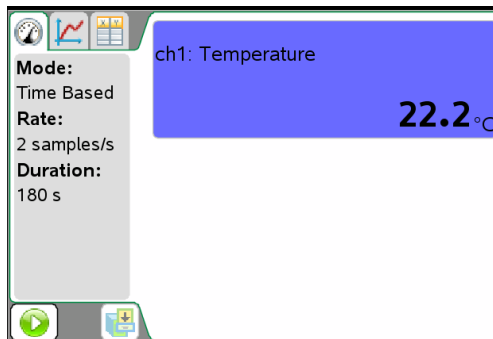
Appendix C

Start DataQuest


DataQuest should automatically start when TI-Nspire software is running on your computer and you connect a TI-Nspire Lab Cradle, Go! Link interface, Go!Temp temperature probe, or Go!Motion motion detector.

Manually Launch DataQuest

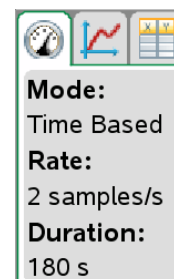
To start DataQuest manually, choose  Vernier DataQuest from the Insert menu.



Views in DataQuest


There are three views in the DataQuest application: Meter, Graph, and Table. Click a tab to change views or choose the desired view from the  View menu.

On the left side of the screen in each view, you will see the View details box. The Meter View details box shows the data-collection settings. The Graph View details box shows graph trace and analysis information. The Table View details box shows data set variable information.



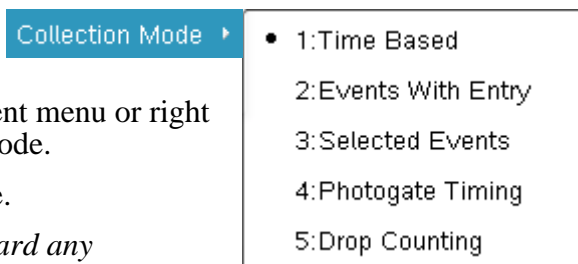
Data Collection Settings

Change the Data-Collection Mode

1. Choose Collection Mode from the  Experiment menu or right-click the Meter Details and select Collection Mode.
2. Select the data-collection mode you want to use.


Note: Changing modes will require you to discard any collected data. To avoid losing data, save the current document and open a new document, or insert a new problem in the current document.

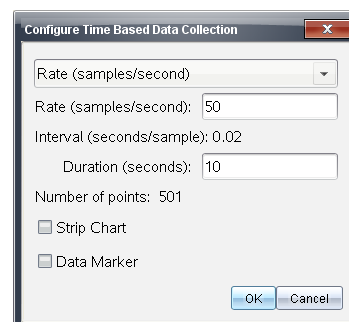
3. A dialog showing the data collection settings for the mode you have selected will be displayed. Adjust the settings as desired for your experiment.
4. When you are done setting up the data collection, select OK.



Change Data-Collection Settings


When you have already set up the data-collection mode and want to make changes to the settings, you can change the values you have entered.

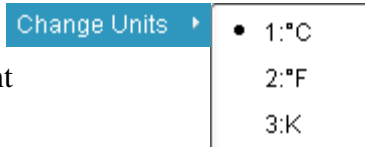
1. Choose Collection Setup from the  Experiment menu or right-click the Meter View details box and select Collection Setup.
2. Make the necessary changes and select OK.



Sensor Settings


Change Units

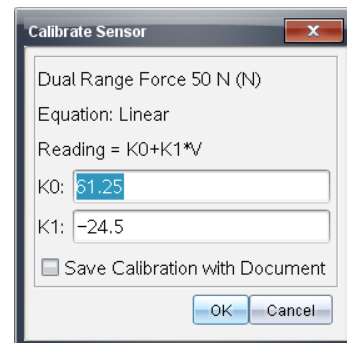
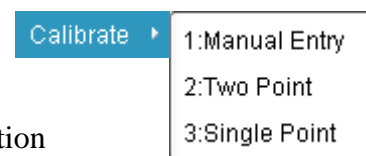
1. Choose Set Up Sensors ► Change Units from the  Experiment menu or right-click the sensor's meter and select Change Units.
2. Select the unit you want to use. The readings from the sensor and any collected data will be displayed in the new unit.



