Teachers Teaching with Technology™
Professional Development from Texas Instruments

Using TI-Nspire™ in Your Classroom Physics

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The TI-Nspire Classroom

Reasoning about algebraic concepts

If the value of x is increased by 5, which expression has a value that must also increase by 5?

A. $x + 7$
B. $4x$
C. $8 - x$
D. $x/2$

(New Hampshire 2006, 45% correct)

If $ab + ac = 0$ and $a \neq 0$, then which statement must be true?

A. $b = 0$
B. $c = 0$
C. $b = c$
D. $b = -c$

(New Hampshire, 2006, 39% correct)

Exponential growth/decay

x	y
-4	16
-2	4
0	1
2	0.25

Which equation describes the relationship between x and y

16% A. $y = 0.5^x$
15% B. $y = 1/2^x$
18% C. $y = 2^{-x}$
46% D. All of the equations shown describe the relationship between x and y.

(Maine 2006, 46% correct, memorization)

The Challenge:

For many students ideas may "stick" for the moment but do not stay or transfer to new situations

TI Nspire: A Possible Solution

- Use technology to provide different learning experiences that allow students to interact with the mathematics in new ways.
- Structure lessons that take account of well documented trouble spots.
- Ask questions that reveal student thinking - questions that promote reasoning and sense making.

Research suggests

Students learn if

- they are actively involved in choosing and evaluating strategies, considering assumptions, and receiving feedback.
- they encounter contrasting cases- notice new features and identify important ones.
- Struggle with a concept before they are given a lecture
- Develop both conceptual understandings and procedural skills

National Research Council, 1999

- NCTM High School Focal Points suggest reasoning and sense making should be the central focus of high school math

Strengthening the practice of formative assessment produces significant learning gains

(Black & Wiliam, 1998)

"…when teachers learn to see and hear students' work during a lesson and to use that information to shape their instruction, instruction becomes clearer more focused and more effective."

NRC, 2001, p 350

The questions

- "…**the only point of asking questions is to raise issues about which a teacher needs information or about which students need to think**."
- The responses a task might generate and the ways of following up have to be anticipated
- Questions are a significant part of teaching where attention is paid to how they are constructed, used to explore, then develop learning

(Black et al, 2004)

A "TI-Nspired" Teacher

- Asking Questions
- Facilitating Discussion
- Asking Questions
- Assessing Student Understanding
- Asking Questions
- Shaping Instruction Based on What Students are Thinking

A "TI-Nspired" Student

- Engaging in Inquiry
- Making Conjectures
- Building Sense-Making

What is the math/science?

Why does is work?

A "TI-Nspired" Classroom

- Promote classroom discourse.
  - Often, teachers ask a short question, one student gives a short answer, and then the teacher moves on.
- Probe deeper:
  - Ask "Why?"
  - Ask for students to reason things out.
  - Have students comment on other students' comments.

Pedagogical Foundation:

Students **learn mathematics** by

- taking mathematical actions on mathematical objects,
- observing the mathematical consequences, and
- reflecting on their meanings.

Dick, 2007

Types of Activities:

- Action/Consequence/Reflection
- Investigative Activities
- Simple "how to" lessons

- Focus on asking questions that generate reasoning and sense making about the mathematics

TI-Nspire Activities

- Address key math/science concepts
- Questions to ask
- We will consider
  - Planning - alignments within courses
  - The Student perspective
  - The Teacher perspective
  - Formative assessment opportunities
  - Extensions and further inquiries
  - Impact on understanding
- And discuss how the activities might play out in your classroom

Goals of the Workshop:

- Become comfortable using the TI-Nspire handheld and TI-Nspire Computer Software – Teacher Edition
- Recognize that TI-Nspire provides opportunities for students to engage in reason and sense making, and making connections
- Recognize the implications of having students create and use their own documents, along with the value of exploration and investigation using pre-made documents
- Recognize that when students struggle with fundamental concepts TI-Nspire activities can help provide scaffolding and develop understanding

Reasoning/Sense Making Questions

- **Compare and contrast**: How are they alike? How different?
- ***Predict forward***: "What would happen if . . ?"
- ***Predict backward*****:** "How can I make…happen?" "Is it possible...?"
- **Analyze a connection/relationship**:
  "When will...be (larger, equal to, exactly twice, …) compared to ...?"
  "When will…be as big as possible?"
- **Generalize/make conjectures**:
  "When does...work?" "Under what conditions does…behave this way?"
  "Describe how to find…" "Is this always true?"
- **Justify/prove**: "Why does…work?"
- **Consider assumptions** inherent in the problem and what would happen if they were changed
- **Interpret information, make/justify conclusions:**
  "The data support…" "This…will make…happen because…"

Burrill & Dick, 2008

Core Belief for TI-Nspire

Educators who appropriately and effectively integrate TI-Nspire into their activities and lessons with peers and students will enhance both the teaching and learning of mathematics and science, leading to increased student achievement.

Your active participation in this institute will provide you with content insights, questioning strategies, and technology skills to support your success with TI-Nspire.

References

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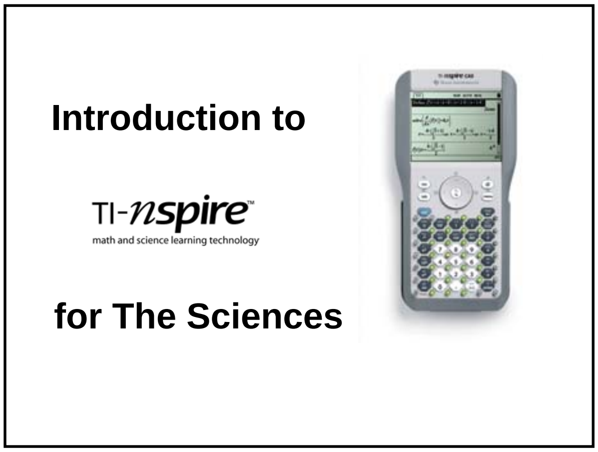
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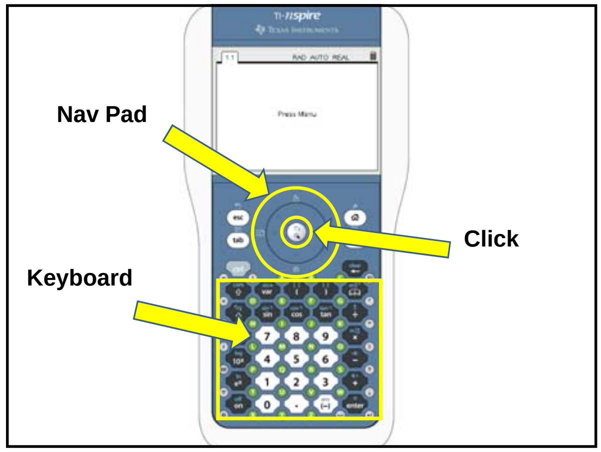
TI-nspire
math and science learning technology
for The Sciences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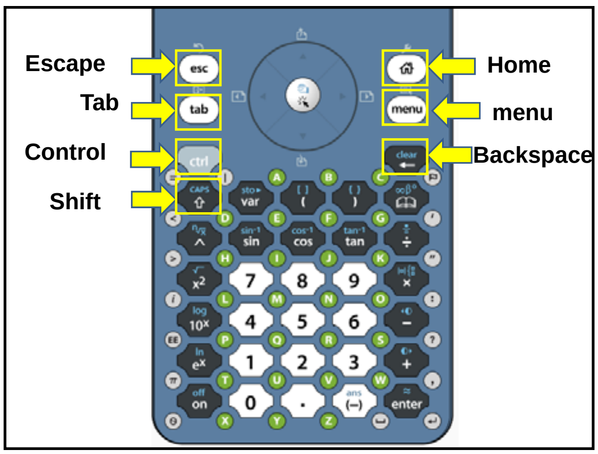
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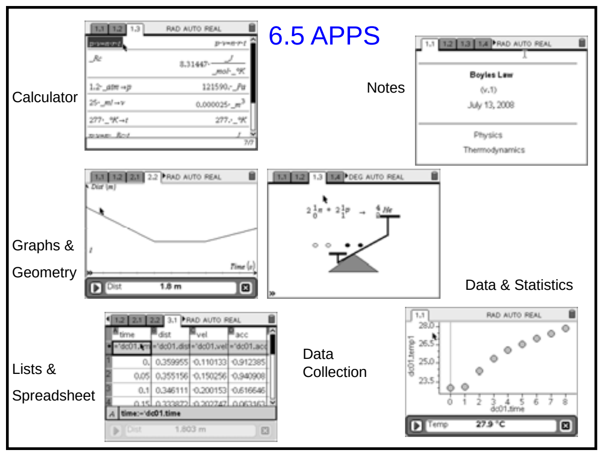
6.5 APPS
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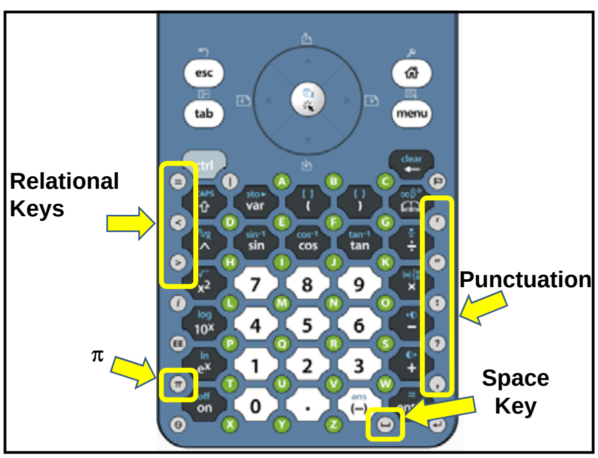
Graphs &
Geometry
Data & Statistics
Lists &
Spreadsheet
Data
Collection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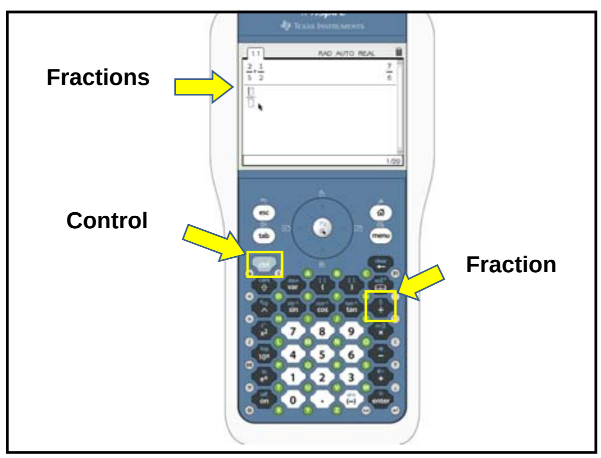
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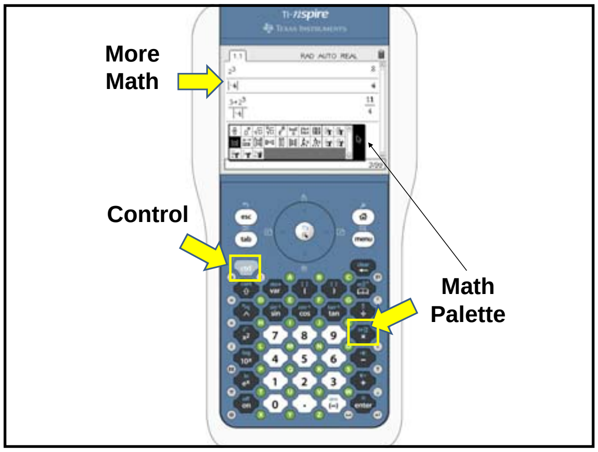
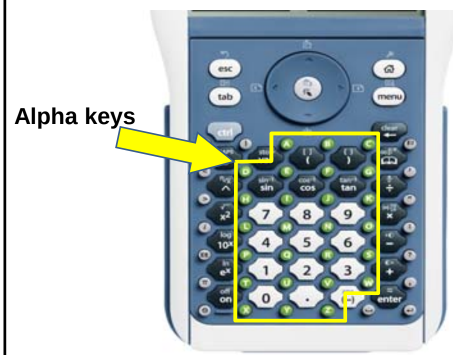




Unit Conversion

Important ctrl Keys

ctrl Z or ctrl esc for Undo

ctrl Y or caps esc for Redo

Repeat for multiple levels of Undo and Redo

ctrl C for Copy [once you highlight what you want to copy]

ctrl X for Cut [once you highlight what you want to cut]

ctrl V for Paste [once you have copied to the clipboard]

ctrl S for Save or Save As

ctrl D to launch the Data Collection APP

Press the ctrl followed by the letter or command.

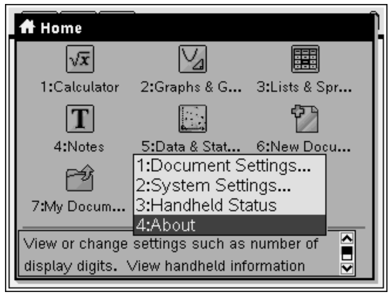
Let's get started!

Checking and Updating OS on Handheld

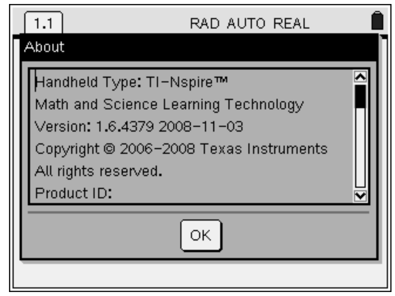
Checking TI-Nspire OS

Press Home 8 System Info

Home



System Info



About

System Info opens a menu that enables you to view and change document and system settings. You can also view detailed information about your handheld and its battery status.

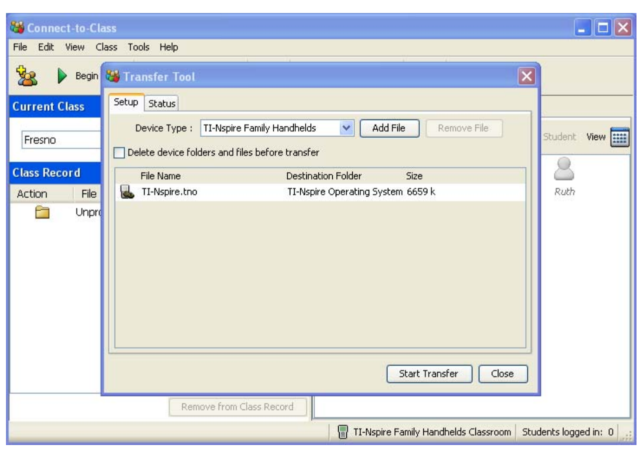
Viewing handheld details on the About screen

The **About** screen displays information about the TI-Nspire™ handheld type, the operating system (OS) version, and product ID.
For information regarding OS updates, see the chapter *Transferring Files* in the electronic version of the handheld guidebook. This guidebook is available on the Texas Instruments web site: http://education.ti.com/guides.

Using Connect-to-Class to Update the Handheld OS

Note: Connect-to-Class can be configured to either manually or automatically check for updates to the software and handhelds. See the Connect-to-Class Reference book or the Help menu.

Connect the handheld to the computer via the USB cable. You may connect multiple handhelds at one time using the provided USB hub.



Click on the menu option Tools then Transfer Tool. In the dialog box indicate the type of device and click on Add File. Browse to find the new handheld OS file. Click Start Transfer to begin.

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The Transfer Tool

Connect-to-Class™ software includes a Transfer Tool that you can use to transfer files to TI-Nspire™ handhelds when a class session is not active. The Transfer Tool allows you to transfer document files and operating system (OS) files to a succession of handhelds, without requiring students to log in.

The Transfer Tool streamlines the file transfer process. You can select TI-Nspire™ document and OS files that you have stored on your computer and install them on your students' TI-Nspire™ handhelds. Once the transfer begins, it continues until you stop it. TI-Nspire™ handhelds can be connected in succession and receive queued files. Connect-to-Class™ software keeps track of what handhelds have been connected and the status of file transfers to those handhelds.

If you are sending the same files to your entire class, sending files to devices when students are not present, or if you do not plan on collecting documents using Connect-to-Class™, then you should use the Transfer Tool. Transfer Tool does not require a student's login to send files to the handheld; it simply sends the files to connected devices, allowing you to send files with or without students present. The Transfer Tool also allows you to clear folders and files on the handheld, as well as transfer TI-Nspire™ OS files.

This section covers the information you need to know to use the Transfer tool.

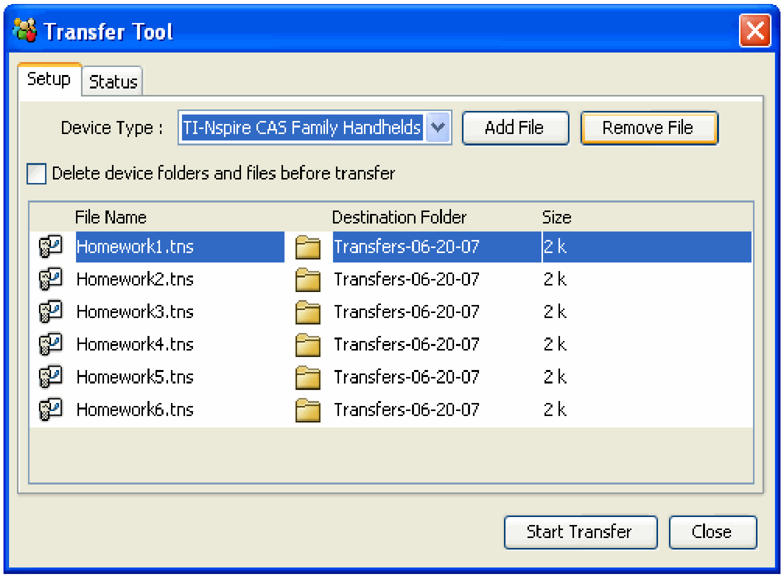
Opening the Transfer Tool

You can open the Transfer Tool from the Connect-to-Class™ software home screen.

To open the Transfer Tool

1. If you have a class session running, end it.
2. Select **Tools > Transfer Tool**.

   The Transfer Tool dialog displays.



3. Select the Device type from the drop down menu.

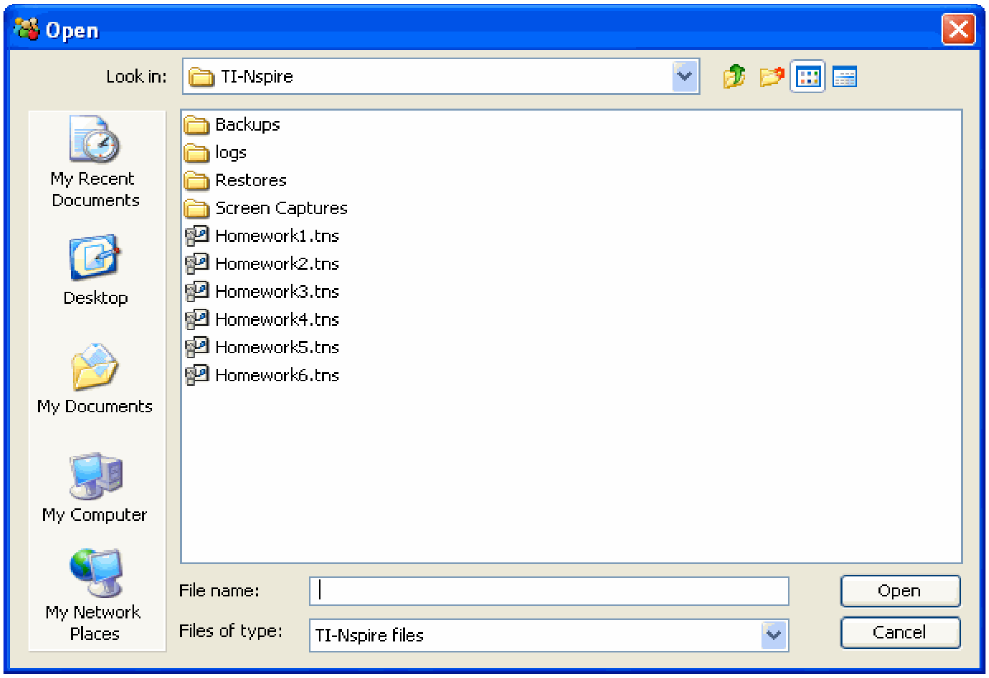
Adding files to the transfer list

You must add TI-Nspire™ document files and operating system files (OS) to the transfer list in order to transfer them.

Only one OS per device type may be added to the list. The OS must be a newer version than the one currently on your handheld. You cannot transfer a version of the OS that is already on the handheld, or an older version of the OS.

Adding files to the transfer list

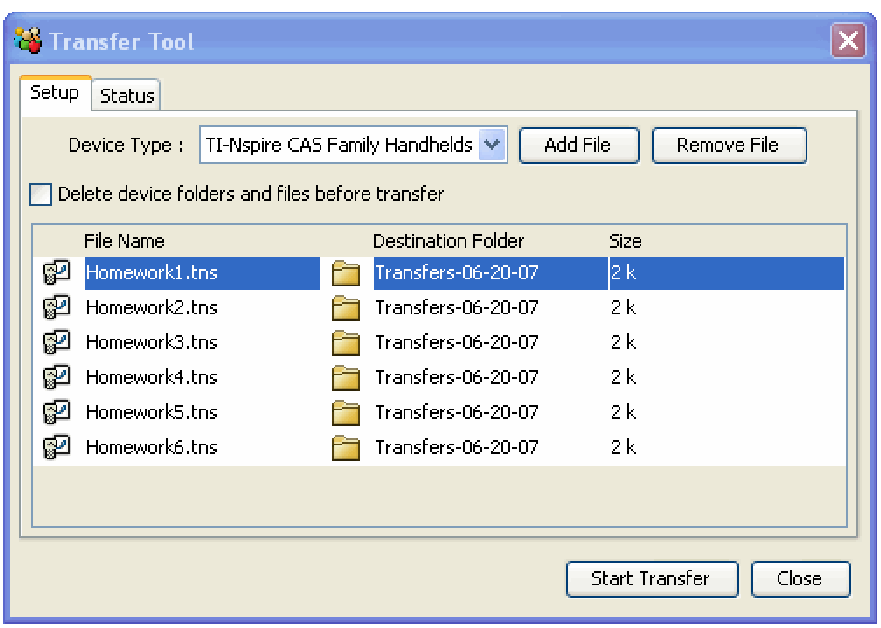
1. If you have not already done so, select the Device type from the drop down menu.
2. Click the **Add File** button.
3. The Open window displays.



4. Navigate to the file you want to add, and click to select it.

   Note: To select multiple files, press and hold the **Ctrl** key while clicking each file name.

5. Click **Open**. The file(s) are added to the list on the Transfer Tool screen.



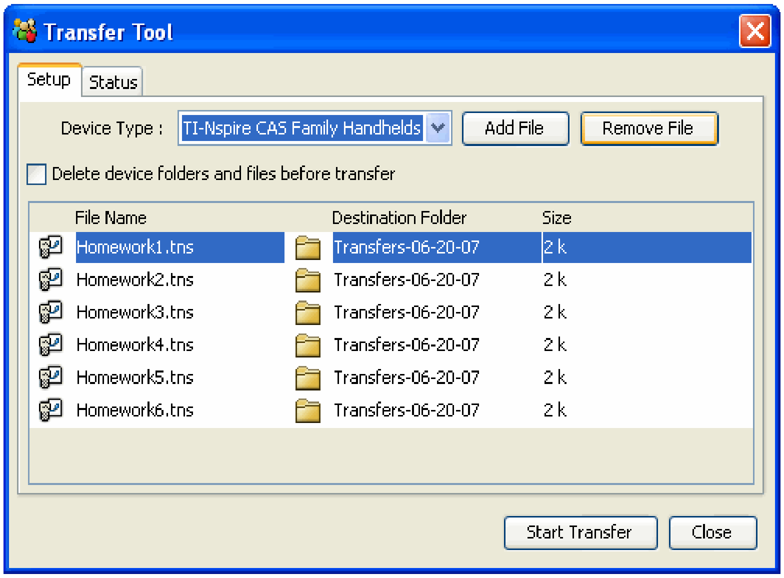
6. Repeat Steps 2 -5 until all files for transfer are added to the list.

7. Click **Start Transfer** to send the files.

Removing files from the transfer list

If there are TI-Nspire™ documents or OS files in the transfer list that you no longer want to have available for transfer, you can remove the files from the transfer list.

1. Click the name of the file you want to remove from the transfer list.



2. Click **Remove File**.

Changing the destination folder

To change the destination folder for the file transfer, double click in the cell and type a new name for the destination folder. Files that you transfer will be stored in this folder on student handhelds.

If the destination folder name you designate does not exist on student handhelds, the software creates it.

Note: Folder names may use alphanumeric characters. Special characters (? / | : * " " < > |) are not allowed.