Calibrate a Sensor



Not all sensors can be calibrated. Check the sensor booklet for specific information about your sensor. For most experiments, the sensor's stored calibration is recommended. In some instances, you may want to calibrate a sensor to get readings that are even more accurate.

1. Choose Set Up Sensors ► Calibrate from the  Experiment menu or right-click the sensor's meter and select Calibrate. Select the appropriate calibration option for your situation:
 - Manual Entry – Use Manual Entry when you know the calibration equation and want to enter the coefficients directly.
 - Two Point – Use Two Point for most calibrations.
 - Single Point – Use Single Point when only one known calibration value is attainable (for example, calibrating a Barometer to match the current atmospheric pressure). Single Point calibration will only affect the intercept of the calibration equation.
2. Perform a live calibration (Two Point or Single Point).
 - a. Place the sensor in the desired calibration environment, enter the reference value, wait for the voltage readings to stabilize, and select Keep.
 - b. Two Point only – place the sensor in a second calibration environment, enter the reference value, wait for the voltage readings to stabilize, and select Keep.
3. Note the updated calibration equation, modify if necessary (Manual Entry), and select OK.



Zero a Sensor

Not all sensors can be zeroed. Check the sensor booklet for specific information about your sensor.

To zero a sensor, select Set Up Sensors ► Zero from the  Experiment menu or right-click the sensor's meter and select Zero. **Note:** When you have more than one sensor you want to zero at the same time, select Set Up Sensors ► Zero ► All Sensors from the  Experiment menu.

ch1: Force 0N

Reverse a Sensor

Not all sensors can be reversed. Check the sensor booklet for specific information about your sensor.


Choose Set Up Sensors ► Reverse from the  Experiment menu or right-click the sensor's meter and select Reverse. The sign of the sensor reading is changed as noted in the example.

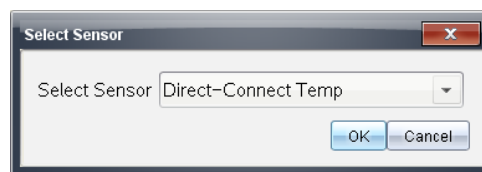
ch1: Force 1N

ch1: Force(↓) -1N

Appendix C

Non-AutoID Sensors

The DataQuest Application supports older, non-AutoID sensors. To manually set up a sensor, connect the sensor to the interface and the interface to your computer. Choose Advanced Set Up ► Configure Sensor from the  Experiment menu, and select the interface and channel your sensor is connected to. Select your sensor from the drop down list and click OK.



Non-AutoID sensors must be set up everytime they are used and will not be identified by the software when opening a saved file.

Data Collection

Start Data Collection

To start data collection, click the Start Collection button or choose Start Collection from the  Experiment menu.




Keep Data Points (Event Based Data Collection)

To store a data point during Events with Entry or Selected Events experiments, click the Keep button or choose Keep from the  Experiment menu.




Stop Data Collection

To stop data collection, click the Stop Collection button or select Stop Collection from the  Experiment menu.



Extend Data Collection (Time Graph Collection)

To extend a time graph experiment duration to one and one-half times the current duration, choose Extend Collection from the  Experiment menu before or during a collection. The time listed in the menu will be the new duration for the experiment.

Extend Collection (270 s)

Store Data Sets

To store a data set, click the Store Current Data Set button or choose Store Data Set from the  Experiment menu.

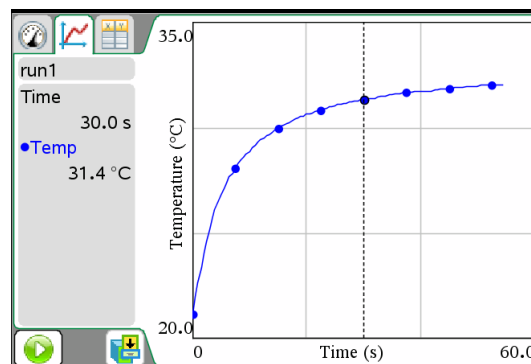


Graphical Display of the Data


By default, DataQuest will graph the most recent (latest) data set on the graph. When two or more of the same type of sensor are connected, data from those sensors will be plotted on the same graph.