Viewing transfer status

To view the status of individual file transfer for a selected handheld, click on the + before the file name to expand the display.

In the expanded view, the following information displays for each connected handheld:

- DeviceID (and device icon).
- Name of file
- Progress bar for that file on that handheld.
- Error conditions:
  - Low battery
  - Wrong device type
  - Memory full
  - Lost connectivity

Other transfer status information

- When a new device is connected, the status updates.
- The device progress of a file disappears when it reaches 100%.
- Incomplete device transfers remain in the expanded view of the file status.
- During a transfer session, the transfer tool keeps track of what device IDs have connected and successfully completed one or more transfers.
- If a device unplugs and then replugs into the transfer session, the transfer tool shows the status of completed transfers, and resumes transfer of other files, if necessary.
- During a transfer, if you select the Setup tab, all the controls are disabled (read only).

If you stop a transfer

- Files under the Setup tab remain listed.
- Status information for the transfer no longer displays under the Status tab. The message “No transfers are active. Use the Setup tab to configure and start the transfer” displays.

Deleting device folders and files before transferring files

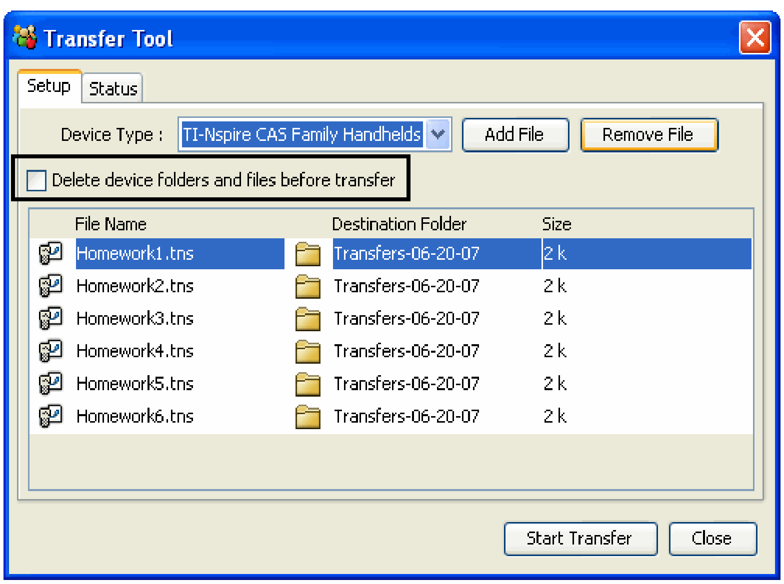
The Transfer Tool provides the option to delete all files and folders on each connected handheld before beginning a new file transfer. This allows you to "baseline" your students’ handhelds to make sure that your students’ handhelds contain only the files you want them to use. By default, this option is not selected.

You will find this option useful whenever your student’s handheld should be blank. Here are some times when you might want to delete folders:

- At the end of a semester, grading period, or conclusion of any Instruction module
- Before administering exams

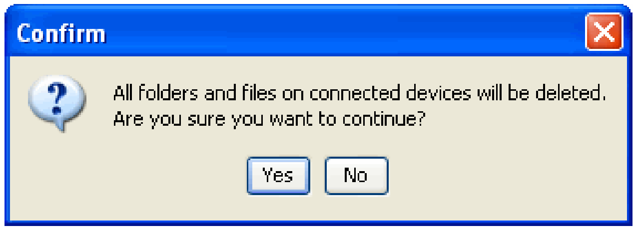
To delete folders and files on connected handhelds

1. Click the check box next to the option.



2. Click the **Start Transfer** button to begin the deletion.

   A message displays to confirm that you want to delete the folders and files.



3. Click **Yes** to confirm.

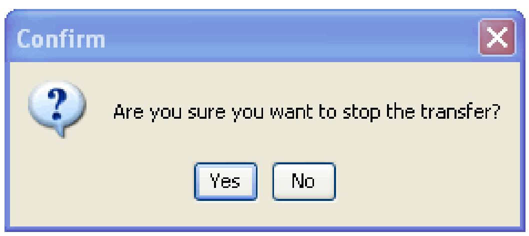
   The status tab tracks the progress of the delete actions as they occur, displaying which devices have been plugged in, and when the actions are completed.

Stopping file transfers

You can stop a file transfer at any time.

To stop a file transfer

1. Press the **Stop Transfer** button.
2. A warning dialog displays, asking if you are sure you want to stop the transfer.



3. To confirm that you want to halt transmission, click **Yes**. Transfers are stopped.

   Note: If any student devices received the file or files, those files remain on the devices.

Closing the Transfer tool

When you finish transferring files to your students' TI-Nspire™ handhelds, close the Transfer tool. To do this, click **Close**.

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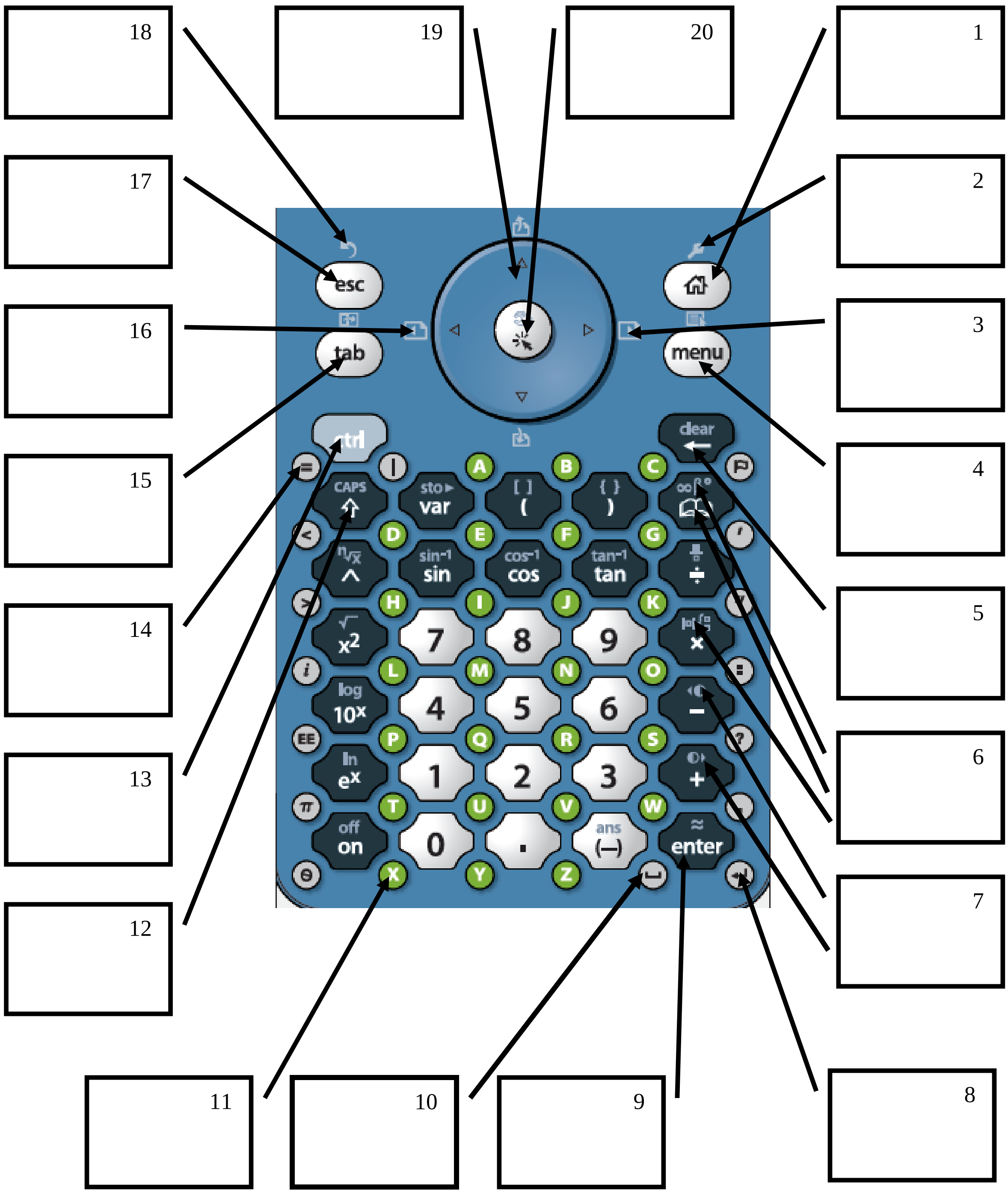
TI-Nspire™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Exploring Motion with the CBR 2

Physics – Student Activity

Name ________________________

Class ________________________

Activity Overview:

- *In this investigation you will explore motion over time from two different points of view. In the first instance, you will be shown a graph of some motion that has occurred, and your job will be to describe a motion sequence that could be represented by the given graph. In the second part of the investigation, you will be given a script that describes some motion, and then you will produce a sketch that you think would be the result of the described motion. In both cases you will verify your answers using the CBR 2 and your TI-Nspire CAS handheld. All motion will be in the x or y direction—that is, motion in one dimension.*
- *At the end of this investigation you will be able to assess your learning and understanding.*

Materials:

- *TI-Nspire™ CAS handheld*
- *CBR 2 with appropriate cables and a few clamps (one per team)*
- *Various objects and ramps to help in making the required motion*
- *Exploring_Motion_with_the_CBR_2_Physics.tns*

How to Use the CBR 2 with the TI-Nspire *Data Collection* Application (Optional)

Your teacher will demonstrate how to use the CBR 2 with your TI-Nspire handheld and its *Data Collection* application.

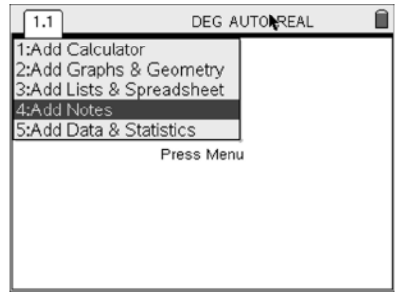
Some skills you will need are:

- Create a new document on the TI-Nspire
- Find and open a document on your handheld
- Save a document, give it a name, and create or find a folder
- Launch the *Data Collection* application
- Adjust the settings from the *Data Collection* application menu
- Add a new application to your problem
- Adjust the window in *Graphs & Geometry*
- Use the Segment tool in *Graphs & Geometry*
- Add a new problem to your document
- Hide and show the function edit line in *Graphs & Geometry*
- Start and stop data collection
- Send and receive files from your TI-Nspire

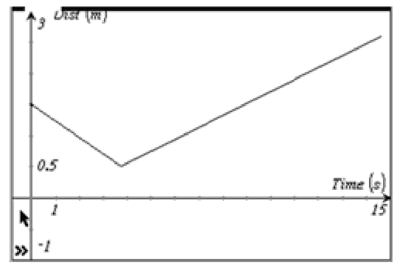
Part 1 – Given a Distance vs. Time Graph, Write a Script to Describe the Motion

In this part your team will be given seven graphs of distance vs. time data. Your job will be to write a script that, when followed, will produce the same graph.

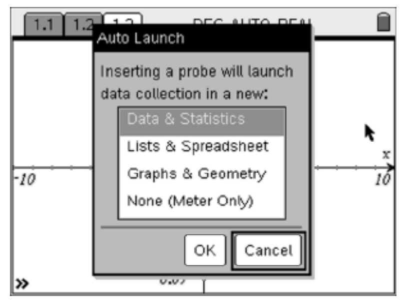
1. Open a new document on your TI-Nspire handheld and select **Notes** as the first page. On this page, write in the assignment name, date, team name, names of the team members, and other relevant information, including that this is Part 1.



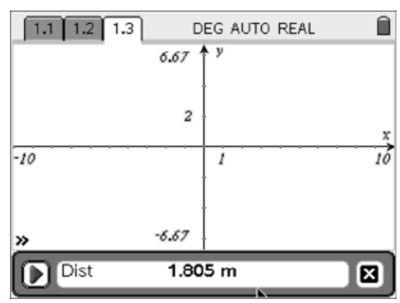
2. Add another *Notes* page and write your script for the motion shown in the image to the right for Graph I.



3. Now add a *Graphs & Geometry* page and plug the CBR 2 into the TI-Nspire handheld. Cancel the pop-up screen by pressing (tab) until the Cancel option is highlighted and then pressing (enter).



4. Now launch the *Data Collection* application again by pressing by pressing (ctrl) (D).

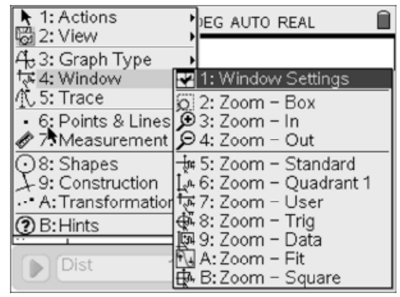


Exploring Motion with the CBR 2

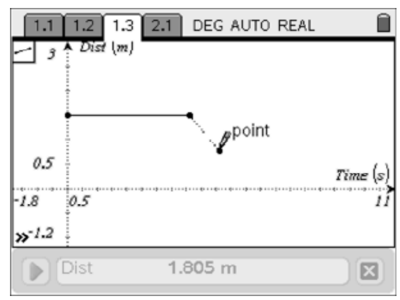
5. Set up the data collection as needed for the above graph and your script. Press menu to explore the options when your focus is on the *Data Collection* application. Use ctrl tab to change the focus from *Graphs & Geometry* to *Data Collection*. Finally, we want to have the data that you collect displayed on the current *Graphs & Geometry* application. To do this, change the focus to the *Data Collection* application and Select **MENU > Experiment > Display Data In > App(s) on Current Page**.

6. After doing this, you will see the function entry line on *Graphs & Geometry*. To hide this, you will need to switch applications (ctrl tab) and then use ctrl G to hide it. This is a toggle, so you may bring the function entry line back with the same keystrokes.

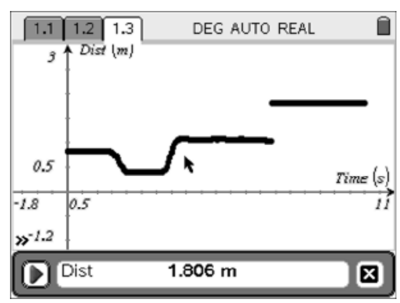
7. Examine Graph I and determine the time and distance settings you think you will need. Set up the window as you want it from the *Graphs & Geometry* menu by selecting **MENU > Window > Window Settings** and then adjusting the values. Use tab to move to different lines, and then highlight OK and press enter. You may also adjust the window settings from the *Graphs & Geometry* screen by clicking on the numbers at the ends of the axes.



8. At this time, you need to draw the line segments that represent the graph that you were given. This is what you will do in part 2 of the investigation. To draw, select the **Segment** tool from the Points & Lines menu. (Select **MENU > Points & Lines > Segment** when your focus is on *Graphs & Geometry*.) Then, move to the location you want to start drawing and press the click key to start a segment and then again to end the segment. This is an option, unless your teacher requires it.



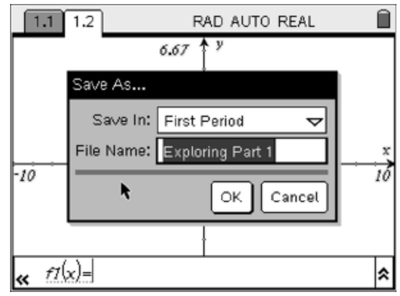
9. Once all the settings are made on the TI-Nspire and your team has arranged the CBR 2 and the moving object(s), you should collect the data. Switch to the *Data Collection* application (ctrl tab) and then with the play button highlighted, press enter. The data collection will occur for the time interval you selected, and the data will appear as a scatter plot on the *Graphs & Geometry* screen.



10. If the plot of the data is close to the given graph, then you may move on. If you are off or mess up the motion for some reason, you should repeat and discard the first data set.

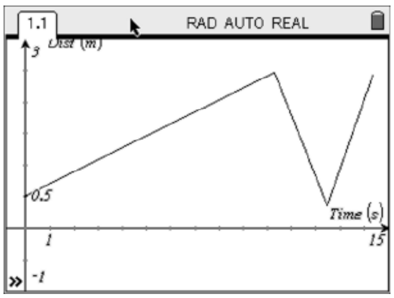
11. You might want to add a *Notes* page after the data collection is successful where you can reflect on success or failure.

12. When satisfied, add a new problem and continue through the other six graphs, saving the document periodically using ctrl S. Note: The first time you save, you will need to give the document a name and place it in the correct folder.

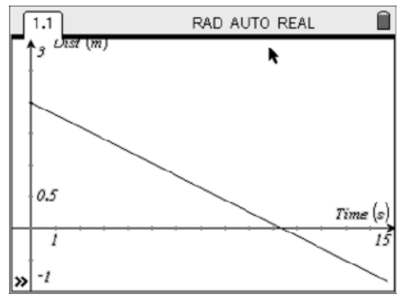


13. Repeat the steps above for the following graphs:

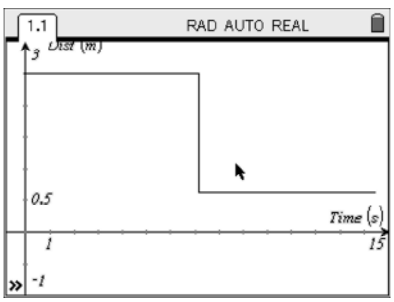
Graph II



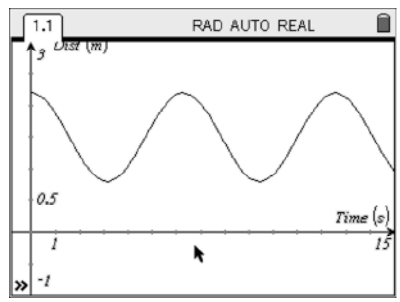
Graph III



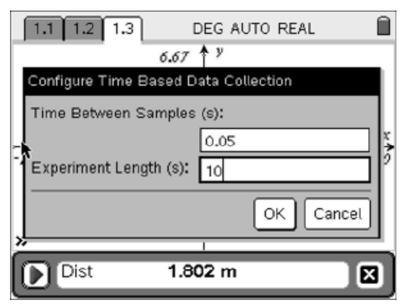
Graph IV



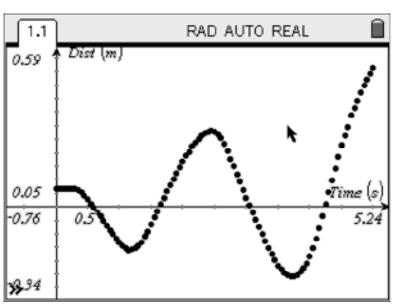
Graph V



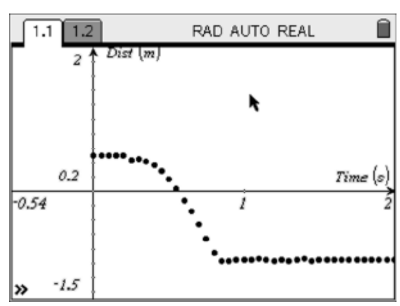
*Notice that the time of the experiment in the next two graphs is different. Adjust the time of the experiment and the *G&G* window as needed. From the *Data Collection* application, select **MENU > Experiment > Set Up Collection > Time Graph**. Enter the values that your team thinks best to help match the graphs. Use tab to switch between the data entry boxes and the OK button.



Graph VI



Graph VII



14. When you have finished all seven graphs, save the document and then send it to each person in the team and to your teacher.

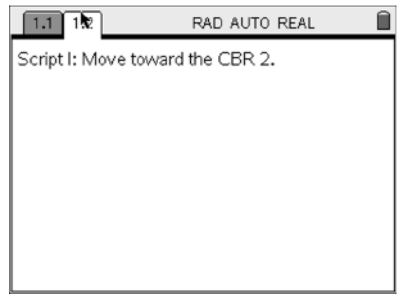
Exploring Motion with the CBR 2

Part 2 – Given a Script for Motion, Make a Sketch of the Resulting Distance vs. Time

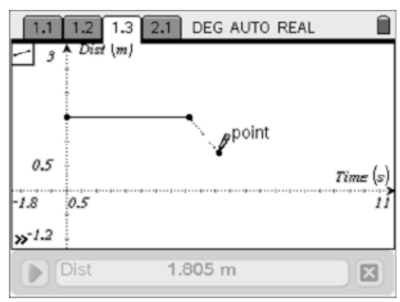
In this part of the investigation, you will be given seven scripts for motion over time. Your team will create a sketch of the distance vs. time plot that you think will occur and then verify using the CBR 2.

1. Open a new document and add a *Notes* page. On this page, write in the assignment name, date, team name, names of the team members, and other relevant information, including that this is Part 2.
2. You may want to write the script again in a *Notes* page on the TI-Nspire to avoid confusion.

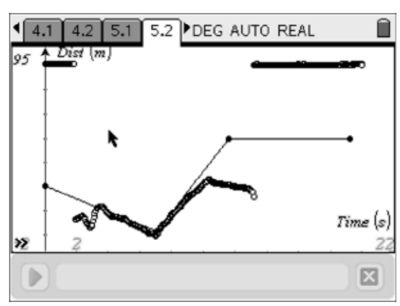
Script I: **Move toward the CBR 2.**



3. Add a *Graphs & Geometry* page, launch the *Data Collection* application, and set up the data collection as you did in Part 1. In this part, there should be more consideration of the time needed to do the motion, so you will probably want to adjust the time graph from 5 seconds. Make sure you have the data that you collect displayed on the current *Graphs & Geometry* application. To do this, select **MENU > App(s) on Current Page**.
4. After you have all of the settings made for the *Data Collection* application, switch to the *Graphs & Geometry* application and adjust the window. Consider the maximum distance, since most motion should occur within 6 meters of the CBR 2. Then, as the last thing you should do before collecting the data, draw what they think will happen with the distance vs. time plot as a result of the described motion in front of the CBR 2. Use the **Segment** tool from the Points & Lines menu or other options in *Graphs & Geometry* application, including function graphing, to draw your sketch.



5. Switch to the *Data Collection* application, arrange the moving object(s), and then collect the data.



Exploring Motion with the CBR 2

6. If your attempt is far outside the window setting, you may lose part of your sketch due to the **Zoom-Stat** that occurred after the data collection. Adjust the window in again if you think you were close, but if you know it was a bad run, just collect the data again, discarding the last set of data.
7. You might want to add a *Notes* page after the data collection, where you may reflect on success or failures.
8. When satisfied, add a new problem and continue through the other six scripts. Save the document periodically using ctrl S.

   Script II: Move back and forth in front of the CBR 2.

   Script III: Drop an object on the CBR 2.

   Script IV: Stand half the distance away from the CBR 2 and then jump toward it.

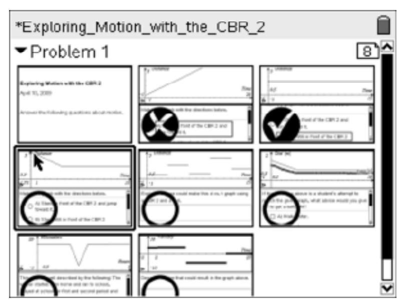
   Script V: Point the CBR 2 at an open doorway and then shut the door.

   Script VI: Roll a ball up a ramp, toward the CBR 2.

   Script VII: Rush away from the CBR 2.
9. When finished, save and then send the document to each person in your group and to your teacher.

Part 3 – The Assessment

1. Collect the *Exploring_Motion_with_the_CBR_2_Physics.tns* file from your teacher. Work on this as an individual or as a team as per your teacher's instructions.
2. As you move from page to page using ctrl ▶, you will see a section to enter your answers. In the case of a multiple guess or true/false, you will just move to your answer and press enter to pick. Use ctrl tab to switch from the top screen to the bottom. When you are finished, use ctrl ▲ to see how well you did. The circle means you have not answered the question or it was an open response; the check or x indicates you got it right or wrong, respectively.



3. Discuss your answers and the experience of this investigation with your team and the class, as guided by the teacher. Save and send the assessment to your teacher.

Extensions – Creating Your Own (Optional)

1. As a team, create a sketch of some motion over time and then describe how it could occur in a script. Swap your sketches with another team and write a script to describe their motion. Then regroup with the other team and compare scripts.
2. Repeat the process above with another team. This time, start with a script. Make your solution sketch and then swap scripts. After you get your solutions to the other team's script, compare sketches.

Exploring Motion with the CBR 2

Physics – Teacher Notes

Activity Overview: Exploring Motion with the CBR 2

As students prepare to learn about motion as a function of time in your class, they come to the table with certain prior knowledge. In some cases, what they know about motion in one dimension is true, and in some cases what they know is not true. In this investigation we will establish understandings about motion that will serve as a canvas for teaching mechanics in your course.