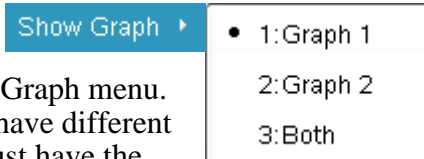
When you have two different types of sensors connected, data from the different sensors will be plotted on two separate graphs.

When a Motion Detector is connected, two graphs will be displayed – position and velocity.




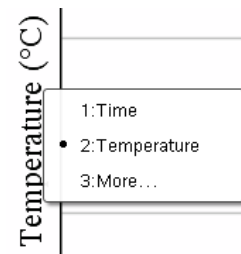
Show Graphs

To change the graph displayed, select Show Graph from the  Graph menu. You can select Graph 1, Graph 2, or Both. The two graphs can have different dependent (y-axis) data with different ranges; however, they must have the same independent data and range.




Change what is graphed on the axes

To change the data columns plotted on a graph, right click the axis label, or select X-Axis Column or Y-Axis Columns from the  Graph menu. Select from the available columns. Use the More option to plot multiple columns on the same axes.

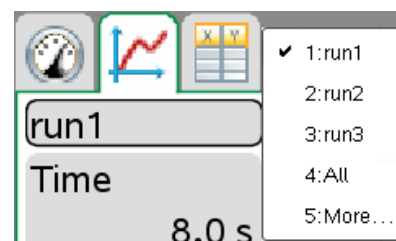


Change which data set is graphed


To plot a different data set or multiple data sets on the same graph, click the run indicator or choose Select Run from the  Graph menu.

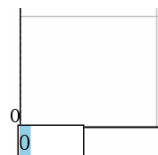
Select All to display all data sets.

Select More to display any combination of stored data sets.





Adjust the Graph Window Settings

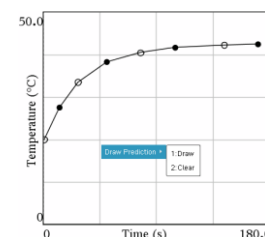
To manually adjust the window settings, click the axis labels or choose Window Settings from the  Graph menu.




Draw Prediction

Use the draw prediction feature before data collection to predict the outcome of the data collection. To add a prediction to a graph, choose Draw Prediction from the  Analyze menu and select Draw. Click the graph in the desired locations. When finished press the Esc key.

To remove a prediction, choose Draw Prediction from the  Analyze menu, and select Clear.

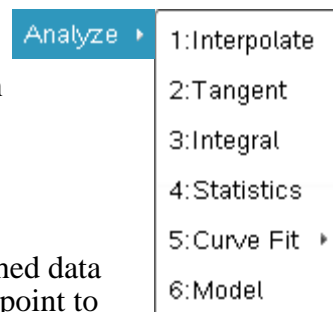


Analyze Data

You can perform multiple types of analysis on your data. For most analysis options, the results will apply to all data points unless a region of data is selected first. Choose your desired analysis option from the  Analyze menu.

Interpolate

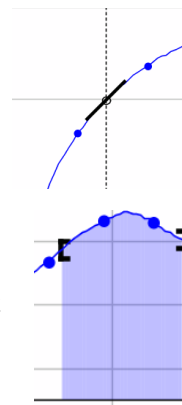
Use Interpolate to examine a graph trace between and beyond the graphed data points. The examine line will move from pixel to pixel instead of data point to data point. This is recommended when examining curve fits.



Appendix C

Tangent

Use Tangent to get a measure of the rate of change of the data at a specific point. A segment is drawn on the graph to help visualize the rate and the rate of change (labeled slope) is displayed in the Graph View details box.



Integral

Use Integral to get a measure of the area between your data and the x-axis. Find the area under all data points or under a selected region of the data. You can adjust the region used by clicking and dragging the brackets. The integral region is shaded on the graph and the area is displayed in the Graph View details box.

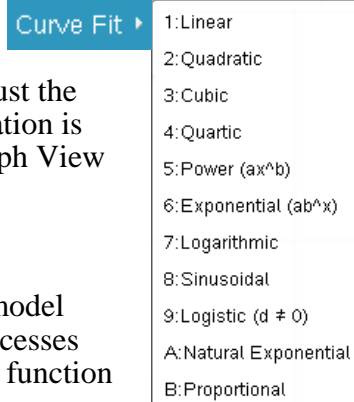
Statistics

Use Statistics to find minimum, maximum, mean, and standard deviation of your data. Find these values for all data points or a selected region of the data. You can adjust the region used by clicking and dragging the brackets. The statistical values are displayed in the Graph View details box.

Samples: 101
min: 0.163
max: 0.593
mean: 0.394
dev: 0.127

Curve Fits


Use Curve Fits to find the best-fit equation of a curve fit function. Curve fit all data points or a selected region of the data. You can adjust the region used by clicking and dragging the brackets. The curve fit equation is graphed on the axes and the equation values are displayed in the Graph View details box.

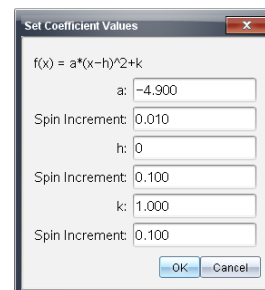


Model


Use Model to manually fit a mathematical equation to your data. A model differs from a Curve Fit in that there are no statistical or iterative processes used to determine the best fit. You can define your models using any function of the variable x .

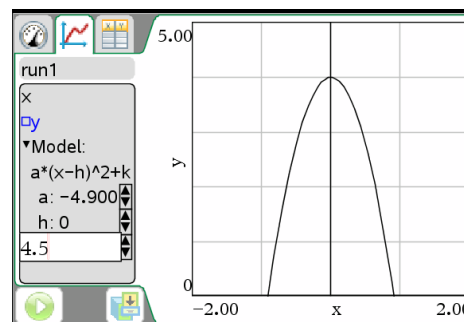
To enter a model:

1. Choose Model from the  Analyze menu.
2. Select one of the predefined equations or enter your own. The model must be a function of the variable x .
3. Enter your estimates for the coefficient values.
4. Modify the spin increment value if desired.
5. Select OK.




You can adjust the coefficients in your model to obtain a good match of your data.

- Click on the spin increment buttons (.
- Click on the coefficient and type a new value.
- Right-click the Graph View details box, then select the Modify Model option.




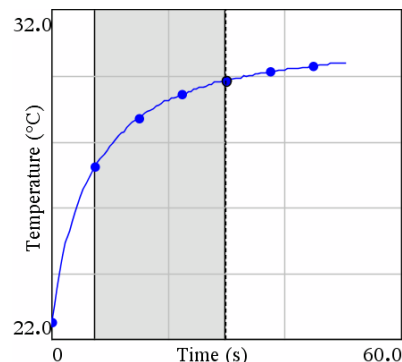
Remove an analysis feature from a graph

Use the remove option to remove an analysis (integral, statistics, curve fit, or model) from a graph. To do this, choose Remove from the  Analyze Menu. If there are more than one, the analysis options will be listed in the order in which they were created.

Select a Region on a Graph

When you want to look more closely at a specific region of data or analyze only a portion of the data, you can click and drag across the graph to select a region. The selected region is indicated by shading. Once a region is selected, you can:


- Zoom in on the region (Choose Zoom In from the  Graph menu)
- Analyze the region (see above)
- Strike the data within or outside the selected region (see below).

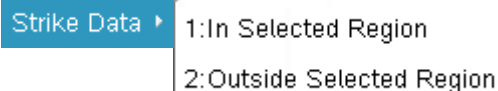


Strike Data


When there are data points that you wish not to have considered in the graphing or analysis of your data, you can “strike” that data. Striking data does not delete the data; rather, data is displayed in the data table with a single line drawn through it and calculated column cells based on struck data will be blank. Struck data is not displayed on the graph.