Teacher Preparation and Notes:

- *This investigation can be done easily in one period if the students have been introduced to both the TI-Nspire and the CBR 2. If this is their first experience, you would need most of two class periods or one Block class to fully complete this investigation. You may not want to do all seven graphs and all seven scripts in parts 1 and 2. You could assign different graphs/scripts to different groups to get full coverage, use one of each as a demonstration to the class before they start, or just pick some to be done and use the others for later assessments or not at all. You may want to cut out some of the steps and make the investigation less complicated. If your students are comfortable with CBR 2 data collection with the TI-Nspire and the Data Collection application, you can take some shortcuts and make this investigation involve more inquiry and be less directed.*
- *As you prepare for this event, you will need to make sure you have the appropriate cables for your CBR 2s and that the CBR 2s are working, with relatively strong batteries. Also, you should collect various materials and objects that the teams might want to use to produce/reproduce the required motion. Be subtle about this, so as to avoid contaminating the groups with your ideas on how to make the motion.*
- *Students may need an overview of the Data Collection application and the CBR 2. It is assumed the students can move around in a TI-Nspire document. This may be the first time that they add a new problem to a document.*
- *You will need to demonstrate data collection with the TI-Nspire by using the TI-Nspire software. It is best to use the Teacher Edition in the SmartView/Emulator mode so students can see which keys you press. Using the CBR 2 with the computer requires the USB mini-A to standard-A adapter or a printer cable (USB type A, male to USB type B, male). You will want to use teams of 2 or 3 as you do this investigation.*
- *Your groups will need some space to do their movements, but all motion will usually occur within 4 meters of the CBR 2. The problem is the width of the signal sent from the CBR 2. You must make sure that other objects (metals are a particular problem) just off line of the moving object do not reflect the signal. The students will figure this out rather rapidly, in most cases, but it would useful if you checked on them to make sure they are successful on the first graph they try. After that, they will do well on their own. Another issue is that teams may want to describe all of the motion at once and then verify. It turns out that if they are wrong, all the attempts will be wrong, so they will have to redo. If you consider this a constructivist event, it will be better for those who don't have a clue.*

Exploring Motion with the CBR 2

Materials:

- *TI-Nspire™ CAS handheld technology (one per student)*
- *TI-Nspire CAS Teacher Edition computer software and projector with data collection cables*
- *Student worksheet: Exploring_Motion_with_the_CBR2_Student_Physics.doc*
- *Calculator file: Exploring_Motion_with_the_CBR_2_Physics.tns*
- *CBR 2™ with appropriate cables and a few clamps (one CBR 2 per team of two or three)*
- *Extra AAA and AA batteries and a battery tester (optional)*
- *Ramps, balls, metersticks, cars, coffee filters, and other objects*
- *Connect-to-Class, TI-Nspire Navigator, TI-Nspire Link with direct connect cable or unit-to-unit cables to send the assessment file and collect the student documents with results*

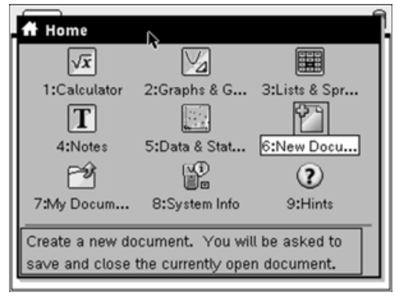
Suggested Related Activities:

To download any activity listed, go to education.ti.com/exchange and enter the number in the quick search box.

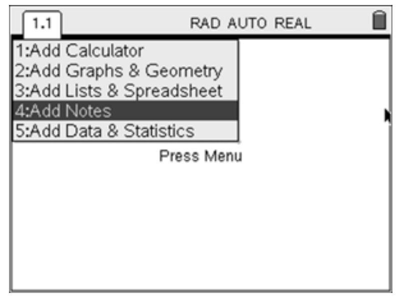
- *Rolling a Ball on an Inclined Plane — 8550*
- *Various Activities found at TI Physics: http://www.tiphysics.com/*
- *Two Exploration books: Math and Science in Motion: Activities for Middle School and Modeling Motion: High School Math Activities with the CBR, found at http://education.ti.com/educationportal/sites/US/sectionHome/activitybook_section_datacollection.html*
- *Atomic Learning Tutorials: http://movies.atomiclearning.com/k12/ti_nspire/*
- *CBR 2 references at http://education.ti.com/educationportal/sites/US/productDetail/us_cbr_2.html*

How to use the CBR 2 with the TI-Nspire Data Collection Application (Optional)

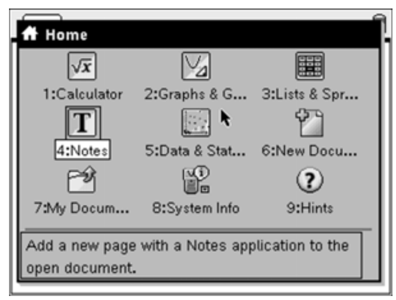
You will need to establish a sequence for the students to follow as they collect data with the CBR 2 and their TI-Nspire. This requires a few TI-Nspire skills that the students may already have. These are the steps that they should follow as they collect data.



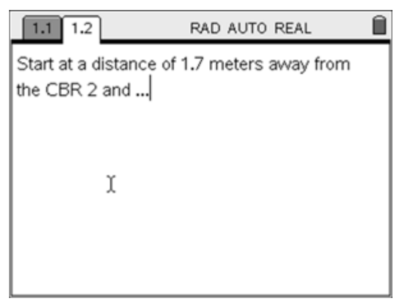
1. Open a new document by pressing and selecting **New Document**. If prompted to save or discard, choose the right choice.

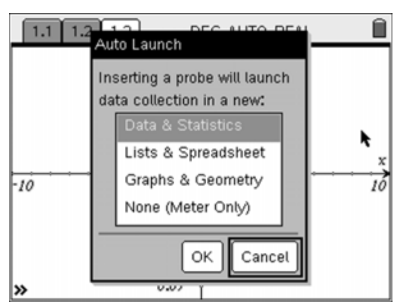


2. Select **Notes** as the first page of the document. Have the students write in the assignment name, date, team name, names of the team members, and other relevant information (part 1 or part 2).



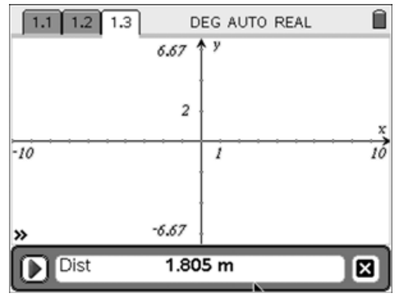
3. Have the students insert another *Notes* page, and on that page they should write the script for the motion that would produce the given graph (from part 1).





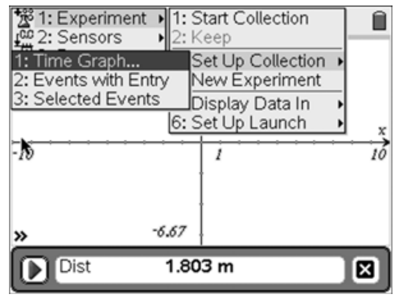
4. Now the students should add a *Graphs & Geometry* page by pressing (or ctrl I)and selecting **Graphs & Geometry**. This is where they will test their script using the CBR 2.
5. Plug the CBR 2 into the TI-Nspire handheld and cancel the pop-up screen by pressing tab until the **Cancel** option is highlighted and then pressing enter.

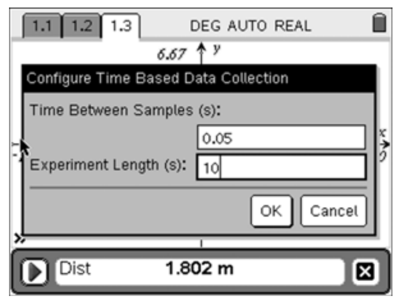
6. Now we will launch the *Data Collection* application again by pressing ctrl D. We want to set up the data collection for the individual graph we have been assigned this time.



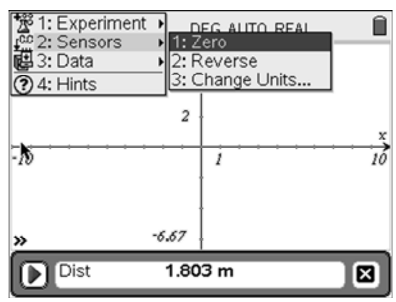
7. Explore the settings available with the *Data Collection* application by pressing menu when the Data Collection console is the point of focus (use ctrl tab to change the focus from *Graphs & Geometry* to *Data Collection* as needed).

8. You may adjust the time of the experiment from the *Data Collection* application by Selecting **MENU > Experiment > Set Up Collection > Time Graph**. Enter the values that your team thinks best to help match the graph. Use tab to switch between the data entry boxes and the OK button.

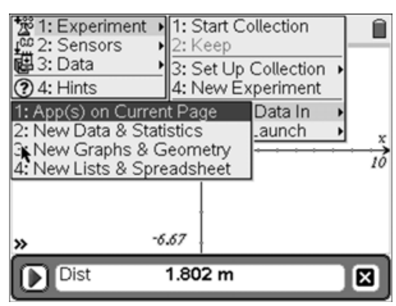




9. To adjust the CBR 2, select **MENU > Sensors > Zero** will set the distance currently being displayed by the CBR 2 at 0 meters. Then everything closer than that will read as a negative distance. To undo the zeroing of a probe, just select **MENU > Experiment > New Experiment**.

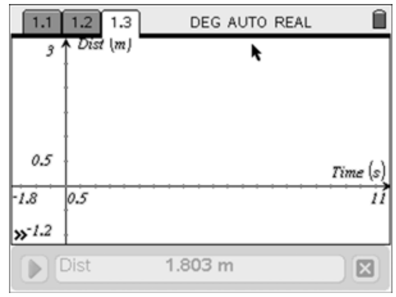


10. Now we want to have the data that you collect displayed on the current *Graphs & Geometry* application. To do this, select **MENU > Experiment > Display Data In > App(s) on Current Page**.

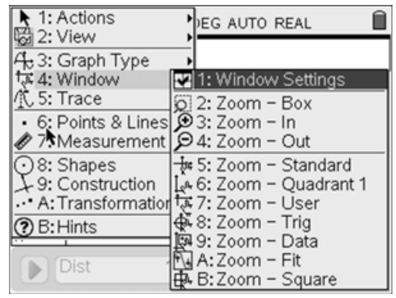


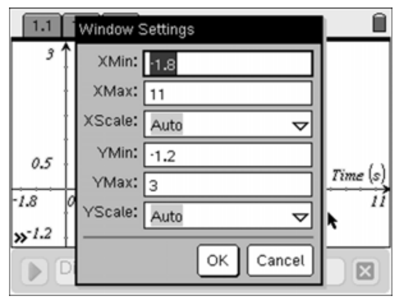
Exploring Motion with the CBR 2

11. After doing this, you will see the function entry line on *Graphs & Geometry*. To hide this, you will need to switch applications (ctrl tab) and then use ctrl G to hide it. This is a toggle, so you may bring the function entry line back with the same keystrokes.

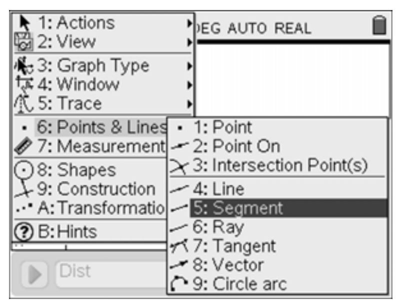


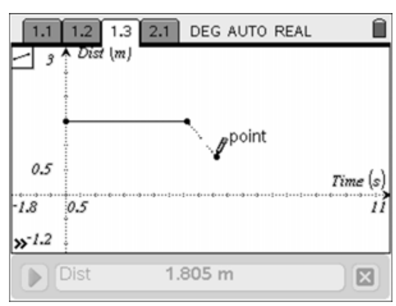
12. At this time, you could draw the line segments that represent the graph that you were given. This is what you will do in part 2 of the investigation. To draw, you would need to first set up the window as you want it from the *Graphs & Geometry* menu by selecting **MENU > Window > Window Settings** and then adjusting the values. Use tab to move to different lines, and then highlight OK and press enter. You may also adjust the window settings from the *Graphs & Geometry* screen by clicking on the numbers at the ends of the axes.





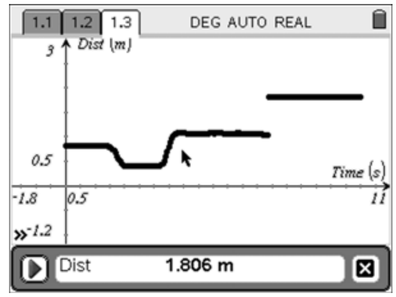
13. To activate the **Segment** tool, select **MENU > Points & Lines > Segment**. Then, move to the location you want to start drawing and press (click) to start a segment and then again to end the segment.



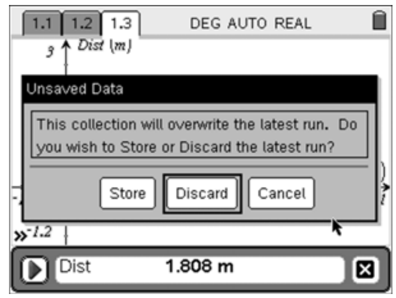


Exploring Motion with the CBR 2

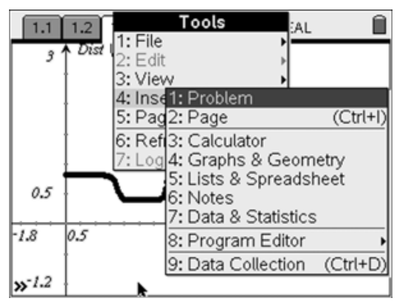
14. When you are set to collect your data, switch to the *Data Collection* application (ctrl tab) and then with the play button highlighted, press enter. The data collection will occur for the time interval you selected, and the data will appear as a scatter plot on the *Graphs & Geometry* screen.



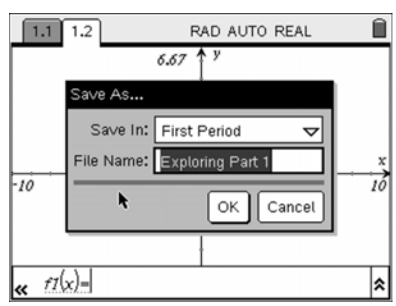
15. If you are far off your expectations or you just messed up, you can collect the data again. One thing that might happen is that the window will adjust after the data collection (the *Data Collection* application does a **Zoom-Data**). If this occurs and you have a good data set, you can just manually change the window back, as before. If you repeat the experiment, you need not worry about the window. To collect the data again, make sure your focus is on the *Data Collection* application and that the play button is highlighted. When you press enter, you will be asked whether to store or discard the data. Use tab and select the Discard option. Data collection will start right after you make your choice.



16. If you are successful, you will need to add a new problem to your document. If not, repeat the previous steps. To get the new problem, press ctrl home for the Tools menu (🔧) and select **Insert** to insert a second problem in the document. Then start the process over with the *Notes* page to describe the motion for the next graph. When you finish the second graph to your team's satisfaction, insert another problem and continue through part 1.



17. Don't forget to save the document. Press ctrl S and then select a name and folder.



Part 1 – Given a Distance vs. Time Graph, Write a Script to Describe the Motion

1. In this part, the teams will be given seven graphs of distance vs. time data. Their job will be to write a script that, when followed, will produce the same graph.
2. They will write each script in a problem in their TI-Nspire document, using one document for part 1 and another part 2. Each graph will then be associated with a problem number in the TNS file.
3. After they write the script, they will add a *Graphs & Geometry* page and launch the *Data Collection* application to display in that page. See the instructions above.
4. Once all the settings are made on the TI-Nspire and the team has arranged the CBR 2 and the moving object(s), they should collect the data. An option here would be for the team to draw or graph a function on the *Graphs & Geometry* screen to represent the graph they were given before they collect the data. Since this is not exactly a Match Me activity, a sketch is not required.
5. If the plot of the data is close to the given graph, they may move on. If they are off or they mess up the motion for some reason, they may repeat and discard the first data set. You might want them to add a *Notes* page after the data collection where they can reflect on their success or failures.
6. When satisfied, add a new problem and continue through the seven graphs. They should save the document periodically using ctrl S.
7. When they are finished, have the teams save and then send the document to each person in the group and to the teacher.

Part 2 – Given a Script for Motion, Make a Sketch of the Resulting Distance vs. Time

1. This part should be done in a new document, and it is just the opposite of the first part. The teams will be given seven scripts for some motion, and they will need to sketch a graph that they believe will represent the distance vs. time plot for each script.
2. You may want the teams to write the script again in a *Notes* page on their TI-Nspire to avoid confusion. They should then add a *Graphs & Geometry* page, launch the *Data Collection* application, and set up the data collection as in Part 1. In this part, there should be more consideration of the time needed to do the motion, so teams will probably want to adjust the time graph from 5 seconds.
3. After all of the settings are made for the *Data Collection* application, the students should switch to the *Graphs & Geometry* application and adjust the window. As they consider the maximum distances, remind them that most motion should occur within 6 meters of the CBR 2. Then, as the last thing they do before collecting the data, they should use the Segment tool from the *Graphs & Geometry* menu to draw what they think will happen with the distance vs. time plot as a result of the described motion in front of the CBR 2.
4. They should then switch to the *Data Collection* application, arrange the moving object(s), and then collect the data.

5. If their attempt is far off of the window settings they may lose part of their sketch due to the **Zoom-Stat** that occurred after the data collection. Have them adjust the window in *Graphs & Geometry* again if they think they were close, but if they know it was a bad run, they should just collect data again, discarding the last set of data.
6. You might want them to add a *Notes* page after the data collection where they can reflect on their success or failures.
7. When satisfied, add a new problem and continue through the seven scripts. They should save the document periodically using ctrl S.
8. When they are finished, have the teams save and then send the document to each person in the group and to the teacher.

Part 3 – The Assessment

1. Send the *Exploring_Motion_with_the_CBR_2_Physics.tns* to each person and have them answer the questions. Since it is a self-check, the teams can collaborate on the answers if they wish.
2. Debrief the teams and the class using the assessment document and the documents from Part 1 and Part 2. What did they think they knew that was proved to be true and what did they think they knew that turned out to be false?

Extensions – Creating Your Own

1. Have the teams create a sketch of some motion over time and then describe how it could occur in a script. They would then swap sketches with another team and write a script. The teams would then compare scripts.
2. Then the teams could write a script and make a sketch of what they think the distance vs. time plot would look like. They then should find another team, different from the team in step 1, and swap scripts. Each team would then make a sketch and then compare as before.

Roller Coaster Energy

Physics – Student Activity

Name ______________________

Class ______________________

Activity Overview:

- *With this action/consequence/reflect .tns file, students will develop an understanding of kinetic energy, gravitational potential energy, and the conservation of mechanical energy.*

Materials:

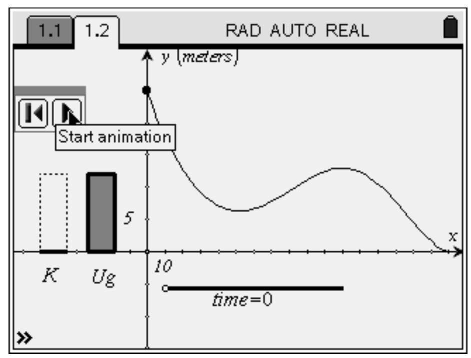
- *TI-Nspire™ CAS handheld*
- *RollerCoasterEnergy_Physics.tns*

Frictionless Roller Coasters Depict Conservation of Mechanical Energy

Press the play button to animate the frictionless roller coaster. 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. Indentify 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 time = 0 and the roller coaster is at its highest point.

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

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

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 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?

Roller Coaster Energy
Physics – Teacher Notes

Activity Overview:

- *With this action/consequence/reflect TNS file, 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 conservation of energy.*

Materials:

- *TI-Nspire™ CAS handheld*
- *RollerCoasterEnergy_Physics.tns*

Related Activity:

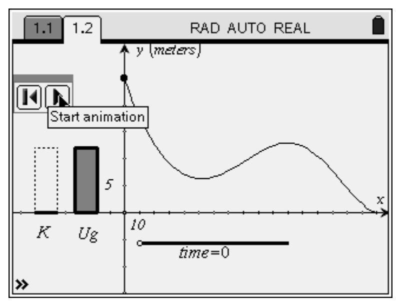
- *Potential and Kinetic Energy by Peter Fox #9601*

Frictionless Roller Coasters Depict Conservation of Mechanical Energy

Press the play button to animate the frictionless roller coaster. 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?

   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. A possible answer may be: **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, U_g is large.**



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

   a) Is this a distance versus time graph?

   No.

   b) What variable is on the horizontal axis?

   Distance in the *x*-direction

   c) What is the vertical axis?

   Distance in the *y*-direction, measured in meters

   d) How many meters above ground level is the roller coaster at the start?

   25 meters

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

   The gravitational potential is at a maximum.

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

   The kinetic energy is at a minimum.

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

   They are equal three times: once at about 1.8 seconds, once at 5.6 seconds, and again at 6.5 seconds.

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

   $U_g = K$ when the roller coaster is at half of its maximum height above the ground. 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?)

   The potential energy bar graph increases again, and the kinetic energy bar graph gets 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?

   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?

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

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

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

   d) Can the kinetic energy ever be negative?

   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 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.

   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 potential energies. Describe the sum total of the two bar graphs for this frictionless roller coaster.

   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 looks like it is equal to the maximum K, but they occur at different times. Qualitatively, the sum of the kinetic and potential energies 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 was friction, how would that affect the total energy?"* **The total energy would not stay constant. Friction would reduce the total amount of kinetic energy in the system by slowing the roller coaster down. The maximum kinetic energy would be less than it is in the current simulation.**

9. What did you learn from this exploration activity?

   This may have served as an introduction to kinetic, potential, and mechanical energy and its conservation. Students may have become better at interpreting bar graphs.

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Ohm's Law

Physics – Student Activity

Name ______________________

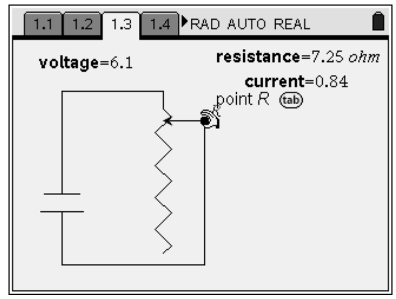
Class ______________________

Activity Overview:
In this activity you will explore the effects of changing resistance or voltage in a simple DC circuit and develop the relationship between the basic quantities of voltage, resistance, and current.

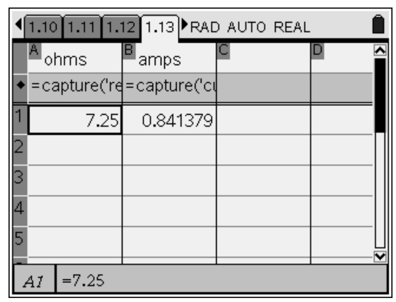
Materials:
- *TI-Nspire™ CAS handheld*
- *Ohms_Law_Physics.tns*

Problem 1

Open the *Ohms_Law_Physics.tns* file on your TI-Nspire handheld. Read the instructions on pages 1.1 and 1.2. On page 1.3 is a schematic diagram of a simple DC circuit. You will explore the effect of changing resistance by dragging point *R* and noting the change in values on the screen. Move *R* to the extremes and experiment slowly with different positions of *R*. On the following pages, answer the questions on the screen by using the up or down arrow keys to highlight your answer, and press to select that answer.

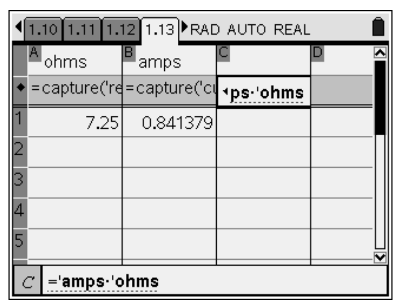


As you move point *R*, data are being captured and recorded in a spreadsheet on page 1.13. This data can be plotted on page 1.10.



On page 1.10, press tab to move between the axis variable selection boxes. Select ***ohms*** for the horizontal axis and ***amps*** for the vertical axis. Consider the shape of this graph and what it means mathematically.

On page 1.12, you are asked to move to the spreadsheet on page 1.13. In the formula cell, enter the formula **=amps·ohms** and then press enter. (The variables can be selected by pressing the sto→ var button, or they can be typed in.) What does the value calculated in Column C represent? Look back to the original circuit on page 1.3 for a clue.



Problem 2

In Problem 2, you use a similar circuit, but you change the voltage. On page 2.2, you will find a voltage regulator. Drag the end of the needle to change the source voltage. Again, experiment with a wide range of voltages and watch what other quantities change values and in what manner.

Again, data is captured as you vary the voltage. Plot this data on page 2.7 in a similar manner to what you did in Problem 1.