	Time	Temp
3	6.0	24.8
4	6.5	25.2

To strike data, select a region, then choose Strike Data from the  Data menu. Select whether to strike through data inside or outside the selected region.



Restore Data

Use this option to restore struck data. Select a region (optional), then choose Restore Data from the  Data menu. Select whether to restore data In Selected Region, Outside Selected Region, or Restore All Data.

Tabular Display of the Data

DataQuest also displays data in a data table. In addition to viewing collected sensor data, you can enter data manually and perform column calculations. Use the scroll bar and scroll buttons to view the data.

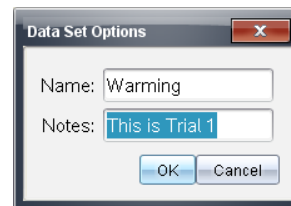
Data collected will populate the Latest Data Set in the table. This data set is identified with **red, bolded text** in the Table View Details box. Storing a Data Set will change the data set identified as the Latest.

	run1		run2	
	Time	Temp	Time	Temp
1	0	24.9	0	28
2	0.5	24.9	0.5	28
3	1.0	24.9	1.0	28
4	1.5	24.8	1.5	28
5	2.0	24.8	2.0	29
6	2.5	24.8	2.5	29
7	3.0	24.8	3.0	29


Appendix C

Data Set Options

To change the name of a run or to add notes about the data set, double-click the run name or right-click the table and select Data Set Options.




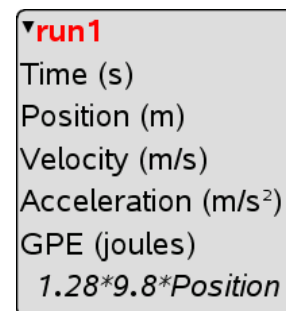
Column Options

Use the column options to change the name of the column and to modify the display precision of any column. Choose Column Options from the  Data menu and select the column you wish to modify.

Calculated Columns


Calculated columns are used to generate data based on existing columns in a data set. For example, you may want to calculate gravitational potential energy from height measurements or you may want to linearize pressure-volume data by plotting pressure vs. the reciprocal of the volume data.

To add a calculated column, choose New Calculated Column from the  Data menu. The equation you enter must use one of the data columns in the data set.



Manually Entered Data


For experiments that require hand-entered data, launch DataQuest in a new document or problem without any sensors connected. Use the default x and y columns to manually enter data values. You can use the Column Options to rename your columns if desired (see above).

To add additional manual columns, choose New Manual Column from the  Data menu.

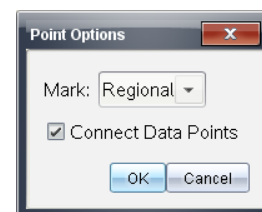
run1		
	x	y
1	5.00	18.60
2	10.00	5.8
3	15.00	-22.50

DataQuest Options

Points Options


Use the point options to determine how the data are drawn on the graph. To access the Point options, choose Point Options from the  Options menu.

Mark refers to the symbol used to distinguish the different traces on a graph. The Mark options are None, Regional, or All. You can also choose whether to have the data points drawn connected.

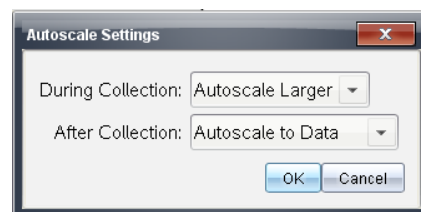


Regional/Connected is the default for Time Graph data collection. All/Not Connected is the default for Event based data collection.


Autoscale Settings

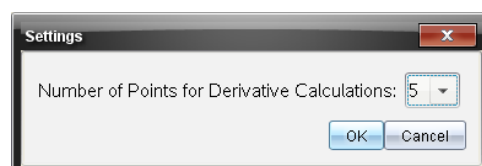
Use the Autoscale Settings to set the scaling behavior of the application during and after data collection. To access Autoscale Settings, choose Autoscale Settings from the  Options menu.