What does the shape of this graph suggest?

Do a linear regression by selecting **MENU > Analyze > Regression > Show Linear (mx+b)**.

Look at the value of the slope of the equation. What quantity does the value represent? Look back to the original circuit on page 2.2 for a clue.

The equation, $y = mx$ does not represent the quantities being used. Rewrite this equation using the true quantities: voltage (V), current (I), and resistance (R).

This equation represents Ohm’s law.

Ohm’s law is a relationship between the quantities V, I, and R. The relationship between the units can also be determined from the equation. Answer the question on page 2.11 relating to the units. On page 2.12, you are asked to rearrange the units and Ohm’s law equations.

Ohm's Law

Physics – Teacher Notes

Activity Overview: Ohm's Law

In this activity, students will explore the effects of changing resistance or voltage in a simple DC circuit and will develop the relationship between the basic quantities of voltage, resistance, and current.

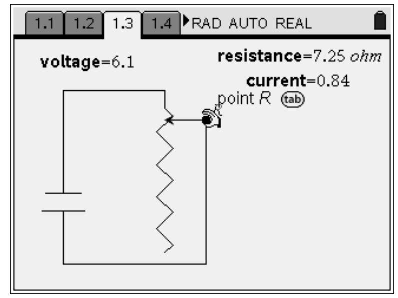
Teacher Preparation and Notes:

- *Estimated time for activity: 20–30 minutes*
- *This activity requires that students have Ohms_Law_Physics.tns file on their TI-Nspire handhelds.*
- *Students need little preparation for this activity. It can be used as an exploratory learning activity.*
- *Students may work individually, or in pairs with one handheld.*
- ***To download the student TI-Nspire document(s) (.tns file(s)), student worksheet, and standards and textbook alignments, go to education.ti.com/exchange and enter "12870" in the quick search box.***

Materials:

- *TI-Nspire™ handheld technology*
- *TI-Nspire CAS handheld technology*
- *Ohms_Law_Physics.tns*

Problem 1

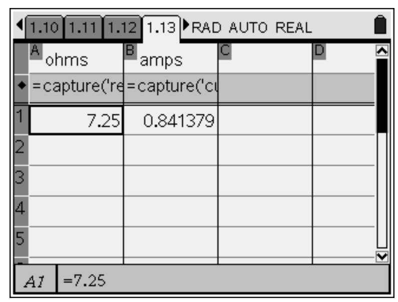


Open the *Ohms_Law_Physics.tns* file on your TI-Nspire handheld. Read the instructions on pages 1.1 and 1.2. On page 1.3 is a schematic diagram of a simple DC circuit. You will explore the effect of changing resistance by dragging point *R* and noting the change in values on the screen. Move *R* to the extremes and experiment slowly with different positions of *R*. On the following pages, answer the questions on the screen by using the up or down arrow keys to highlight your answer, and press ⓧ to select that answer.

Teacher Tip: *Use this opportunity to discuss terminology and the symbols used in the schematic diagram. Ask students to predict what will happen before they drag point R.*

Answers:

1.4: resistance 1.5: current
1.6: voltage 1.7: resistance increases
1.8: false



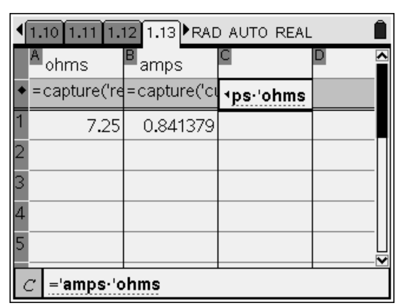
As you move point *R*, data are being captured and recorded in a spreadsheet on page 1.13. This data can be plotted on page 1.10.

Teacher Tip: *The TI-Nspire software uses variables of several types.* ***Current*** *is used as a value variable from page 1.3. The same name cannot be used for a different variable, such as the list variable now called* ***ohms*** *in column A of the spreadsheet. To avoid confusion, have a discussion with students about this naming.*

On page 1.10, press (tab) to move between the axis variable selection boxes. Select ***ohms*** for the horizontal axis and ***amps*** for the vertical axis. Consider the shape of this graph and what it means mathematically.

Answer:

1.11: inversely proportional



On page 1.12, you are asked to move to the spreadsheet on page 1.13. In the formula cell, enter the formula **=amps·ohms** and then press (enter). (The variables can be selected by pressing the (sto→ var) button, or they can be typed in.) What does the value calculated in Column C represent? Look back to the original circuit on page 1.3 for a clue.

Answer:

1.12: Column C should have a constant value equal to the voltage from page 1.3.

Ohm's Law

Problem 2

In problem 2, you use a similar circuit, but you change the voltage. On page 2.2, you will find a voltage regulator. Drag the end of the needle to change the source voltage. Again, experiment with a wide range of voltages and watch what other quantities change values and in what manner.

Answers:
2.3: current increases
2.4: As voltage is increased, current increases. This suggests a direct proportion.

Again, data are captured as you vary the voltage. Plot this data on page 2.7 in a manner similar to what you did in problem 1.

What does the shape of this graph suggest?

Answer:
2.8: This graph is linear, meaning that the relationship is a direct proportion.

Do a linear regression by selecting **MENU > Analyze > Regression > Show Linear (mx+b)**.

Look at the value of the slope of the equation. What quantity does the value represent? Look back to the original circuit on page 2.2 for a clue.

Answer:
2.9: The slope of the equation will be circuit resistance.

The equation $y = mx$ does not represent the quantities being used. Rewrite this equation using the true quantities: voltage (V), current (I), and resistance (R).

This equation represents Ohm's law.

Teacher Tip: *The value of b should be 0 but may appear as a very small number (e.g., $2.4E^{-14}$) with a large negative power of 10. Discuss this with students so that they are comfortable ignoring b.*

The equation y = mx becomes V = RI. Discuss the variations of this equation.

Ohm's law is a relationship between the quantities V, I, and R. The relationship between the units can also be determined from the equation. Answer the question on page 2.11 relating to the units. On page 2.12, you are asked to rearrange the units and Ohm's law equations.

Answer:
2.11: 1 V = 1 A·Ω
2:12: The variations of the unit relations and Ohm's law are:

1 Ω = 1 V/A	$V = IR$
1 A = 1 V/Ω	$I = V/R$
	$R = V/I$

Wrap Up:

- *This is a simulation that can be used to discover and discuss the relationships between V, I, and R. This applies to a simple DC circuit only.*

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Light at a Distance

Physics – Student Activity

Name ______________________

Class ______________________

Activity Overview:

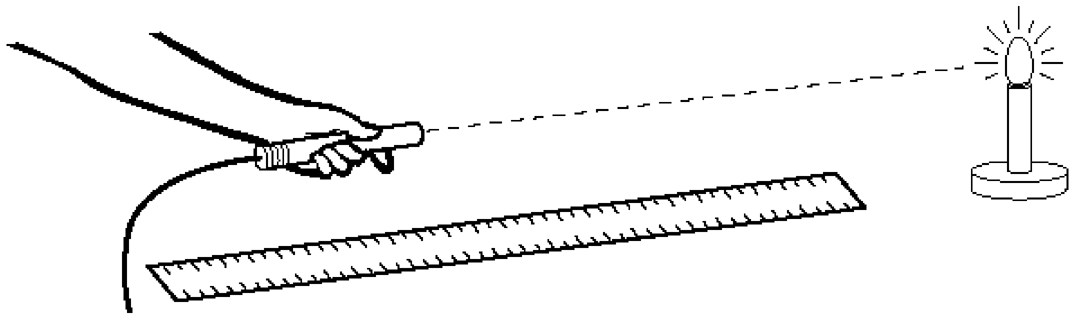
- *In this investigation your team will design an experiment that will use a light probe and the TI-Nspire handheld to reveal the relationship between light intensity and distance. Once your design has been completed, your teacher will approve, modify, or reject it. Upon approval of your experiment, you will conduct it as a team and then analyze your results. Then you will compare your results with known relationships and parse your units to see if your data are consistent with accepted values.*

Materials:

- *TI-Nspire™ CAS handheld technology (one per student)*
- *Light source*
- *One light probe and EasyLink per group*
- *Tape*
- *Tape measure or meterstick*
- *Unit-to-unit cable*

Some skills you will need:

- Create a new document on the TI-Nspire
- Save a document, give it a name, and create or find a folder
- Launch the *Data Collection* application
- Adjust the settings from the *Data Collection* application menu
- Use events with entry for data collection
- Add a new application to your problem
- Use various tools in *Data & Statistics*
- Do a regression and plot a function in *Data & Statistics*
- Load data into *Lists & Spreadsheet*
- Start and stop data collection
- Send and receive files from your TI-Nspire
- Use units in the *Calculator* application



TI Light Sensor Specifications: The TI light sensor uses a phototransistor to measure relative irradiance. The units of irradiance are milliwatts per square centimeter. The light sensor's output is a voltage that is linearly proportional to the amount of irradiance it senses. The range of light over which the sensor is sensitive is 10 mW/cm^2 to 1 mW/cm^2. The auto-ID resistor in the sensor causes the automatic conversion of the measured voltage to relative units. The sensor is direction dependent and achieves the highest output when the end of the sensor is pointed directly at the light source. The light sensor is sensitive in the visible and near-infrared (IR) light range. The light sensor is designed to work in air only—it is not waterproof. The light sensor readings are also sensitive to temperature.

Experimental Design

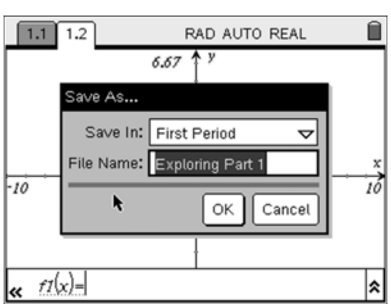
1. Gather your team and discuss how you plan to attack the problem of determining the relationship between light Intensity and distance.

2. Start a new document on your TI-Nspire and create a first page using the *Notes* application. Report on this page the assignment name, date, team name, names of the team members, and other relevant information.

3. Design the experiment and explain your approach by using the *Notes* application and other applications as needed. Include a drawing in *Graphs & Geometry*. If you don't have an artist on your team, make sure you label your drawing. Include the variables you can determine in the experiment and how you plan to control them.

4. Identify any safety issues and how your team will address them.

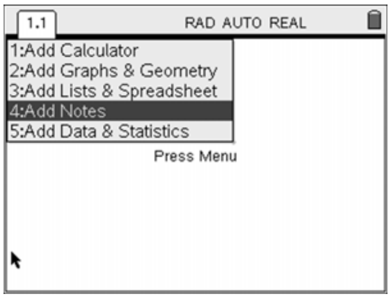
5. When you finish the design, save the document, ctrl S, and send it to all team members and the teacher. Discuss your design with the teacher and make any modifications required. Note: The first time you save, you will need to give the document a name and place it in the correct folder.

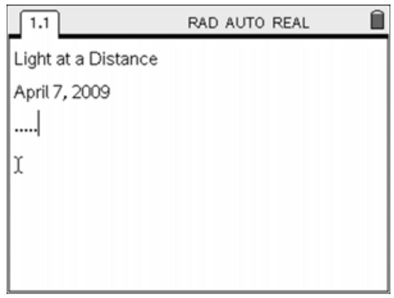


Data Collection

1. Once you have your experiment approved, set it up as you had proposed.

2. Open a new document on your TI-Nspire (or just add a problem to the Experimental Design document) and create a first page using the *Notes* application. Report on this page the assignment name, date, team name, names of the team members, and other relevant information (unless you have already done this in the Experimental Design part of the document).





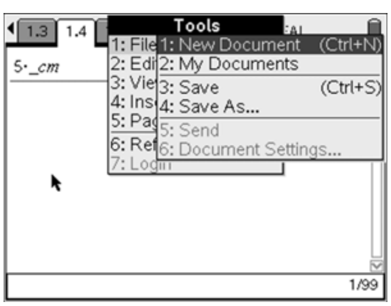
3. As you collect data, make sure you are getting the light most directly on your light probe. You can do this by moving it slightly and looking for the position that gives the highest value. If you are too close to the light source, you will get a reading of 1. Make sure you move so that the highest reading you get is less than 1.

4. Save the document periodically as you move through the experiment, and add *Notes* pages to help document your work.

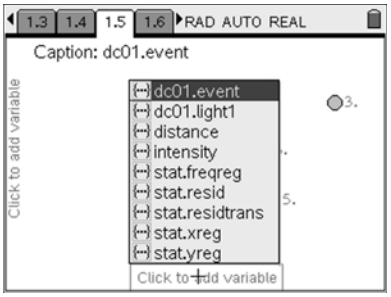
5. If you make a mistake with your data entry, it might be best to just start over or get your teacher to help you to fix it after you finish.

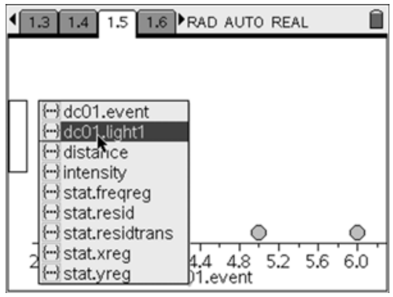
Data Analysis

1. Now that you have your data, save the document and send it to each person in the group. To send, hook up to another handheld and press ctrl to get the Tools menu (), and then select **File > Send**.

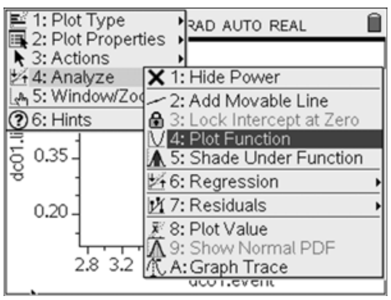


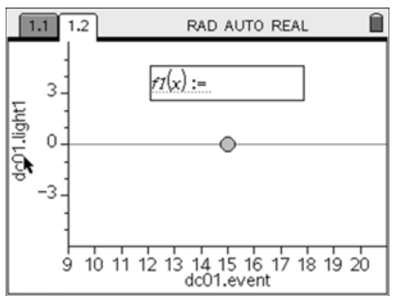
2. In the *Data & Statistics* application, you can look at the data if you don't already have it set up. To set up the plot, move your cursor to the bottom and select the event list. Then move to the left and select **light1**.



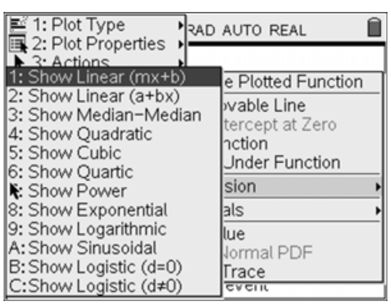


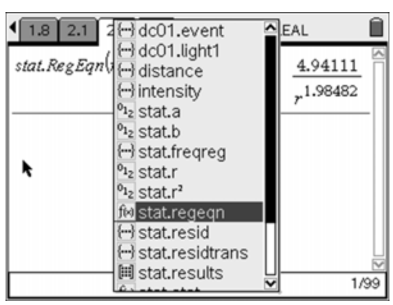
3. Now you may guess the function shown by the pattern in the plot by selecting **MENU > Analyze > Plot Function**, as shown, and keying in the guess.



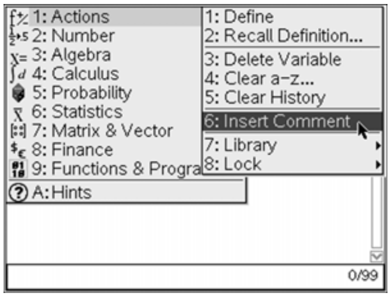


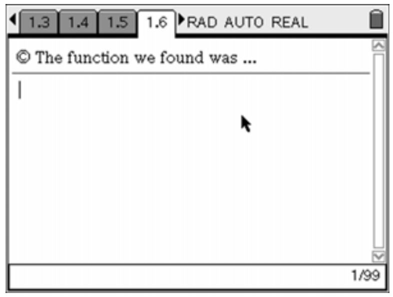
4. If you want to do a regression, select the appropriate mathematical model from the menu after selecting **MENU > Analyze > Regression**. This value will be stored as a variable for later use. You might want to explore different types of regressions until you get a nice fit and then return to the guess method. Each guess will be stored in the problem, but only the last regression will appear in the variables list as *stat.regeqn*.



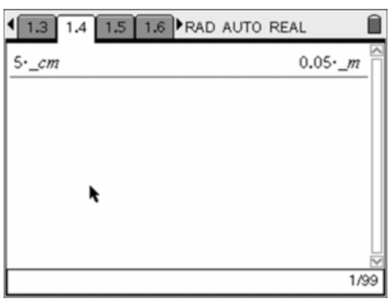


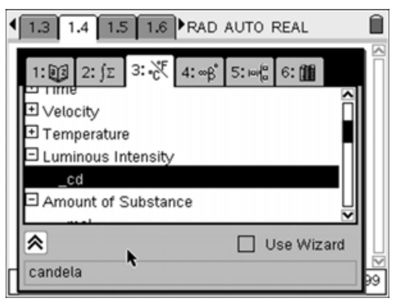
5. Once you determine the best equation for the pattern in the data, move to the *Calculator* and after doing some research on what equations you should have discovered, compare what you found with the theory. Use the **Comment** tool to help document what you find. Select **MENU > Actions > Insert Comment**.



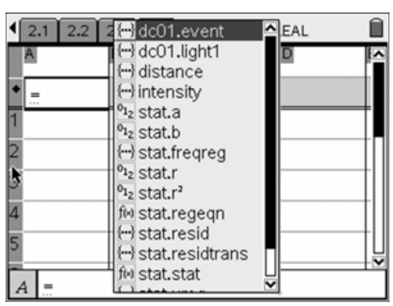


6. Once you think you have discovered the true relationship between light Intensity and distance, try to parse the units in your equation. You may access the units built into your CAS handheld by using the underscore (ctrl _) with the units attached. You may also pull units from the catalog (catalog). Note that the units are in SI unless you change the settings under System Info (**HOME > System Info**).

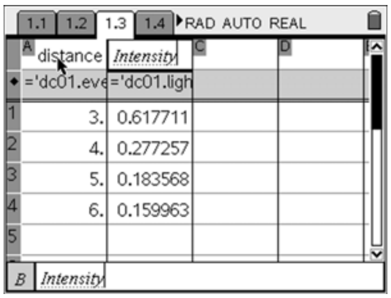


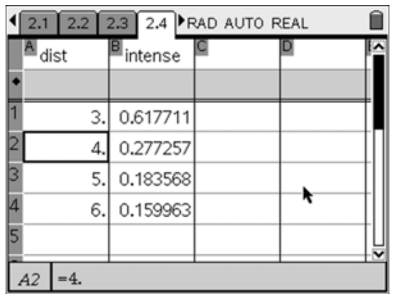


7. Your team may also want to look at your data in a list. To do this, add a *Lists & Spreadsheet* page by pressing HOME and selecting **Lists & Spreadsheet**. Move to the diamond line and press (=)(sto→ var) to select the distances (events). Repeat this in the second column for the light data.



8. You might want to name the columns as shown. Pick names that might be sensible. Make sure you are in the header of the column. This is where you could edit the data by clearing the diamond line and breaking the association between these new names you created and the stored lists from the data collection. Then you may enter a cell and delete, change, or null. Remember that the plots shown in *Data & Statistics* would need to change to show these new lists.





9. When you have finished your analysis, add another *Notes* page and explain what you discovered and what it means.

10. Save this final document and send it to each person in the team and to your teacher.

Extensions – Other Experiments with Light (Optional)

- Design an experiment that will verify the wattage established for various light bulbs. Is a 60-watt bulb really 60 watts?
- Design an experiment to look at different 75-watt light bulbs and determine how the clear, frosted, incandescent, florescent, and other types vary in Intensity.
- Design an experiment that uses different-colored filters or polarizers to see how the intensity of a light varies.
- Design an experiment that verifies the inverse square law for motion, magnetism, or electric change.

Light at a Distance

Physics – Teacher Notes

Activity Overview: Light at a Distance

This investigation has two goals. For the first part, we want to involve students in the experimental design process. We will set up some parameters, but the teams should design, get approved, and implement an experiment that answers the question, "What is the relationship between light intensity and distance?"

For the other part, we are trying to expand student understanding of the inverse square law and to help them see this outside of Newtonian mechanics, discussing the grand unified theory and why it might actually be true.

Teacher Preparation and Notes:

- *Estimated time for activity is one class period if students are familiar with the TI-Nspire and the Data Collection application.*
- *You will need to collect some light sources for the students to use. Have these available for the teams, but don't force their use. Just have them if they want them in their designs.*
- *You will need table space for the data collection and power supplies if you use light sources other than flashlights. Flashlights that allow you to spread the beam from wide to narrow work well. Small distances work better than long ones. Think centimeters rather than meters.*
- *A list of TI-Nspire skills appears in the student worksheet.*
- *TI Light Sensor: The TI light sensor uses a phototransistor to measure relative irradiance. The units of irradiance are milliwatts per square centimeter. The light sensor's output is a voltage that is linearly proportional to the amount of irradiance it senses. The range of light over which the sensor is sensitive is 10 mW/cm^2 to 1 mW/cm^2. The auto-ID resistor in the sensor causes the automatic conversion of the measured voltage to relative units. The sensor is direction dependent and achieves the highest output when the end of the sensor is pointed directly at the light source. The light sensor is sensitive in the visible and near-infrared (IR) light range. This means you can use it with IR-emitting diodes as well as all visible light sources. The light sensor is designed to work in air only—it is not waterproof. The light sensor returns relative readings, not absolute irradiance readings. Values may vary from light sensor to light sensor. The light sensor readings are also sensitive to temperature.*
- *You will need to demonstrate data collection with the TI-Nspire using the TI-Nspire software. It is best to use the Teacher Edition in the SmartView/Emulator mode so students can see which keys you press. Using the EasyLink with the TI light probe with the computer requires the USB mini-A to standard-A adapter or the Go!Link.*
- *You will want to use teams of 3 or 4 as you do this investigation.*

Light at a Distance

Materials:

- *TI-Nspire™ CAS handheld technology (one per student)*
- *TI-Nspire CAS Teacher Edition computer software and projector with data collection cables*
- *Light sources (various)*
- *Student worksheet Light_at_a_Distance_Student_Physics.doc*
- *One light probe and EasyLink per group of three or four*
- *Tape*
- *Tape measure or meterstick*
- *Connect-to-Class, TI-Nspire Navigator, TI-Nspire Link with direct connect cable or unit-to-unit cables to send the assessment file and collect the student documents with results*

Suggested Related Activities:

To download any activity listed, go to education.ti.com/exchange and enter the number in the quick search box.

- *Light Intensity — 12336*
- *Various Activities found at TI Physics: http://www.tiphysics.com/*
- *Light at a Distance: Distance and Light Intensity — 3987*
- *WATT's the Deal? — 4030*

Light at a Distance

Part 1 – The Set

Ask the students some questions about light and distance:

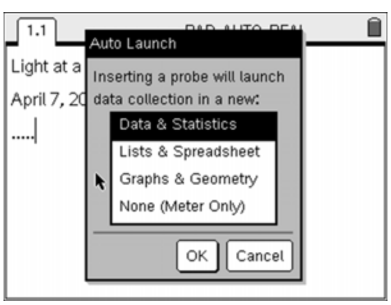
- Have them find the brightest light source (the sun?) and explain how they know it is the brightest.
- What units are used for brightness?
- What is the meaning of these units?
- How do you measure light intensity? (watts/m^2)
- Do you know what happens to light intensity as a light comes closer to your? Moves away from you? Is this change linear? Exponential? Quadratic? (Power)
- How far away does a light need to be from for you to be unable to see it? During the day? The night?
- What is the effect of ambient light when you consider the intensity of a single light source?
- What is the difference between brightness, flux, and intensity when we speak of light? [see Brightness, Luminance, and Confusion from Information Display, March 1993, Charles P. Halsted: http://www.crompton.com/wa3dsp/light/lumin.html]
- What is GUT? (grand unified theory)

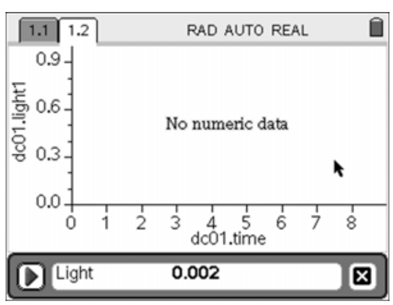
Note: You could place these questions in a TI-Nspire document as open response or even multiple guess.

Part 2 – TI-Nspire Skills

Students will need to be able to move around in the TI-Nspire environment. A list of skills is on the student worksheet. Some of these are explained below.

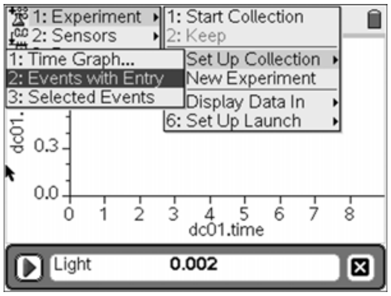
To launch the *Data Collection* application, usually you just need to plug it into the TI-Nspire. Connect the EasyLink and the light probe, and then in a new document, plug the EasyLink into the TI-Nspire. This will result in the Auto Launch shown. Select *Data & Statistics*. If the Auto Launch does not appear, you can use ctrl D to get this screen.



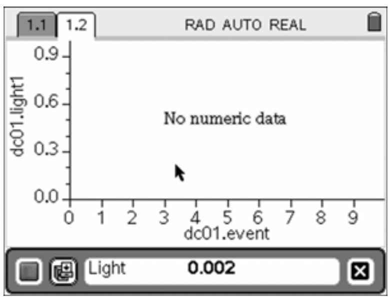


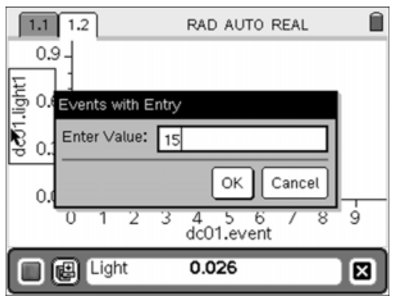
Light at a Distance

The students will need to use events with entry for data collection. To set this up, select **MENU > Experiment > Set Up Collection > Events with Entry**

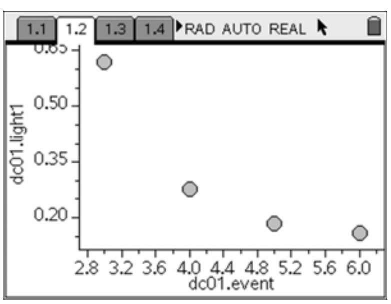


Now when you start data collection (by pressing enter when the play button is highlighted), you will see a file cabinet that is highlighted. When the reading stabilizes, you can capture this value by pressing enter and keying in the distance to the light source. In this instance, we have 15 cm.



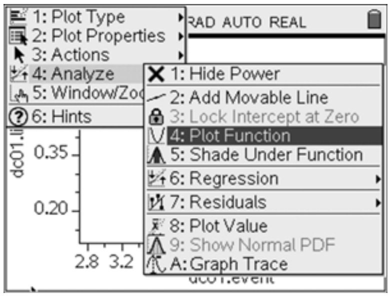


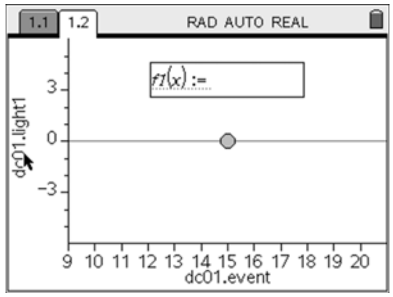
Once the team has collected all of the data needed, they should e to the stop button and press enter. If there is a misstep, the students could repeat the whole data collection or they could just redo the particular distance again, deleting the data later. This is much more complicated, and for a novice user it would probably be easier to just start over. When you are finished with the data collection, just tab over to the X button and press enter.



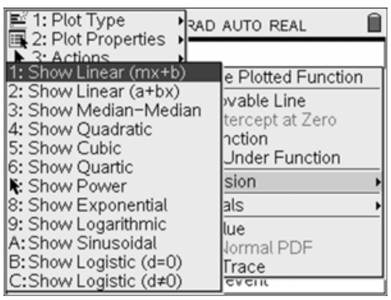
Light at a Distance

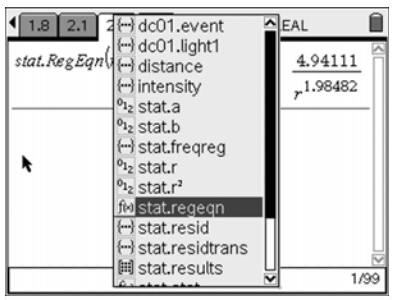
From the *Data & Statistics* application, the students can guess a function that models the data, or they may do a regression. To plot the guess, select **MENU > Analyze > Plot Function**, as shown, and key in the guess.



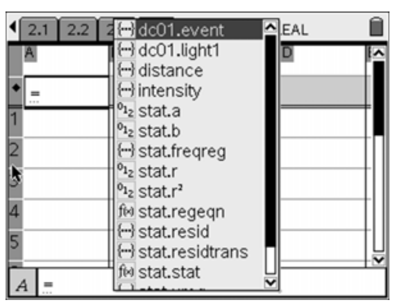


For the regression, select the appropriate mathematical model from the menu after selecting **MENU > Analyze > Regression**. This value will be stored as a variable for later use. Students might explore different types of regressions until they get a nice fit and then return to the guess method. Each guess will be stored in the problem, but only the last regression will appear in the variables list as *stat.regeqn*.



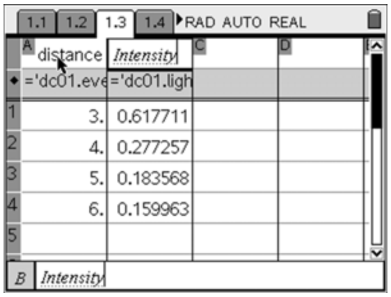


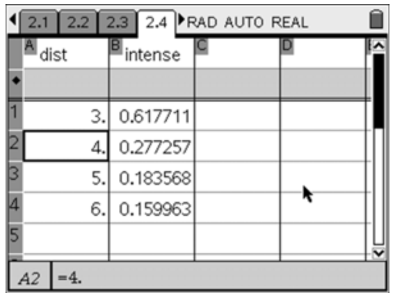
Students may also want to look at the data in a list. To do this, they should add a *Lists & Spreadsheet* page by pressing HOME and selecting **Lists & Spreadsheet**. Move to the diamond line and press (=)(sto→ var) to select the distances. Repeat this in the second column for the light data.



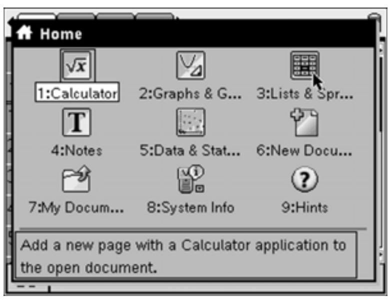
Light at a Distance

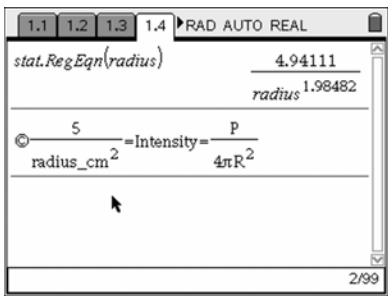
You might want to name the columns as shown. Pick names that might be sensible. Make sure you are in the header of the column. This is where you could edit the data by clearing the diamond line and breaking the association between these new names you created and the stored lists from the data collection. Then you may enter a cell and delete, change, or null. Remember that the plots shown in *Data & Statistics* would need to change to show these new lists.



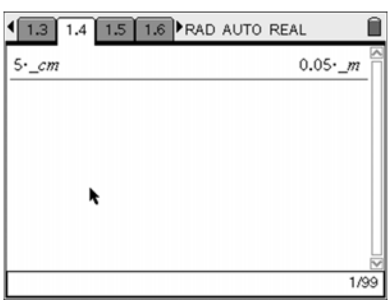


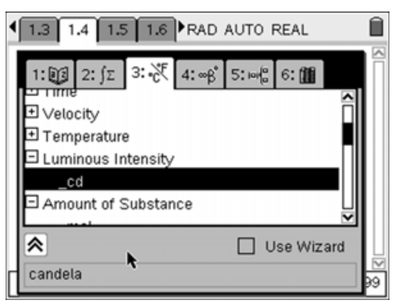
Once they have their relationship established, they can parse it in the *Calculator* application (press ⌂ and select **Calculator** to insert a *Calculator* page.).





Units can be used on your data by using the underscore (ctrl ⎵) with the units attached. You may also pull units from the catalog (📖). Note that the units are in SI unless you change the settings under System Info (⌂ 8).





Part 3 – Experimental Design

1. Once the students have a clear idea of how to use the technology and what the question is, let them team up and start the design process. Have the students describe with drawings the experiment that they want to do. Ask them to list variables and how they will control them so that only light intensity and distance influence the data. The students should write and draw in the TI-Nspire environment using the appropriate applications (*Notes*, *Graphs & Geometry*, etc.). This could be problem 1 in their lab document, moving on to problem 2 for the actual experiment, when approved.

2. Once the design is done, the students will send you the document for comment using Connect-to-Class, Link software, or just unit-to-unit. You might want to have the team present to the class their design by opening their file on the Teacher Edition software or using the TI-Nspire overhead panel. This would allow for peer review but should only be done after all teams have completed their designs.

3. Approve, modify, or reject the design and then proceed based on your decision.

Part 4 – Data Collection

1. Once the team has approval of their design, they should collect the materials they need and collect the data. Make sure they follow their procedure and that they acknowledge any safety issues that came up in the discussion of the design.

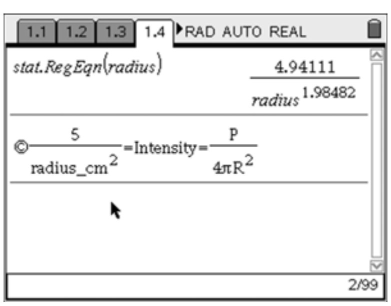
2. After successful data collection, the team should put up their equipment, straighten up their work area, save the document, and send the document to the each team member.

Part 5 – Data Analysis

1. This part should be done by the team, but each team member might experiment with the data. The final analysis should occur in the document that will be submitted by the team.

2. The students should do some research on mathematical models that they would expect to see in this data. This should lead them to the inverse square law and a power function.

3. Using the *Calculator*, the teams should try to identify the units in the parts of the equation. In the case of the function shown, it is clear that the power should be –2 and that 5 is $\frac{P}{4\pi}$, with the distance in centimeters and the intensity in milliwatts.



Extensions – Other Experiments with Light

- Have the students design an experiment that will verify the wattage established for various light bulbs. Is a 60-watt bulb really 60 watts?
- Have the students design an experiment to look at different 75-watt light bulbs and determine how the clear, frosted, incandescent, florescent, and other types vary in Intensity.
- Have the students design an experiment that uses different-colored filters or polarizers to see how the intensity of a light varies.
- Have the students design an experiment that verifies the inverse square law for motion, magnetism, or electric change.

Law of Gravity

Physics – Student Activity

Name ________________________

Class ________________________

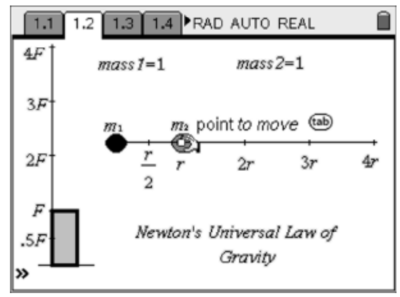
Activity Overview:

- *There is a force F between any two masses (m_1 and m_2). This force F depends on the distance r between the centers of the two masses.*
- *Explore this relationship by moving the open point to change the distance.*

Materials:

- *TI-Nspire™ CAS handheld*
- *LawOfGravity_Physics.tns*

Part 1 – Move the Planet



Advance to page 1.2, whose screen is shown at right. Press ctrl to grab the open point in *mass2*. Move this point and observe the relationship between the distance and the force.

1. As the distance between the two masses is decreased, what happens to the force?

2. True/False: If the distance is doubled, the force is cut in half.

3. Describe the relationship between the force and the distance between the masses. In your description, also discuss the direction of the force.

Part 2 – Change Distance and Mass

You can answer the self-check questions. Then advance to page 2.2. You can move the same point to adjust the distance. This time the distance will jump to the indicated values.

The mass can also be changed by clicking twice on *mass1* or *mass2* and entering a different number.

4. When m_1 and m_2 are separated by a distance r, the force of attraction between them is F. If the distance r between the two masses is cut in half, what is the force?

5. If the distance between the two masses is a third of r, what is the force? Show work to explain your answer. Use the formula on page 2.2 to show work.

Law of Gravity

Answer the following question on page 2.5. To toggle over to the calculator panel of page 2.5, press ctrl tab. Give the decimal approximation for your answer.

6. What would the distance between the centers of the two masses need to be for the force to be reduced by a factor of 2? (In other words, what distance makes the force 0.5*F* or *F*/2?)

Use page 2.2 to help you answer the following questions and to help you explain your answers.

7. What happens to the force when the distance is doubled? Tripled? Quadrupled?

Move m_2 back to position *r*. Double-click on the text that says *mass2*=1. Arrow over to the end and use backspace (clear) to remove the 1. Press 2 and then enter.

8. a) What happens to the force when one of the masses is doubled? Explain.

   b) What happens to the force when both masses are doubled? Explain.

9. Force *F* is exerted between m_1 and m_2 when they are separated by distance *r*.

   a) What is the force when m_2 is tripled and *r* is doubled?

   b) What is the force when m_1, m_2, and *r* are doubled?

   c) How could you get a force of 4/3*F*?

10. a) Notice what happens to the size of the planet when the mass is increased. For example, change m_2 to 8 or 16. Does this affect the distance *r* between the two planets? Explain.

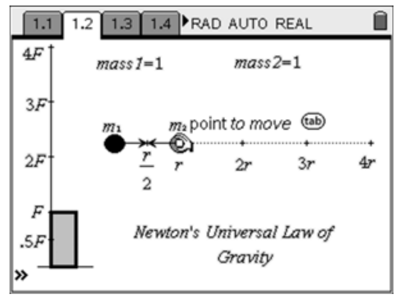
    b) Write about what you learned by doing this activity.

Law of Gravity
Physics – Teacher Notes

Activity Overview:
- *There is an attractive force F between any two masses (m_1 and m_2). This force F depends on the distance r between the centers of the two masses. It is an inverse square law relationship. Students will explore this relationship by moving the open point to change the distance.*

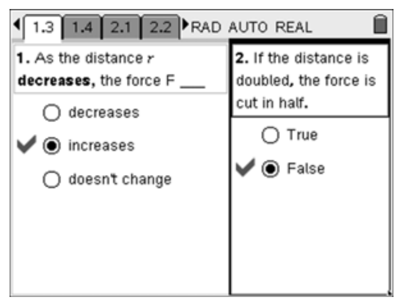
Materials:
- *TI-Nspire™ CAS handheld*
- *LawOfGravity_Physics.tns*

Part 1 – Move the Planet



Students are advised to advance to page 1.2, whose screen is shown at right. Press ctrl to grab the open point in *mass2*. Move this point and observe the relationship between the distance and the force.

Students can answer the following six questions on their TI-Nspire. The answers of these self-check questions can be checked by pressing **Menu > Check Answer**.



1. As the distance between the two masses is decreased, what happens to the force?
   The force increases.
2. True/False: If the distance is doubled, the force is cut in half.
   False; the distance increases by a factor of 4 when the distance between the centers of the two masses decreases by a factor of 2.
3. Describe the relationship between the force and the distance between the masses? In your description, also discuss the direction of the force.
   Because the ATTRACTIVE force decreases as the distance increases, it is an inverse relationship. But actually it is an INVERSE SQUARE LAW RELATIONSHIP.

Students will explore more about what this inverse square law means in the next part.

Part 2 – Change Distance and Mass

Students will advance to page 2.2. They can move the same point to adjust the distance. This time the distance will jump to the indicated values. The mass can also be changed by clicking twice on *mass1* or *mass2* and entering a different number.

4. When m_1 and m_2 are separated by a distance r, the force of attraction between them is F. If the distance r between the two masses is cut in half, what is the force?
   4F

5. If the distance between the two masses is a third of r, what is the force? Show work to explain your answer. Use the formula on page 2.2 to show work.

$$\mathbf{9}F = G\frac{m_1 m}{\left(\frac{1}{3}r\right)^2} = \frac{1}{\frac{1}{9}}F$$

Question 6 is to be answered on page 2.5. To toggle over to the calculator panel of page 2.5, press ctrl tab. Give the decimal approximation for your answer.

6. What would the distance between the centers of the two masses need to be for the force to be reduced by a factor of 2? (In other words, what distance makes the force 0.5*F* or *F*/2?)
   $\sqrt{2} \approx 1.414$

Students will use page 2.2 to help them answer the following questions and to help you explain.

7. What happens to the force when the distance is doubled? Tripled? Quadrupled?
   Doubled *r* gives *F*/4, tripled *r* results in *F*/9, and quadrupled *r* gives *F*/16.

Move m_2 back to position *r*. Double-click on the text that says *mass2*=1. Arrow over to the end and use backspace clear to remove the 1. Press 2 and then enter.

8. a) What happens to the force when one of the masses is doubled? Explain.
   With the relationship $F = Gm_1m_2/r^2$, if one of the masses is doubled, the force is doubled.

   b) What happens to the force when both masses are doubled? Explain.
   The force is quadrupled because 2 × 2 = 4. Masses vary directly with the force.

9. Force *F* is exerted between m_1 and m_2 when they are separated by distance *r*.

   a) What is the force when m_2 is tripled and *r* is doubled? **¾*F***

   b) What is the force when m_1, m_2, and *r* are doubled? **No change. It would be *F*.**

   c) How could you get a force of 4/3*F*? *Teachers may need to provide the hint 4/3F = 12/9F.*
   m_1 = 3, m_2 = 4 (or some other variation that multiplies to 12), and the distance is 3*r*

10. a) Notice what happens to the size of the planet when the mass is increased. For example, change m_2 to 8 or 16. Does this affect the distance *r* between the two planets? Explain.
   The distance *r* doesn't depend on the size of the planet or the masses. The distance is measured from the center of one mass to the center of the other.

   b) Write about what you learned by doing this activity.
   Gravity is an attractive force that varies directly with the mass and inverse square with the distance of separation.

Coulomb's Law

Physics – Teacher Notes

Activity Overview:

In this activity, students explore the relationship between force, charge, and distance for two charged particles, i.e., Coulomb's law. Students observe how force changes with distance by moving a charged particle. By fitting the data collected for force vs. distance to a power regression equation, students determine that electrical force is inversely proportional to distance squared. After determining the dependence of electrical force on charge, the students are able to write the Coulomb's law equation. Next, students see how force changes with like and unlike charges. The activity ends with an application of Coulomb's law to solve a problem involving two charged particles and a test charge.

Teacher Preparation and Notes:

Before carrying out this activity, review the units of force and electrical charge. You may also want to review the representation of forces with vectors.

- *The screenshots on pages 2–6 demonstrate expected student results. Refer to the screenshots on pages 7 and 8 for a preview of the student TI-Nspire document (.tns file).*
- *This activity is designed to be **teacher led**, with students following along on their handhelds. You may use the following pages to present the material to the class and encourage discussion. Note that the majority of the ideas and concepts are presented only in **this** document, so you should make sure to cover all the material necessary for students to comprehend the concepts.*
- *Students may answer the questions posed in the .tns file using the Notes application or on blank paper.*
- *In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.*
- ***To download the .tns file, go to education.ti.com/exchange and enter "9747" in the search box.***

Materials:

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

- *TI-Nspire™ technology*
- *Pen or pencil*
- *Blank sheet of paper*

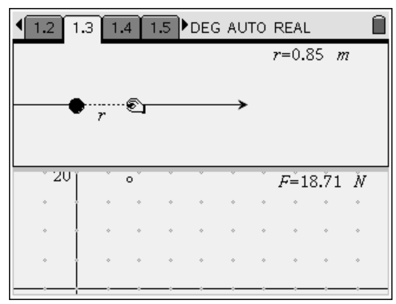
Coulomb's Law

The following questions will guide student exploration in this activity:

- How is electrical force related to the distance between charged particles?
- How is electrical force related to the magnitudes of the charges of separated particles?
- How do the signs of the charges affect electrical force?

In Problem 1 of the activity, students vary the separation of two charged particles. They observe the change in electrical force with varying separation. With a manual data capture of force and distance data, a graph of force vs. distance, and a power regression, students determine the mathematical relationship between force and distance. In Problems 2 and 3, students will vary the charges of the particles. This leads to the writing of Coulomb's law. Problem 4 is an investigation of the effects of like and unlike charges. In the final part of the activity, students move a test charge around two charged particles, one with a known charge and the other with an unknown charge, and observe the net force on the test charge. They are then asked to determine the unknown charge.

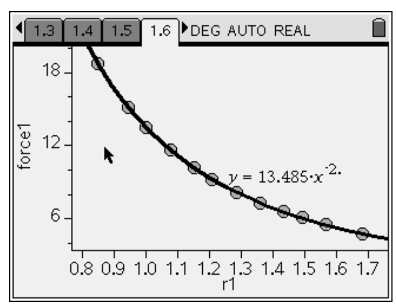
Problem 1 – Electrical Force and Distance



Step 1. Students should open the file **PhysWeek29_CoulombsLaw.tns** and read the first two pages. Page 1.3 shows two positively charged particles separated by a distance *r*. Students should drag the smaller particle to vary the separation between the two charged particles. Then they should answer question 1.

Q1. Describe how *F* changes as *r* changes.

A. *F increases as r decreases.*



Step 2. Next, students should return to page 1.3 and do a manual capture of force and distance data. To capture a data point, students should press ctrl . . Students should capture at least 10–15 data points. The data will be stored in the spreadsheet on page 1.5. On page 1.8, students should make a graph of ***force1*** vs. ***r1***. Then they should use the **Power Regression** tool (**Menu > Analyze > Regression > Show Power**) to find a power regression that fits the data. Then they should answer questions 2 and 3.

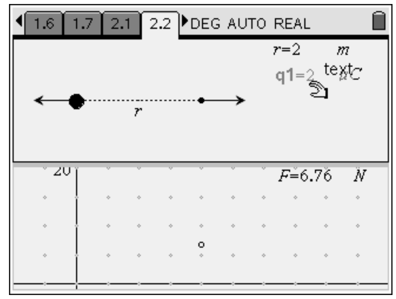
Q2. Write the equation for electrical force (*F*) as a function of distance (*r*).

A. $F = \dfrac{13.485}{r^2}$

Q3. What type of relationship is this? What are some other phenomena that show a similar relationship?

A. *It is an inverse square relationship. Encourage student discussion of other inverse square phenomena, such as gravitational force vs. distance and light intensity vs. distance.*

Problem 2 – Effects of Changing One Charge on Electrical Force



Step 1. Next, students should move to page 2.1 and read the text there. Then they should move to page 2.2, which again shows two positively charged particles separated by a distance *r*. In this simulation, *r* is fixed, but students can vary the charge on the smaller particle (***q1***). Students should vary ***q1*** and observe the effects on *F*. Then they should answer questions 4 and 5.

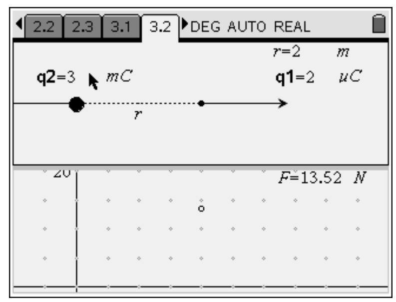
Q4. If ***q1*** is doubled, from +1 to +2 μC, what is the effect on the force?

A. *The force doubles.*

Q5. Describe how doubling ***q1*** would affect the equation relating *F* and *r*.

A. *The value of the constant would change, but the functional form would remain the same—that is, it would still be an inverse square relationship.*

Problem 3 – Effects of Changing Both Charges on Electrical Force



Step 1. Next, students should move to page 3.1 and read the text there. Then they should move to page 3.2, which shows two positively charged particles separated by a distance *r*. In this simulation, students can vary the charges of both particles (***q1*** and ***q2***). Students should vary ***q1*** and ***q2*** and observe the effects on *F*. Then they should answer questions 6–9.

Q6. If the charges on both particles are doubled, what is the effect on the force?

A. *The force increases by a factor of four.*

Q7. What do these data indicate about the relationship between the charges on two particles and the electrical force between them?

A. *The data suggest that force is proportional to the product of the charges. Encourage students to discuss why this must be the case.*

Q8. Write an equation for electrical force *F* in terms of q_1, q_2, and *r*. Let the constant of proportionality be *k*.

A. $F = k\frac{q_1 \bullet q_2}{r^2}$; *encourage student discussion on how to derive this equation.*

Q9. What are the numerical value and units of *k*?