- Autoscale Larger – expands the graph range when needed to ensure each data point appears on the graph. This is the default setting and only applies while collecting data.
- Autoscale From Zero – adjusts the graph range to ensure all data points and the origin (0,0) are displayed with little or no extra space. This only applies after collection is complete.
- Autoscale to Data – adjusts the graph range to show all data points with little or no extra space around the points. This is the default setting and only applies after data collection.
- Do Not Auto Scale – maintains the current window range regardless of the collected data. This can be applied either during or after collection.




Derivative Settings

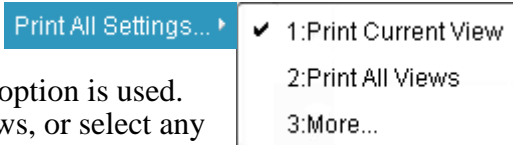
Use the derivative settings to set the number of points used in derivative calculation. The default value is five. To access this setting, choose Derivative Setting from the  Options menu.




Print All Settings

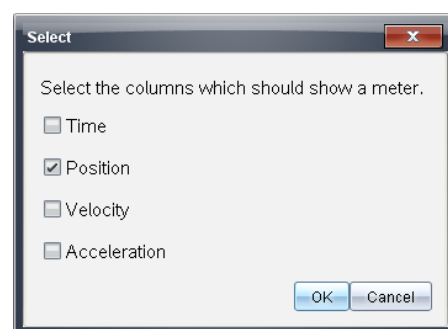
Use the Print All settings to determine which DataQuest views are printed when the Print All printing option is used. Choose from Print Current View (default), Print All Views, or select any one or combination of views to print. The Print All Settings are specific to each DataQuest App so multiple instances of the app must be set up separately.

To access Print All Settings, choose Print All Settings from the  Options menu.




Show/Hide Meters

You can display (or hide) a meter for any column of data. This is useful for calculated columns of data. To select which meters to display, choose Show/Hide Meters from the  Options menu. **Note:** Meters for calculated columns will only show live values during data collection.




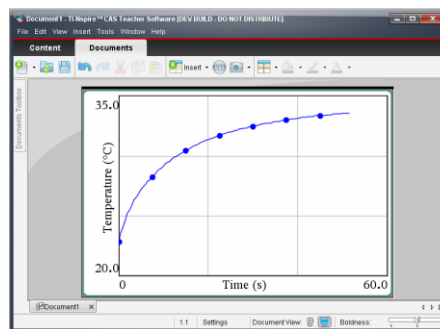
Appendix C

Hide View Details (Show View Details)

The View details boxes, tabs, and collection buttons can be hidden if desired. To hide the View details, choose Hide View Details from the  Options menu. When the details are hidden, use the menus to change views and control data collection.

Note: View details will automatically be hidden in some split screen views and when the application window gets too small.

To show View details when they are hidden, choose Show View Details from the  Options menu.

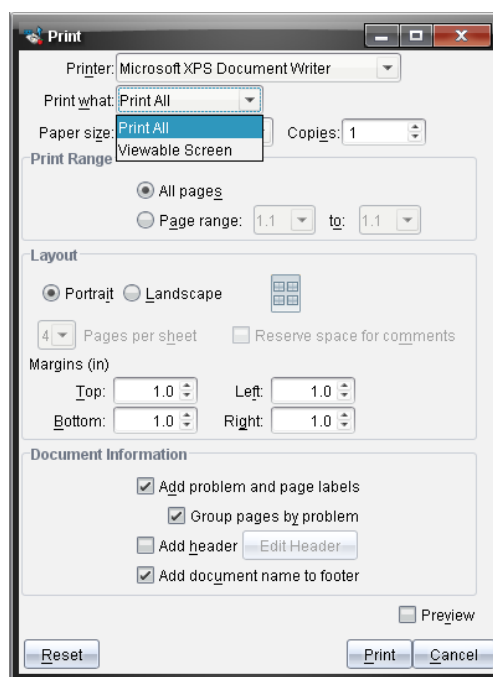


Print a Document

To print a TI-Nspire document, choose Print from the File menu, or use Ctrl+P. When printing, you have two options, Print All and Viewable Screen. Viewable Screen is the default print option.