A. *To solve this problem, students should first solve the equation they derived above for k, as shown below:*

$$k = \frac{F \bullet r^2}{q_1 \bullet q_2}$$

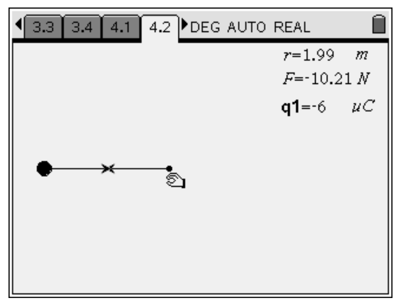
Then students should use the simulation on page 3.2 to obtain specific values for F, r, q_1, and q_2 and use these values to calculate the value of k. For example, if r = 2 m, $q_1 = 1 \times 10^{-6}$ C, and $q_2 = 1.5 \times 10^{-3}$ C, then F = 3.38 N. Therefore, $k = 9 \times 10^9\ N{\cdot}m^2/C^2$, as shown below:

$$k = \frac{(3.38\ N)(2\ m)^2}{(1 \times 10^{-6}\ C)(1.5 \times 10^{-3}\ C)}$$

$$= 9 \times 10^9\ N \bullet m^2 / C^2$$

Problem 4 – The Effect of the Signs of the Charge on Electrical Force

Step 1. Next, students should move to page 4.1 and read the text there. Then they should examine the simulation on page 4.2, which shows two charged particles separated by a distance *r*. In this simulation, ***q1*** is negative. Students should vary *r* by dragging the smaller point and observe the effects on *F*. Then students should vary ***q1*** and observe the effects on *F*. They should then answer questions 10–13.

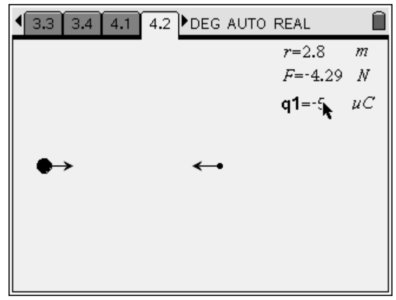


Q10. How are the electrical force and the force vectors in this simulation different from those on pages 1.3, 2.2, and 3.2?

A. *The force in this simulation is negative; it was positive in the other simulations. The force vectors in this simulation are pointing toward each other. In the other simulations, the force vectors pointed away from each other.*

Q11. Are these particles being attracted or repelled by each other? How is this different from the previous simulations?

A. *In this simulation, the particles are attracted to each other. In the other simulations, they were repelled by each other.*



Q12. Use Coulomb's law to determine the charge (***q2***) on the larger particle.

A. *First, solve the Coulomb's law equation for q_2, as shown below:*

$$q_2 = \frac{F \bullet r^2}{k \bullet q_1}$$

Then substitute specific values to solve for q_2. For example, if $r = 2.8$ m, $q_1 = -5 \times 10^{-6}$ C, and $F = -4.29$ N, then $q_2 = 7.5 \times 10^{-4}$ C, as shown below:

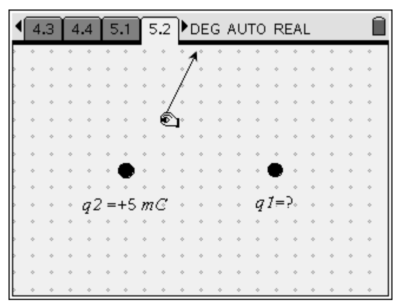
$$q_2 = \frac{(-4.26\ N)(2.81\ m)^2}{(9 \times 10^9\ N \bullet m^2\ /\ C^2)(-5 \times 10^{-6} C)}$$

$$= 7.5 \times 10^{-4} C$$

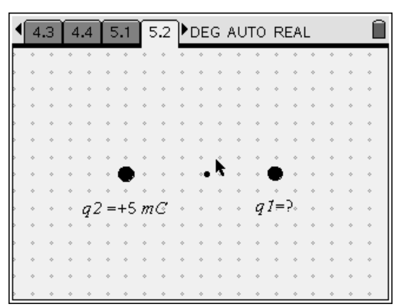
Q13. What is always true about the electrical force vector for each particle, regardless of the magnitude or sign of the charge on the particles?

A. *The magnitude of the force vector is always the same for both particles.*

Problem 5 – Using a Test Charge



Step 1. Next, students should read the text on page 5.1 before moving to page 5.2, which shows a movable test charge and two fixed-point charges. The vector attached to the test charge indicates the net electrical force on the test particle due to ***q1*** and ***q2***. Students should move the test charge and observe the electrical force vector. Then they should answer questions 14–16.



Q14. Is the charge of the test particle positive or negative? Explain your answer.

A. *Charge **q2** is positive, and the electrical force vector of the test charge points away from particle 2. Like charges repel. Therefore, the test charge must also be positively charged.*

Q15. At what point is the net force on the test particle equal to zero?

A. *The net force is zero when the test charge is between the particles and a little closer to particle 1. The distance between the test charge and particle 1, r1, is about 3.5 units. The distance between the test charge and particle 2, r2, is about 4.5 units.*

Coulomb's Law

Q16. Use Coulomb's law to determine ***q1***.

A. *At the point where the net force is zero, F1 = F2, where F1 is the force on the test charge due to q_1 and F2 is the force on the test charge due to q_2, as shown below:*

$$F1 = k\frac{q_1 q_{test}}{r_1^2} \qquad F2 = k\frac{q_2 q_{test}}{r_2^2}$$

Setting these equations equal to each other and rearranging gives an equation for q_1.

$$\cancel{k}\frac{q_1 \cancel{q_{test}}}{r_1^2} = \cancel{k}\frac{q_2 \cancel{q_{test}}}{r_2^2}$$

$$\frac{q_1}{r_1^2} = \frac{q_2}{r_2^2}$$

$$q_1 = \frac{q_2 r_1^2}{r_2^2}$$

Substituting values from the simulation yields $q_1 = \frac{q_2 r_1^2}{r_2^2} = \frac{(5\ mC)(3.5)^2}{(4.5)^2} = 3\ mC$.

CAS & DCC: More Features

Physics – Teacher Notes

Activity Overview: CAS & DCC

This is a guide to more advanced features of CAS (Computer Algebra System) and DCC (Data Collection Console). This is intended as a guided exploration activity to help students become more familiar with the capabilities of CAS and DCC.

Teacher Preparation and Notes:

- *Estimated time for activity: 20 minutes*
- *No preparation needed.*

Materials:

- *TI-Nspire™ CAS handheld technology*
- *Any sensor that connects to the TI-Nspire CAS handheld directly, or a sensor and EasyLink adapter*

Part 1 – CAS

Derive an Equation

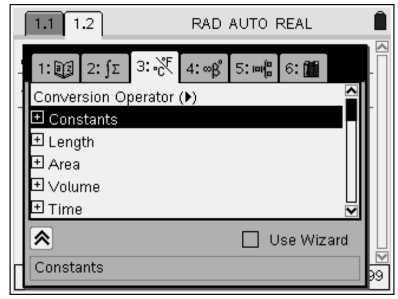
Open a new problem and *Calculator* page by pressing ctrl home **> Insert > Problem > Add Calculator**.

Consider the equations for centripetal force. Enter the following and note the result as successive steps in a derivation:

- **f:= m × a** enter
- **a:= v^2/r** enter
- **f** enter
- **v:= 2πr/t** enter
- **f** enter
- **t:= 1/freq** enter
- **f** enter

CAS & DCC

Conversions



Quantity or unit conversions can be done using littoral symbol manipulation, or by using the built-in units.

Enter 20mi/hr × (5280 ft/mi) × (hr/(3600 s)).

Now press ctrl enter to get the approximate (decimal) value for the answer.

Use the underscore to access the built-in units, and use the conversion operator (▶) to make a direct conversion.

- 20_mi/_hr ▶ _ft/_s enter

In the Bejing Olympics, Usain Bolt ran the 100 m in 9.69 s. What is his average speed in m/s?

What would this be in ft/s? In km/min? In mi/hr?

10.3 m/s; 33.8 ft/s; 0.62 km/min; 23.1 mi/hr

Measurements can be converted into base or standard units.

- 1.2·_atm▶_p returns standard units of pressure.

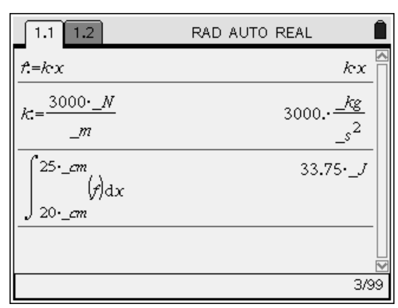
Derivatives and Integrals

A wide range of features to work with functions can be accessed from a *Calculator* page under the Calculus menu.

Templates for derivatives or integrals can also be accessed from the *Calculator* page by pressing ctrl templates.

On a *Graphs & Geometry* page, derivatives can be determined using the **Slope** tool from the Measurement menu; integration can be done (and shown graphically) with the **Integral** tool, also in the Measurement menu.

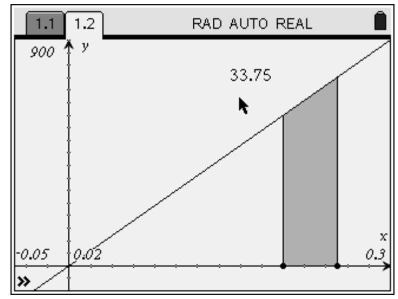
A spring has a spring constant of 3000 N/m and an unstretched length of 15 cm. If the string is stretched from 20 cm to 25 cm, how much work has been done?



On a *Calculator* page:

- Define the function by typing **f:=k·x** and then pressing enter.
- Define the spring constant *k* by typing **k:=3000_N/_m** and then pressing enter.
- Obtain the definite integral template from templates, <u>or</u> obtain the integral template from **Menu > Calculus > Integral**.
- Fill in the template from 20_cm to 25_cm for (*f*)*dx*.

Answer: 33.75_J; Note the units!



On a *Graphs & Geometry* page:

- Plot the function **f1**(x) = 3000x.
- Adjust the window settings to (–0.05, 0.3), (–100, 900).
- **Menu > Measurement > Integral**
- Click on the graph, and press **.2**, enter, **.25**, enter. The integral will be shown numerically and graphically. Grab the value and move it to a convenient location.
- **Menu > Actions > Attributes**
- Select the value, arrow right to increase the precision to the desired degree, and press enter.

Answer: 33.75; Units are not given.

Part 2 – Data Collection Console

The Data Collection Console and menus allow you to design an experiment with a variety of options. When a sensor is connected, the system automatically detects and identifies the sensor. You then have a number of decisions to make:

Display Applications:

- *Data & Statistics*
- *Lists & Spreadsheet*
- *Graphs & Geometry*
- Meter only

Data Collection Console:

- Menus
- Modes (with setup menus)
    - Time Graph
    - Events with Entry
    - Selected Events
    - Monitor

Open a new document and connect a sensor to the handheld. Explore and discuss with a partner the menus and modes available.

Wrap Up:

- This activity is an informational exploration to see and use some of the features of CAS and the Data Collection Console.

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Rates of Cooling

Physics – Student Activity

Name ______________________

Class ______________________

Activity Overview:

In this investigation you will team up with others in your class and explore the rate at which a material cools an object. You may know that it takes a certain amount of energy to change the temperature of a given mass. You will discover some important relationships in this investigation.

Materials:

- *TI-Nspire™ CAS handheld technology (one per student)*
- *TI-Nspire CAS Student or Teacher Edition computer software (one per team)*
- *Vernier EasyTemp™ with USB mini-A to standard-A adapter or Go!™ Temp temperature sensor (2 per team)*
- *Some approved cooling material. This material should be at room temperature and should be voluminous enough to contain the complete metal in both temperature probes.*
- *Container that holds the cooling material*
- *TI-Nspire Computer Link with direct-connect cable*
- *Calculator file Rates_of_Cooling.tns*
- *Paper towels*
- *Safety goggles for some cooling materials*

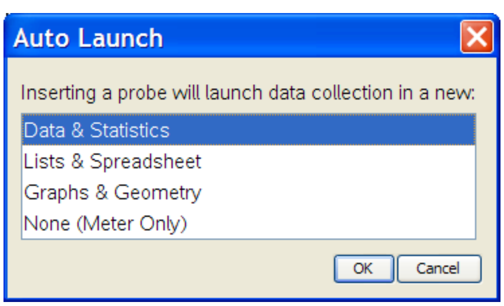
Part 1 – Data Collection

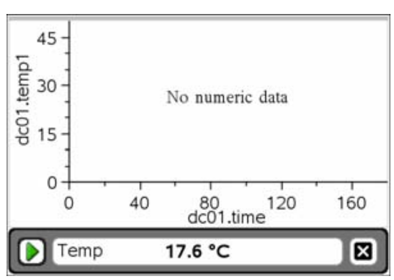
1. Once you form a team, discuss what material you want to use as the cooling agent. Be realistic and make sure you can obtain enough of the material to fully contain both of your temperature probes.

2. Get your selected material approved by your teacher.

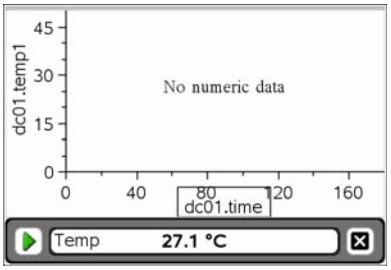
3. Collect the materials you need and move to a computer, where you will open a new document in the TI-Nspire CAS software. Start the document with a *Notes* page that contains all the necessary information (assignment name, the names of individuals on your team, the date, and the name of the cooling material you selected). Save this file with an appropriate name in a location that you can find later. While this is happening, bring your cooling material to room temperature.

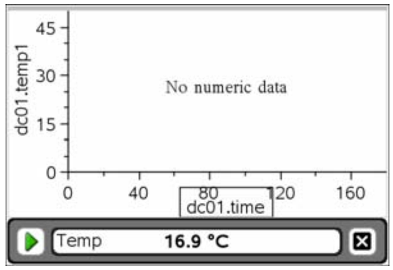
4. Now we want to plug the two temperature probes into the USB ports on the computer. This should launch the *Data Collection* application. If the *Data Collection* application doesn't launch, use Ctrl-D on the keyboard. Select *Data & Statistics* to display the data collection.



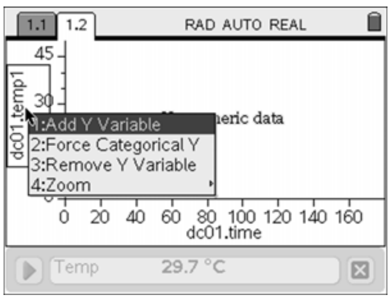


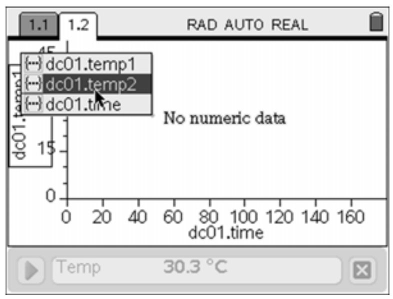
5. You will see one of the temperatures displayed in the *Data Collection* console at the bottom of the page. You want to toggle the display until you see the probe that you will heat. The other probe will be in your cooling material. Place one of the probes in your hand and the other in your cooling material. Use tab to get to the meter display in the middle of the console, and then use the ▲▼ arrow to switch to show the warmer probe.



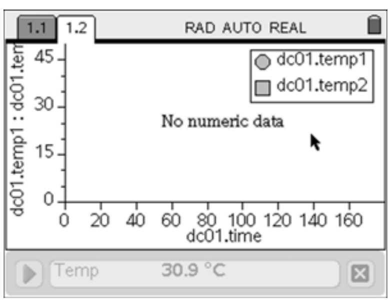


6. Now switch the focus to the *Data & Statistics* application by pressing ctrl tab, and move to the *y*-axis. Press ctrl menu, select **Add Y Variable**, and select **dc01.temp2** for the other probe.





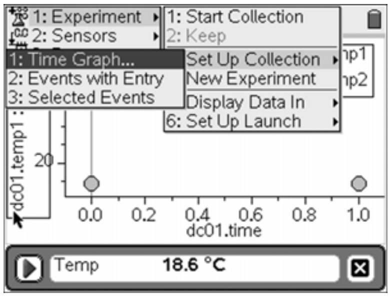
7. Move the legend to the upper-right corner of the page using your cursor.

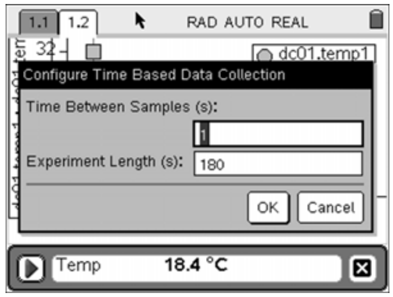


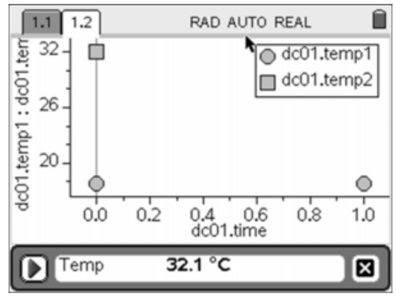
8. Now warm the selected temperature probe to about 5 degrees above the ambient temperature of the cooling material. Note that your body is 37 degrees Celsius. Note: If the difference in temperatures is very large, the warm probe will significantly change the temperature of your cooling solution when they are placed together, and this will disrupt the results of the experiment.

Rates of Cooling

9. Switch your focus to the *Data Collection* console using ctrl tab. You might want to adjust the data collection parameters at this time. Of particular interest is the time you will collect data. Materials cool things at different rates, and this default time setting might be too short or too long. Once you are satisfied, tab to the play button.

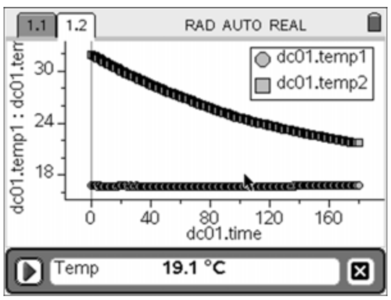


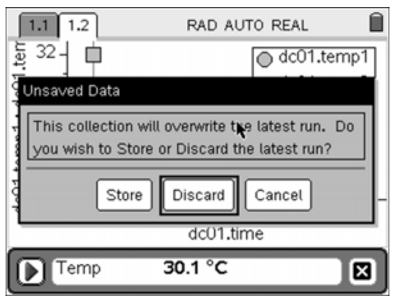




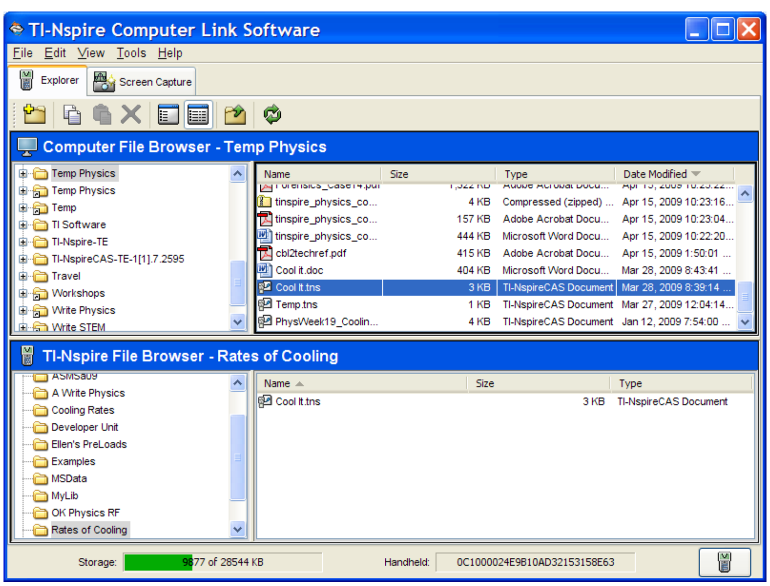
10. To collect the data, place the warm probe in the cooling material and then immediately press enter.

11. If your data plot looks good, dismiss the *Data Collection* application by tabbing to the X and pressing enter. If these are not the results you expected, make any adjustments to the data collection, warm the one probe, and when ready repeat as before. The difference here will be that you will select Discard right after you place the temperature probe in the cooling material.





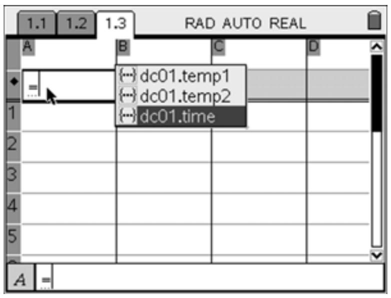
12. Save your document and send the data to each person in your group. Use the TI-Nspire Computer Link software and place it in a folder on the handheld for this class or experiment.

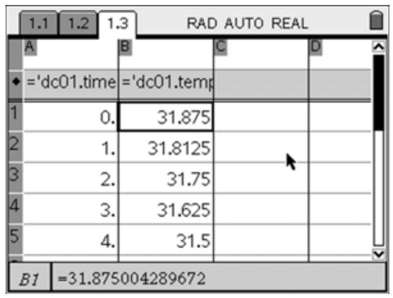


Rates of Cooling

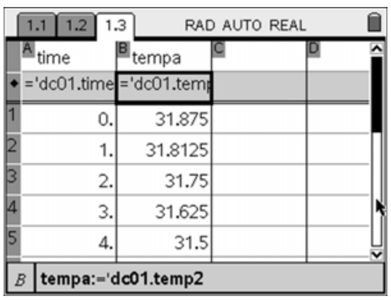
Part 2 – Data Analysis

1. Now we would like to examine the data for some critical points. Insert a *Lists & Spreadsheet* page by pressing and selecting **Lists & Spreadsheet**. On the diamond line, press and then use the keypad to select to see the list of available variables. Select the "time" data for Column A. Repeat this process in Column B, this time selecting the "temperature" data for the probe that started to warm. You might have to take two tries to get the right set of temperatures.

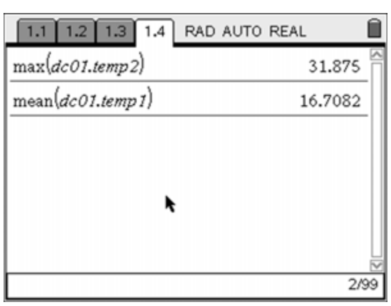




2. Move to the top of these two columns and name them. Move up and down in each column, explore the values, and consider how they change.

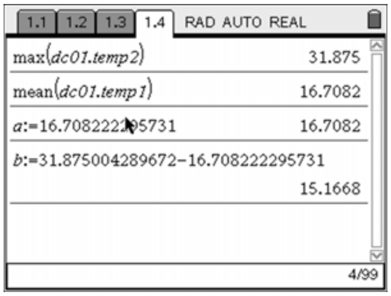


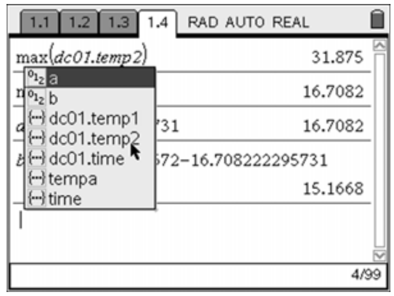
3. We want to model the pattern in the plot of temperature vs. time for the warm probe cooling in your material. We can use the equation Temperature = Ambient_Temp + (Starting_Temp – Ambient_Temp) * Cooling_Factor^{Time}, or $y = a + (b*c^t)$. To help identify the values of the Ambient_Temp and the Starting_Temp, we can insert a *Calculator* page. On this page, we can collect the mean of the list that has the temperatures of the cooling material and the maximum value in the warm probe list. Key in **max(**, select the variable name of the temperature data of the warm probe from the Variables menu (), and press . Then key in **min(**, select the temperature data of the probe in the cooling material from the Variables menu, and press .



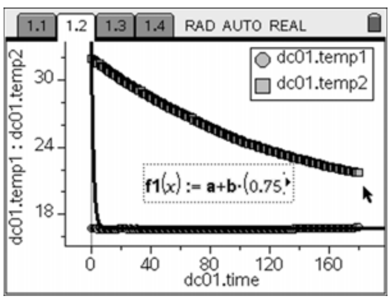
Rates of Cooling

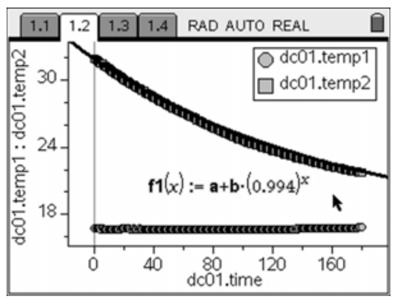
4. Now assign the values to ***a*** and ***b*** using the **:=** assignment command. Notice that the letters will now be bold and ***a*** and ***b*** will be in the variable list.





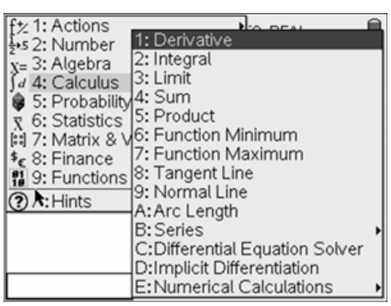
5. Return to the *Data & Statistics* page and try to guess the value of ***c*** by using **Plot Function** from the Analyze menu. Graph the equation **f1**(x) = ***a*** + ***b****c^x and use 0.50 as your starting value for ***c***. Note: You could use **f1**(Time) = ***a*** + ***b****c^{Time}, but we already used Time to stand for the list of times in the *Lists & Spreadsheets* application. Move the label out of the way and click on it to edit until you get a good fit.

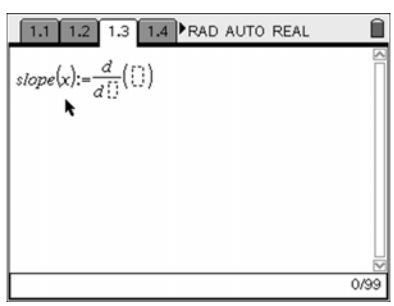


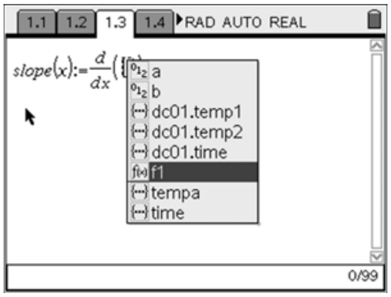


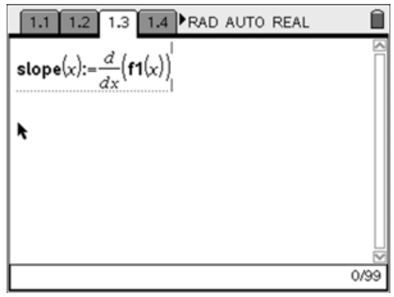
6. To more completely understand what we have here, let's look at the slope of this plot. Notice at the earlier times, we have a steeper slope, while as time goes on, the slope is approaching zero. What is the meaning of this slope? What are the units? The complete set of slopes might have a pattern. The pattern in the slope data can be determined by looking at the slope of the tangent at each point along the data or, more efficiently, by getting the derivative.

7. Go to a *Calculator* page and define the function slope(x) as the derivative of the function **f1**(x) we found. From the Calculus menu, select **Derivative**. Fill in the boxes as shown.

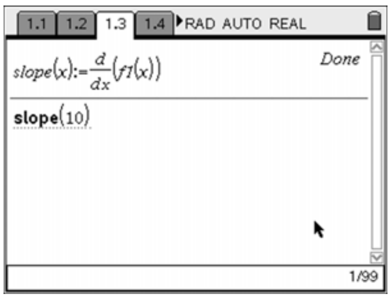


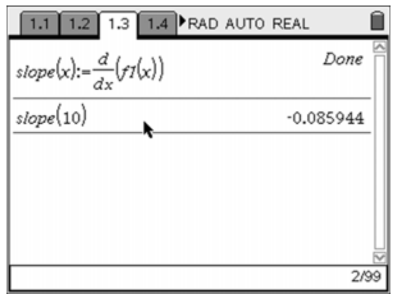




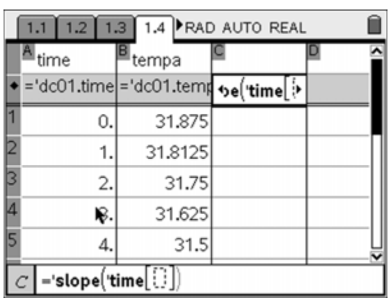


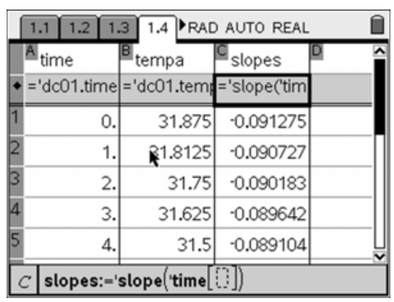
8. Test this new function out using a time of 10 seconds. Examine this number and consider what it means.



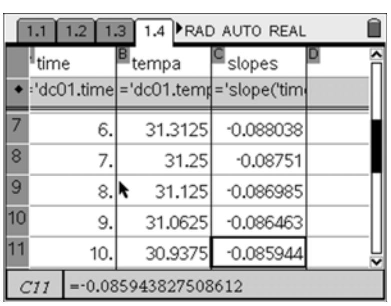


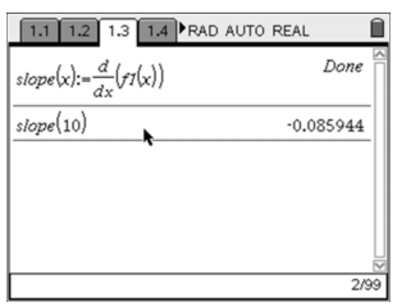
9. To get the slopes for all the times, we can return to the *Lists & Spreadsheet* page and add a third column we can call **Slopes**. First, move to the diamond line and, starting with =, select ***slope*** from the variable key, or just key it in and then reference the **A[ ]** column or **time[ ]** to get the slopes at each time. Move to the top of Column C and name this list.





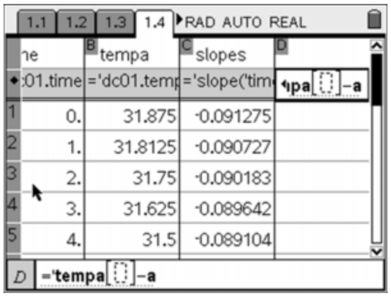
10. Check out the value in the **slopes** column for the time of 10 seconds, and explore the values in the column.

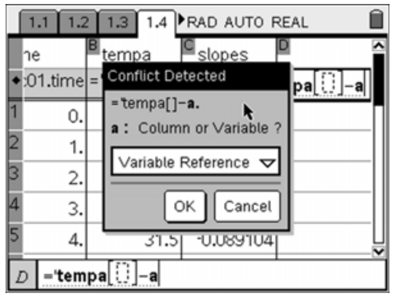




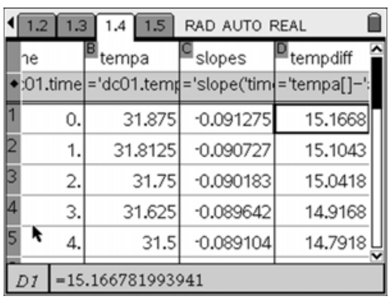
Rates of Cooling

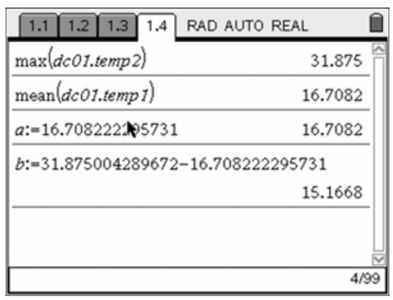
11. These individual slopes occurred at particular times, but they are also associated with how far the current temperature was away from the ambient value. This pattern might be more revealing. That is, looking at the rate at which the temperature is changing over time as a function of how far from the ambient temperature we are, what would you expect the temperature change rate to be if you were far from the ambient temperature? If you were close to it? We can make a column of these values called **tempdiff** by using the formula **=tempa[ ]**–***a***. The value is a variable reference, not a column reference.



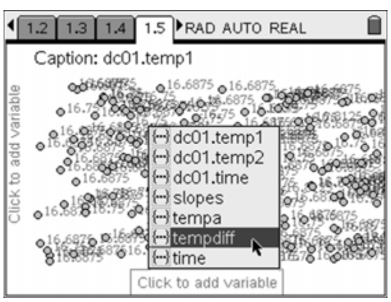


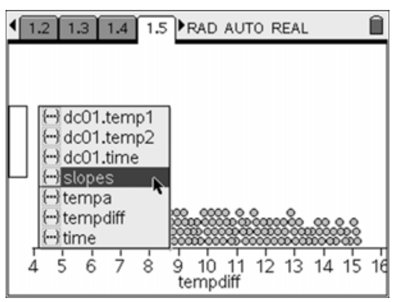
12. Notice the first value in this column. Look at the other values in this list as well.





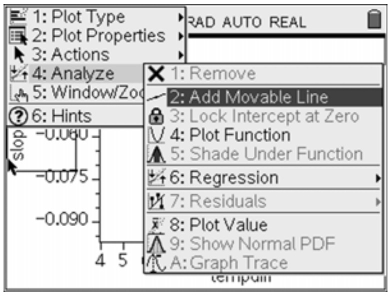
13. To more fully understand the relationship between these lists, we could set up a plot in a new *Data & Statistics* page. Set the *x*-values to **tempdiff** and the *y*-values to **slopes**.

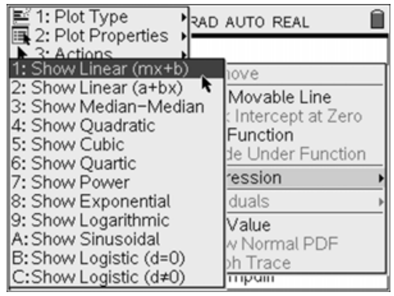




Rates of Cooling

14. What do you see in this plot? What pattern do you see? Add a movable line or do a regression to name this pattern.



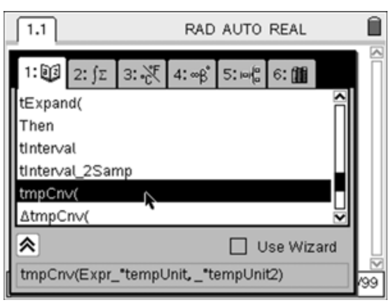


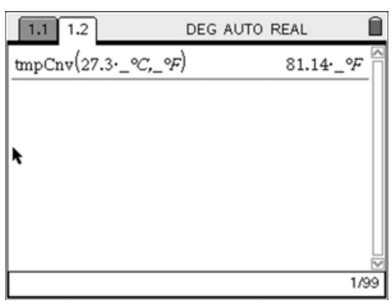
15. What would it mean if the data had a steeper slope than you have here? What is the slope of the function you obtained for the relationship between **slopes** and **tempdiff**? Select one point on the plot and parse its meaning.

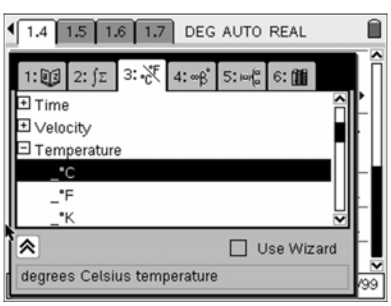
16. Find the specific heat of your cooling material and see if you can relate this to the function you just obtained and the following relationship:

Temperature = Ambient_Temp + (Starting_Temp – Ambient_Temp) * Cooling_Factor$^{\text{Time}}$

17. Convert ***a*** and ***b*** to degrees Fahrenheit, and give the time at which the temperature of your probe would reach 120% of the ambient temperature. To do this, introduce a *Calculator* page (1) and then, using the catalog (), move to the **tmpCnv()** command. The syntax is to give the value you want to convert (you may use ***a*** or the actual value) and then add the units _°C, a comma, and then the units _°F, as shown below. You obtain the units from the catalog () and then select 3 and move to the Temperature line. Expand this area with a right arrow (▸).







18. Save your document and send the completed document to your teacher.

Part 3 – Closure

1. Get the *Rates_of_Cooling.tns* file from your teacher and answer the questions either as a team or individually.

2. Send the completed document to your teacher.

Extensions (Optional)

Find r and k if $a + b \times c^t$ is really equal to $a + (b \times r^{kt})$, with r^{kt} being r^(k*t).

Change the time data to minutes and get a new function and plot. Explore how the plot and function change.

Convert *a* and *b* to degrees kelvin, and give the modified function and plot for temperature vs. time. Determine how your function and plot would change.

Determine the specific heat of your material, and compare it to the known value or report it if you cannot find a published value.

Graph your function in *Graphs & Geometry* and get the tangent line. Measure the slope of this line and get the coordinates of the point at which the tangent line is drawn. Grab the point and move it to a time that is in your data. You may need to just edit the coordinate for *x* to be an integer value. Get the slope value and compare it to the value for that time in your data (in *Lists & Spreadsheet*).

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Rates of Cooling

Physics – Teacher Notes

Activity Overview: Rates of Cooling

Students are familiar with the CSI shows, where the time of death is determined by measuring the liver temperature of the corpse. In this investigation they will explore as a team the cooling rate of some material as the temperature moves from being warmer than room temperature to being room temperature. This experience should be connected to the concept of specific heat, experimental design, and modeling patterns in data.

Teacher Preparation and Notes:

- *Estimated time for activity is one class period or less for data collection and then one full class period for the analysis and use of the Rates_of_Cooling.tns file.*
- *A list of TI-Nspire skills appears on the student worksheet.*
- *You will need to demonstrate data collection with the TI-Nspire using the TI-Nspire software. It is best to use the Teacher Edition in the SmartView/Emulator mode so students can see which keys you press. Using the EasyLink with the two TI temperature probes or with the two EasyTemps on the computer requires the USB mini-A to standard-A adapter or the Go!Link equipment.*
- *You will want to use teams of 2 or 3 as you do this investigation.*
- *Avoid toxic materials.*
- *Obtain the cooling material in advance so that it can be at room temperature.*
- *Students should keep the temperature differential small, not much more than 10 degrees. They can easily heat the probe with their bodies.*

Materials:

- *TI-Nspire™ CAS handheld technology (one per student)*
- *TI-Nspire CAS Student or Teacher Edition computer software (one per team)*
- *Vernier EasyTemp™ with USB mini-A to standard-A adapter or Go!™Temp temperature sensor (2 per team)*
- *TI-Nspire CAS Teacher Edition computer software and projector with data collection cables for demonstration purposes*
- *Various materials to cool in. Teams can select and provide these. You may direct the teams to use the materials you provide. These materials should be at room temperature and should be voluminous enough to contain the complete metal in both temperature probes. It would also be useful to have materials for which the teams can obtain the specific heat values. Some suggested materials are salt, air, water, vinegar, alcohol (90% or 70%), gelatin, ketchup, metal powder, and solutions such as saturated sugar water.*
- *Student worksheet Rates_of_Cooling_Student_Physics.doc*
- *Container that holds the cooling material, won't tilt, and is large enough to hold both temperature probes fully without touching (1 per team)*
- *Connect-to-Class, TI-Nspire Navigator, TI-Nspire Computer Link with direct-connect cable or unit-to-unit cables to send the Rates_of_Cooling.tns file and collect the student documents with results*
- *Calculator file Rates_of_Cooling.tns*

Rates of Cooling

- *Paper towels*
- *Safety goggles for some cooling materials*

Suggested Related Activities:

To download any activity listed, go to education.ti.com/exchange and enter the number in the quick search box.

- *Cooling Rates — 8546*
- *Forensics Case 14—Hot Air, Cold Body: Using Newton's Law of Cooling to Determine Time of Death — 6380*
- *Chill Out: How Hot Objects Cool — 3988*
- *Various Activities at TI Physics: http://www.tiphysics.com/*

Some Skills Your Students Will Need:

- Create a new document on the TI-Nspire software and save it
- Save a document, give it a name, and create or find a Folder
- Open a document on the TI-Nspire
- Launch the *Data Collection* application (using two probes) and dismiss it
- Adjust the settings from the *Data Collection* application menu
- Switch the view in the *Data Collection* console to show the two different temperature probes
- Add a new application to your problem
- Use various tools in *Data & Statistics* including **Add Movable Line** and **Regression**
- Plot a function in *Data & Statistics*
- Load data into *Lists & Spreadsheet* and enter formulas
- Use the *Calculator* application to create variables and assign values
- Start and stop data collection
- Send and receive files from your TI-Nspire software and your handheld
- Use units in the *Calculator* application
- Convert temperature units using **tmpCnv()**
- Use the Derivative function in the *Calculator* application

Rates of Cooling

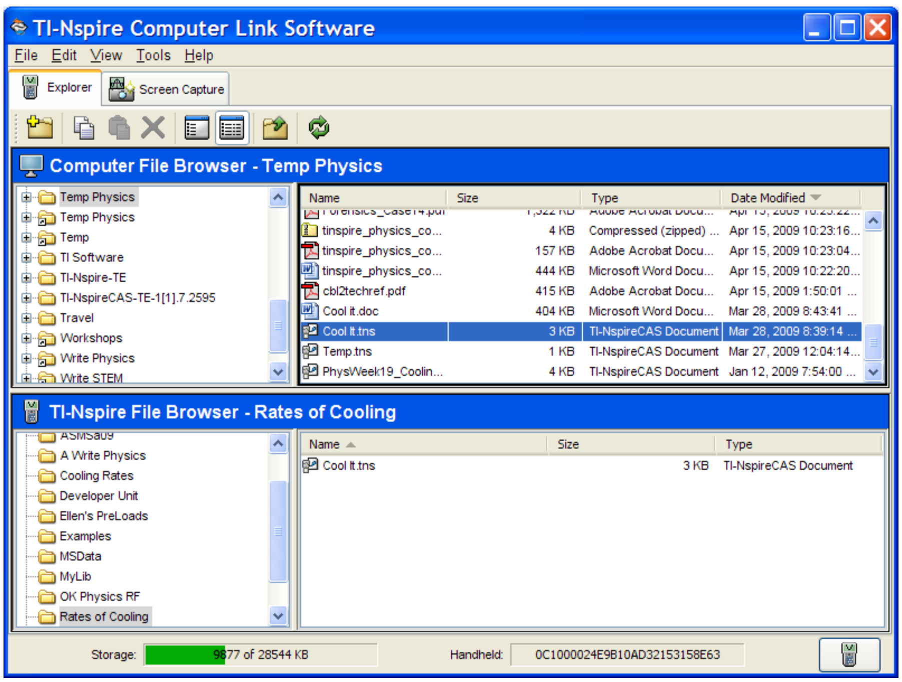
Part 1 – Data Collection

1. Set up the students at a computer with the TI-Nspire CAS software. They will need two temperature probes and the adapters to collect data.

2. Once the teams decide what cooling material they want to use, you will need to approve its use. Make sure the material is not toxic to the computers (or the children) and that you/they can obtain a large enough quantity so that it will hold both temperature probes fully without touching.

3. Let the material sit in your room long enough so that it reaches room temperature.

4. At the end of this part, after the team has collected the data, they will need to save it again and then use the TI-Nspire Computer Link software to send it all the handhelds in the team. You may need to demonstrate this.



Part 2 – Data Analysis

1. This section can be done on the handheld.

2. There is some intensive TI-Nspire use in this part. Monitor the teams and see that each member is working through the steps.

3. You can periodically check for progress by attaching the student handhelds to Connect-to-Class and getting the documents.

4. The examination of the pattern in the slope of their plot could be optional. Have the students answer the questions either in their groups or in a classroom discussion. What is the meaning of this slope? [rate of change in temperature over time] What are the units? [degrees Celsius/sec]

Rates of Cooling

The complete set of slopes might have a pattern. The pattern in the slope data can be determined by looking at the slope of the tangent at each point along the data or, more efficiently, by getting the derivative.

5. Looking at the rate at which the temperature is changing as a function of how far from the ambient temperature we are might be useful. What would you expect the temperature change rate to be if you were far from the ambient temperature? [a high rate of change] If you were close to it? [a low rate of change]

6. If the students use Movable Line, they may need some demonstration of these techniques.

Part 3 – Closure

1. Send the students the Rates_of_Cooling.tns file through Connect-to-Class, through the Computer Link software, using the unit-to-unit link, or with your TI-Nspire Navigator.

2. You may have the teams answer the questions rather than doing this individually.

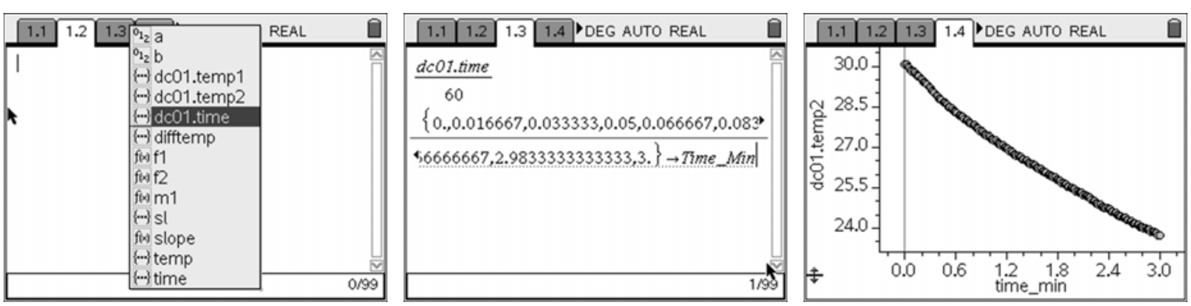
3. Collect the answers.

4. Spend time in class going over the questions and answers that are most relevant to your class. You may wish to revisit these questions in the assessment for this unit.

Extensions (Optional)

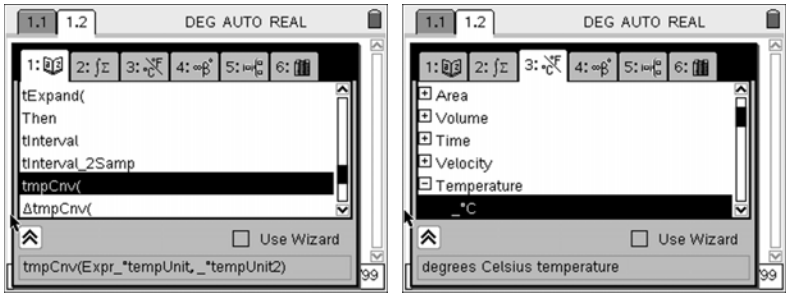
Find *r* and *k* if $a + b \times c^t$ is really equal to $a + (b \times r^{kt})$, with r^{kt} being *r*^(*k***t*).
[For a particular time, you can find *r*^*k* by setting $c^t = r^{kt}$. If *k* is the slope of the slope vs. temperature difference graph, then you can solve for *r*.]

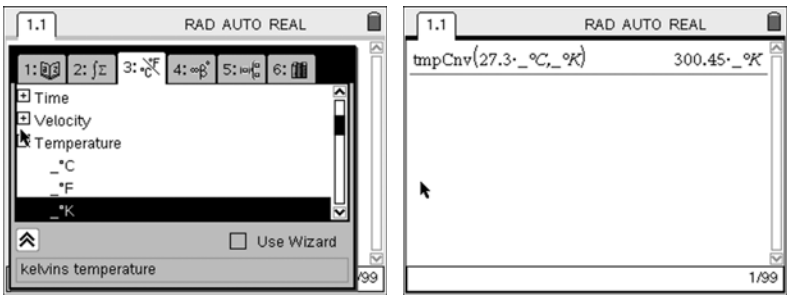
Change the time data to minutes and get a new function and plot. Explore how the plot and function change.



Rates of Cooling

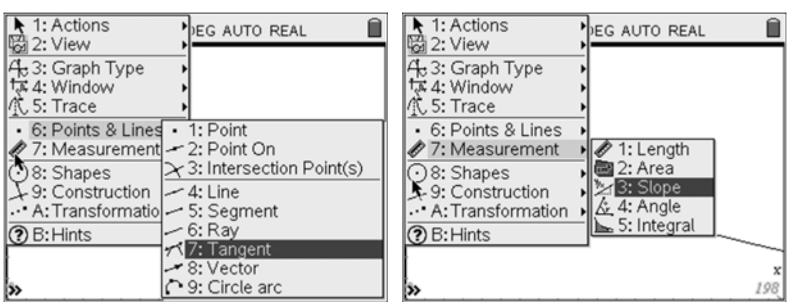
Convert *a* and *b* to degrees kelvin, and give the modified function and plot for temperature vs. time. Determine how your function and plot would change.



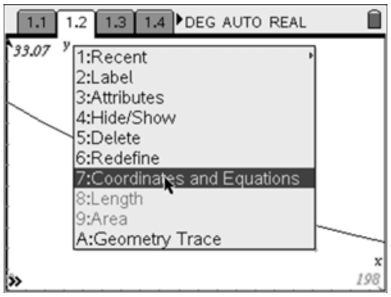


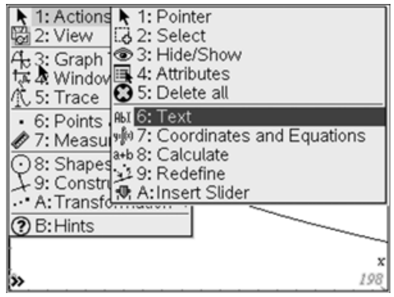
Determine the specific heat of your material, and compare it to the known value or report it if you cannot find a published value.