Print Viewable Screen is a what-you-see-is-what-you-get (WYSIWYG) style of printing. Each page in your TI-Nspire Document is printed as it appears on the screen.

Print All will print all information for a specific application whether or not it appears on the screen. Print All includes printing a full page for each selected view along with the each view's details (for example, data collection settings and analysis details). Which views print is determined by the Print All Settings (see above).






DataQuest Cursors

The DataQuest application uses several different cursors to help identify when there is some special feature available to you through mouse interaction (click, right-click, click-and-hold, etc.). The table below will give you a brief explanation of the different cursors used.

Cursor	Description
	Pointer – The standard cursor you see when using DataQuest.
	<p>Horizontal Resize Cursor – This cursor is shown when you are over the location of an object that can be resized in a horizontal direction. The locations where the Horizontal Resize cursor appears are:</p> <ul style="list-style-type: none"> ▶ The right edge of and View Details box in Meter, Graph and Table View. This will allow you to resize the details box. ▶ The left one-third of the horizontal (x-) axis. This allows you to dynamically adjust the x-min window-setting value without changing the x-max value. ▶ The right one-third of the horizontal (x-) axis. This allows you to dynamically adjust the x-max window-setting value without changing the x-min value. ▶ The left edge of a table cell. This allows you to adjust the width of the column to the left of the cursor. <p>Click-and-hold to grab the object and resize it. After the object has been grabbed, the cursor changes to . Move the cursor left or right to resize the object. Release to anchor the object.</p>
	<p>Vertical Resize Cursor – This cursor is shown when you are over the location of an object that can be resized in a vertical direction. The locations where the Vertical Resize cursor appears are:</p> <ul style="list-style-type: none"> ▶ The space between two DataQuest graphs when both graphs are shown. This will allow you to resize the two graphs as desired. The default is to show both graphs the same height. ▶ The top one-third of the vertical (y-) axis. This allows you to dynamically adjust the y-max window-setting value without changing the y-min value. ▶ The bottom one-third of the vertical (y-) axis. This allows you to dynamically adjust the y-min window-setting value without changing the y-max value. <p>Click-and-hold to grab the object and resize it. After the object has been grabbed, the cursor changes to . Move the cursor left or right to resize the object. Release to anchor the object.</p>
	<p>Translation Cursor – This cursor is shown when you are over the location of an object that can be repositioned up-and-down or left-and-right. The locations where the Translation cursor appears are:</p> <ul style="list-style-type: none"> ▶ The middle one-third of the horizontal (x-) axis. This allows you to dynamically adjust the x-min and x-max window setting values by the same amount, simultaneously. The graph will appear to move left or right. ▶ The middle one-third of the vertical (y-) axis. This allows you to dynamically adjust the y-min and y-max window setting values by the same amount, simultaneously. The graph will appear to move up and down. <p>Click-and-hold to grab the object and resize it. Move the cursor to resize the object. When you move the object, the cursor changes to . Release to anchor the object.</p>

Appendix C

Cursor	Description
	Text Edit Cursor – This cursor is shown when you are over the numeric graph-axis labels. Click to edit the value. Press Enter to save the change. Press Esc to exit without making a change.
	Hollow Pointer – This cursor is shown when the object underneath is selectable in some way. The locations where the Hollow Pointer appears are: <ul style="list-style-type: none"> ▶ The graph-axes text label. Right-click to change what is graphed on the axis. ▶ The analysis selected-region brackets ([or]). Right-click to grab a bracket. Move the cursor left or right to adjust the region used in the analysis calculation. Release to anchor the bracket.
	Pencil Cursor – This cursor is shown when Draw Prediction is active. Move the cursor to the desired location and Click to add a point. Repeat as necessary. Press Esc to end your prediction.

T3 Ticket Outta Here

T3 Ticket Outta Here

2.71828

2.71828

What went well today?

What caused you difficulty?

More of ?

Less of ?

T3 Ticket Outta Here

T3 Ticket Outta Here

2.71828

2.71828

I have learned ...

My question is ...

T3 Ticket Outta Here

2.71828

I have learned ...

My question is ...

My next steps are ...

2.71828

T3 Ticket Outta Here