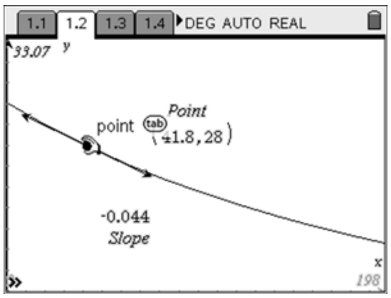
Graph your function in *Graphs &Geometry* and get the tangent line. Measure the slope of this line and get the coordinates of the point at which the tangent line is drawn. Grab the point and move it to a time that is in your data. You may need to just edit the coordinate for *x* to be an integer value. Get the slope value and compare it to the value for that time in your data (in *Lists & Spreadsheet*).

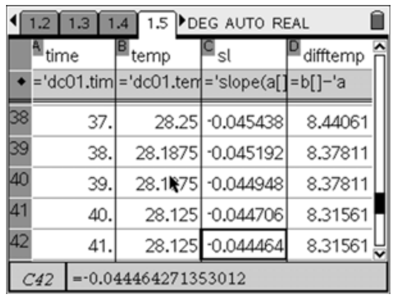


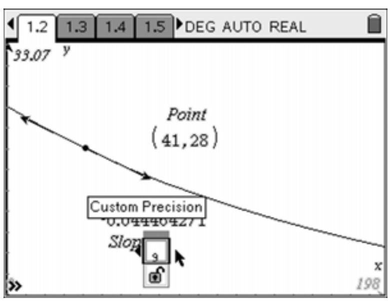
Rates of Cooling

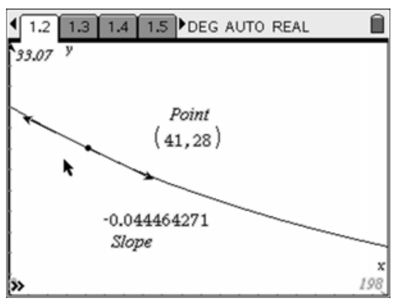












Let's Roll – Ball on a Ramp

Physics – Student Activity

Name ______________________

Class ______________________

Activity Overview:

- *In this activity you will examine the graphs of position, velocity, and acceleration versus time for a ball on a ramp. Following this activity, you will be able to sketch the graph of position versus time, velocity versus time, and acceleration versus time for an object moving with constant acceleration. You will also be able to interpret important values on these graphs.*

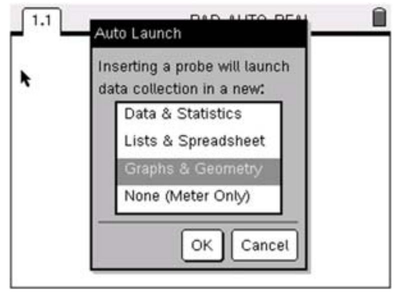
Materials:

- *TI-Nspire™ CAS handheld*
- *CBR 2™*
- *Inclined plane at least 1 m long*
- *Ball: tennis ball size or larger (carts on a ramp can be used instead of balls)*

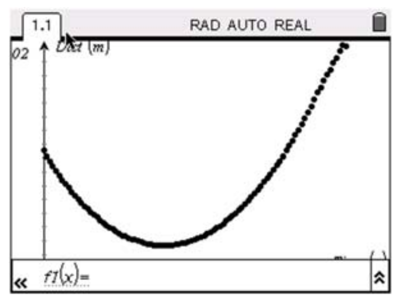
Prior to the Activity Data Collection

1. Place the motion detector at the top of the ramp, and roll the ball up the ramp from the bottom.
2. Sketch a prediction of what the position versus time graph will look like in the space to the right. (Note that the "position" of the ball is the distance of the ball from the motion detector.)
3. Watch the velocity of the ball. Predict the velocity of the ball as a function of time. Sketch the prediction in the space to the right.
4. Now, think about the acceleration. Sketch a prediction of the acceleration as a function of time.

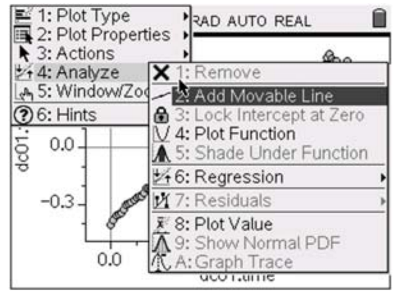
Data Collection



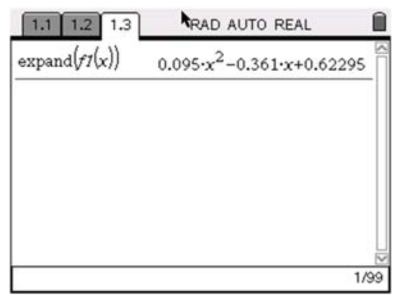
1. Set up a ramp with a small angle. If the ramp is too steep, you will not get very much data. You want the ball to roll up and down the ramp over a time period of at least 4 seconds.
2. Open a new document on the TI-Nspire and connect the CBR 2. Choose *Graphs & Geometry* as the application to collect the data.
3. Give the ball a gentle roll up the ramp, and press enter to begin collecting the data. If the data look as you expect them to, disconnect the CBR 2 and close the *Data Collection* console. If not, press enter to collect data again. Discard the old data. Repeat until you have a smooth set of data.
4. Save this file on your TI-Nspire and send a copy of the document to the other members of your lab group.
5. Sketch your graph to the right or print a copy using the TI-Nspire Computer Link software.
6. Press ctrl G to hide the graph entry line, and examine the data.



7. Select **MENU > Trace > Graph Trace**. Trace to the vertex of the parabola and record the coordinates. *x*: __________ *y*: ________
8. What do the *x*- and *y*-coordinates represent in this data set?
9. Recall the vertex form of a quadratic equation from your algebra class. What is that equation?
10. Use this equation and substitute in the coordinates of the vertex for this data. You do not yet know a value for *A*.
11. Press ctrl G to bring the graph entry line back on the screen. Select **MENU > Graph Type > Function** to bring up the function line.
12. Enter the function. Begin with an initial value of $A = 1$.
13. Grab the outer edges of the parabola and fit the equation to the data set. Record the final equation.



14. Press (home) and insert a *Data & Statistics* page. Set up a plot of velocity as a function of time. How does this plot match your prediction?
15. Select **MENU > Analyze > Add Movable Line**.
16. Grab the line and adjust it so that it fits the data.
17. Record the equation for the line.
18. Explain what the slope of the equation represents and what it means if the velocity versus time plot is linear.
19. How does the slope compare with the *A* value found for the position versus time plot?
20. Why is the *y*-intercept negative? What does the *y*-intercept of the velocity versus time plot represent?



21. Press (home) and select **Calculator**.
22. Expand your equation for **f1**(x) from the parabola that was in vertex form. An example is shown to the right. Enter your equation from 13 above. (A sample is shown to the right.)
23. Identify the acceleration, initial velocity, and initial position from this equation.
24. Add another *Data & Statistics* page. Turn on a plot of acceleration versus time. How does this compare with your prediction?
25. Describe how the equations for the position, velocity, and acceleration will change if the angle of the ramp is increased.

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Let's Roll – Ball on a Ramp

Physics – Teacher Notes

Activity Overview: Let's Roll – Ball on a Ramp

Students will collect data for a ball rolling up and back down a ramp. They will analyze the position, velocity, and acceleration versus time plots. Following this activity, students will be able to sketch the graph of position versus time, velocity versus time, and acceleration versus time for an object moving with constant acceleration. Students will also be able to interpret important values on these graphs.

Teacher Preparation and Notes:

- *Estimated time for activity: 50 minutes (predictions can be done ahead of time to provide more time for the lab during class)*
- *Students should have knowledge of linear and quadratic equations. Knowledge of quadratics includes both vertex and standard forms of quadratic equations.*
- *This is a student-centered lab, with students organized in lab groups with a maximum of 4 students per group.*
- *Students may need to practice rolling the ball. They should keep the ramp at a small angle and may want to begin collecting the data just after they release the ball.*

Materials:

- *TI-Nspire™ handheld technology*
- *TI-Nspire CAS handheld technology*
- *CBR 2™*
- *Inclined plane at least 1 m long*
- *Ball: tennis ball size or larger (carts on ramps can be used instead of balls)*
- *TI-Nspire Computer Link software can be used to print copies of the graphs*
- *Student worksheet Let's_Roll_Student_Physics.doc*

Suggested Related Activities (optional):

To download any activity listed, go to tiphysics.com/activities

- *Rolling a Ball on an Inclined Plane — 8550*

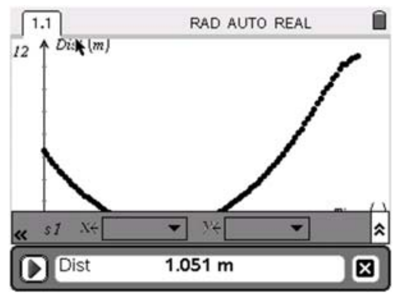
Let’s Roll – Ball on a Ramp

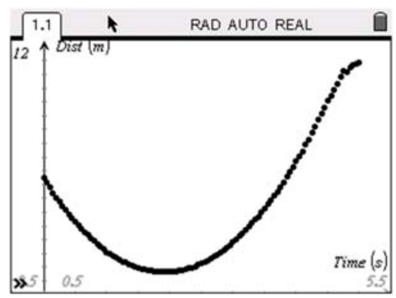
Prior to the Activity Data Collection

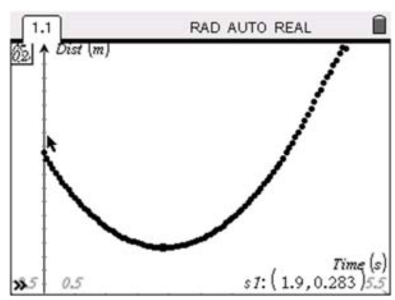
Questions 2–4 involve making predictions. These are provided to engage students and get them thinking about what the data should look like. Research indicates that student conceptual understanding is enhanced when students make predictions prior to collecting data. Students should discuss their predictions with their group members, and you may want to show some predictions prior to the data collection.

Data Collection

1. Set up a ramp with a small angle. If the ramp is too steep, you will not get very much data. You want the ball to roll up and down the ramp over a time period of at least 4 seconds.
2. Open a new document on the TI-Nspire and connect the CBR 2. Choose *Graphs & Geometry* as the application to collect the data.
3. Give the ball a gentle roll, and press enter to begin collecting the data. If the data look as you expect them to, disconnect the CBR 2 and close the *Data Collection* console. If not, press enter to collect data again. Discard the old data. Repeat until you have a smooth set of data.
4. Save this file on your TI-Nspire and send a copy of the document to the other members of your lab group. **See sample data to the right.**
5. Sketch your graph to the right or print a copy using the TI-Nspire Computer Link software.
6. Press ctrl G to hide the graph entry line, and examine the data.
7. Select **MENU > Trace > Graph Trace**. Trace to the vertex of the parabola and record the coordinates. **Answer using sample data: *x*: 1.9; *y*: 0.283**







8. What do the *x*- and *y*-coordinates represent in this data set? **The *x*-coordinate represents time, and the *y*-coordinate represents distance from the CBR 2.**
9. Recall the vertex form of a quadratic equation from your algebra class. What is that equation?

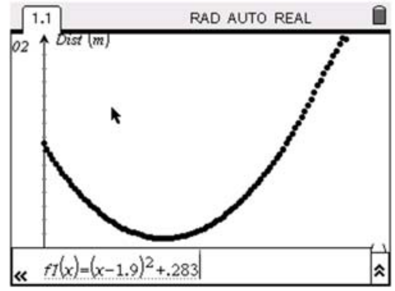
   $y = A(x-h)^2 + k$, where the coordinate of the vertex is (h, k)

Let’s Roll – Ball on a Ramp

10. Use this equation and substitute in the coordinates of the vertex for this data. You do not yet know a value for *A*.

    $y = A(x - 1.9)^2 + 0.283$

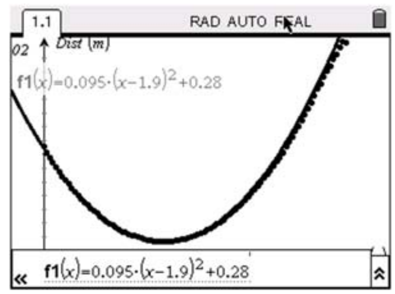
11. Press ctrl G to bring the graph entry line back on the screen. Select **MENU > Graph Type > Function** to bring up the function line.



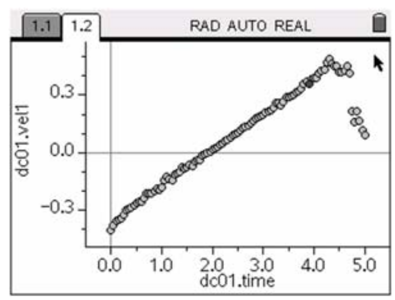
12. Enter the function. Begin with an initial value of *A* = 1.

13. Grab the outer edges of the parabola and fit the equation to the data set. Record the final equation.

    $y = 0.095(x - 1.9)^2 + 0.28$

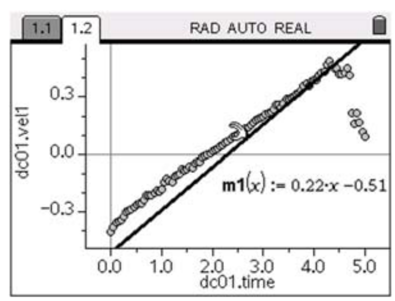


14. Press the home key and insert a *Data & Statistics* page. Set up a plot of velocity as a function of time. How does this plot match your prediction?



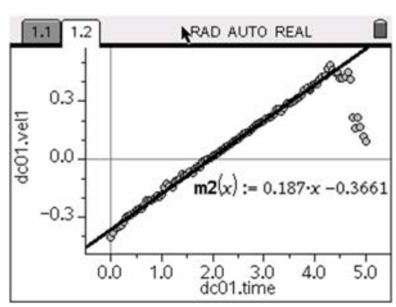
15. Select **MENU > Analyze > Add Movable Line**.

16. Grab the line and adjust it so that it fits the data.



17. Record the equation for the line. **See equation and graph to the right.**

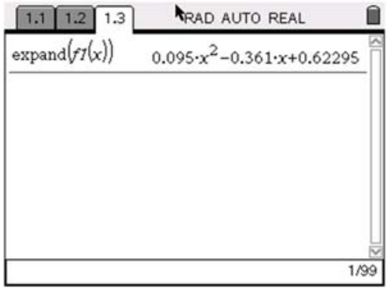
18. Explain what the slope of the equation represents and what it means if the velocity versus time plot is linear. **The slope represents the acceleration. A linear graph for velocity versus time indicates that the acceleration is constant.**



19. How does the slope compare with the *A* value found for the position versus time plot? **The slope is approximately twice the value of *A*.**

20. Why is the *y*-intercept negative? What does the *y*-intercept of the velocity versus time plot represent? **The *y*-intercept represents the initial velocity. It is negative because when the ball began rolling, it was approaching the motion detector.**

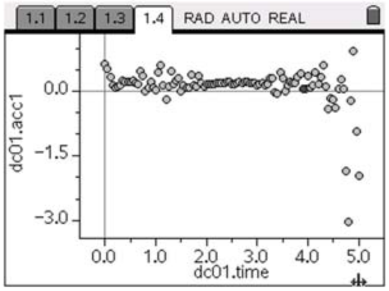
21. Insert a *Calculator* page by pressing (home) and selecting **Calculator**.



22. Expand your equation from the parabola that was in vertex form. An example is shown to the right. Enter your equation from 13 above.

23. Identify the acceleration, initial velocity, and initial position from this equation. **The acceleration is twice the value of 0.95 m/s^2. The initial velocity is –3.61 m/s, and the initial position is 0.62.**

24. Add another *Data & Statistics* page from the (home) screen. Turn on a plot of acceleration versus time. How does this compare with your prediction? **The plot should be horizontal, with a *y*-value approximately equal to the slope of the equation for the velocity versus time.**



25. Describe how the equations for the position, velocity, and acceleration will change if the angle of the ramp is increased. **The acceleration will increase. This means that the coefficient in front of x^2, the slope of the velocity versus time plot, and the *y*-value of the horizontal line on the acceleration versus time graph will all increase. The maximum value for the acceleration is 9.8 m/s^2. (This is the case when the ball is in free fall.)**

Projectile Motion

Physics – Teacher Notes

Activity Overview: Projectile Motion

Students explore projectile motion. They will learn how the initial velocity and angle of launch affect the trajectory of a projectile. In Problem 2, they will examine the horizontal and vertical velocity vectors for the projectile and discover the acceleration is due to gravity in the vertical direction. In Problem 3, they will determine how angle affects the range of the projectile.

Teacher Preparation and Notes:

- *Estimated time for activity: 45 minutes*
- *Load the TNS file Projectile_Motion_Physics.tns onto all student handhelds.*
- *Students should know about the basics of motion with constant velocity and constant acceleration.*
- *Students may work in small groups or individually depending upon the teacher's preference.*
- *There are no handouts for this activity. The students answer on the TI-Nspire.*
- *A sample TNS file with answers and data is included in your materials.*

Materials:

- *TI-Nspire™ handheld technology*
- *TI-Nspire™ CAS handheld technology*
- *If needed, TI-Nspire™ computer software*
- *Projectile_Motion_Physics.tns*
- *Projectile_Motion_Answers_Data_Physics.tns*

Suggested Related Activities (optional):

To download any activity listed, go to ti.physics.com/activities.

- *Two-Dimensional Motion and Vectors — 8876*

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Forces on an Incline

Physics – Student Activity

Name ______________________

Class ______________________

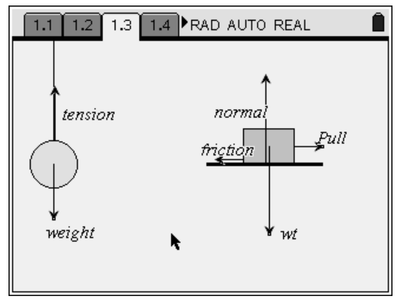
Activity Overview:

A block at rest on an incline has several forces acting on it. How do these forces change and what factors influence these forces? You will investigate pairs of opposing forces that make a situation static, resolve force vectors, and see how forces on an incline depend on some factors. At the end of this activity, you will calculate the forces acting on a block on a given ramp.

Materials:

- *TI-Nspire™ CAS handheld*
- *Forces_on_an_Incline_Physics.tns*

Problem 1



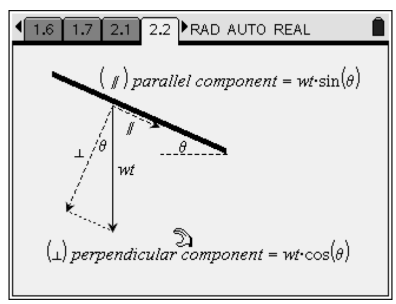
Open the *Forces_on_an_Incline_Physics.tns* file on your TI-Nspire handheld. Follow your teacher's instructions to save this file.

Work through the directions on the pages of the .tns file.

On page 1.3, you can interact with the objects on the screen. Drag the ends of the *weight*, *wt*, and *Pull* vectors, and notice what happens to other forces in order to maintain a static situation.

Answer the questions on pages 1.4–1.7 based on your observations and explorations on the diagram.

Problem 2



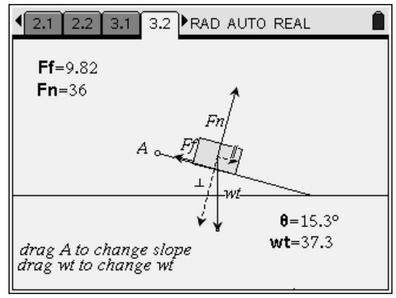
In Problem 1, all forces are vertical or horizontal. On an incline, forces are not all perpendicular to each other. In order to understand what is going on, we need to resolve force vectors into perpendicular components. On an incline, it is easiest to resolve the weight vector into components perpendicular and parallel to the incline. This is done with basic trigonometry.

Study the diagram on page 2.2. The components of the weight vector form a right triangle, with *wt* as the hypotenuse. What trigonometric ratios relate the perpendicular and parallel components to the weight? Rewrite these in equation form to solve for each component.

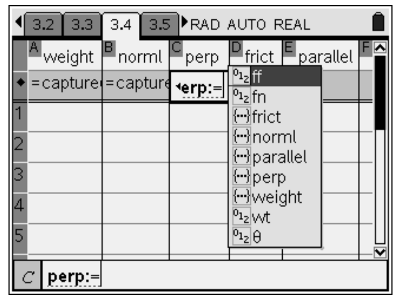
Forces on an Incline

Problem 3

In Problem 3, you will manipulate the diagram and observe how forces in the system change. You can change the weight of the block by dragging the end of the *wt* vector; you can change the slope of the incline by dragging point *A*. Experiment with the system and make observations to allow you to answer the questions that appear on the following pages on the handheld screen.



You will also capture data as you make changes. In Problem 3, capture data by changing the *wt* only. You must drag the weight vector to change the weight of the block. The angle will be changed in problem 4. To capture data, press ctrl and then . (the decimal point). Adjust the weight to a different value and then press ctrl and . again.



The captured data will appear in the spreadsheet on page 3.4. Study the spreadsheet to see how the normal (*fn*) and friction (*ff*) forces changed as the weight was changed.

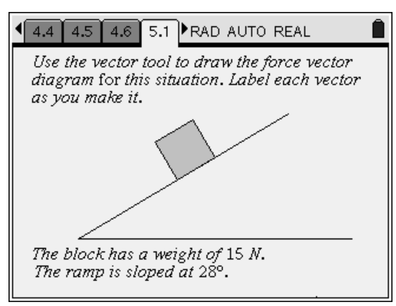
Calculate the perpendicular and parallel components of the weight by entering the formula for finding these components in the formula cells of Columns C and E. Start the formula with "=" and select the variables by pressing sto→ var and choosing the appropriate variable. (Hint: When selecting the variable for weight, make sure to select the variable "weight" and not "wt." Insert the ° symbol from the symbol template by using ctrl ∞β°.)

Problem 4

Problem 4 is a repeat of the same process as Problem 3, except that you will now change the angle of the slope, keeping the weight constant. Again, capture data over a range of angle values, study the spreadsheet, and calculate the perpendicular and parallel components.

Problem 5

Page 5.1 contains a diagram of a block on a ramp. The weight and slope angle are given. Draw vectors for all the forces and components that relate to the situation. Estimate lengths. To access the Vector tool, select **MENU > Points & Lines > Vector**. To make the component vectors dashed lines, select **MENU > Actions > Attributes**. Select the vector, and then arrow down to "Line style is continuous" and press the right arrow to the command that says "Line style is dotted." Press esc when finished.



After you have added to the diagram, proceed to the next page and then insert a new *Calculator* page by pressing the home key and selecting **Calculator**. Use the values given to calculate the actual values of all the forces in the system. Your teacher may have special instructions for saving this file. Please follow the teacher's directions.

Forces on an Incline
Physics – Teacher Notes

Activity Overview: Forces on an Incline
In this activity, students will explore the forces in static situations. They first look at vertical and horizontal forces with a hanging ball and a block on a table. They then see how to resolve a force into perpendicular and parallel components, and they explore how these components relate to the forces on a block on an incline. They end the activity by drawing the force vectors on a block on an incline and by calculating the values of the forces based on given information.

Teacher Preparation and Notes:
- *Estimated time for activity: 30–40 minutes*
- *This activity requires that students have Forces_on_an_Incline_Physics.tns file on their TI-Nspire handhelds.*
- *Students need little preparation for this activity. It can be used as an exploratory learning activity.*
- *Students may work individually, or in pairs with one handheld.*

Materials:
- *TI-Nspire™ handheld technology*
- *TI-Nspire CAS handheld technology*
- *Forces_on_an_Incline_Physics.tns*

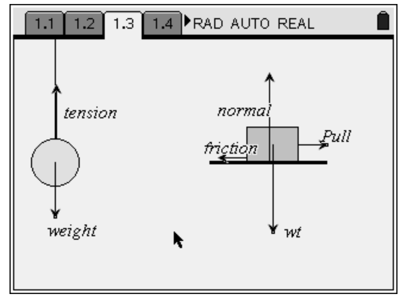
Suggested Related Activities (optional):
To download any activity listed, go to tiphysics.com/activities and find the activity in the list.
- *Friction and Inclined Planes — 12876*
- *Forces on an Inclined Plane — 12875*

Forces on an Incline

Problem 1

Open the *Forces_on_an_incline_Physics.tns* file on your TI-Nspire handheld. Follow your teacher's instructions to save this file.

Teacher Tip: *It is a good idea to have students immediately save their file under a different name (such as "Incline_name" in this case) so that they will have an unblemished original on their handhelds in case of difficulty. Also, you may wish to have students "hand this in" electronically, and you would find it useful to have the students' names attached to the file.*



Work through the directions on the pages of the TNS file.

On page 1.3, you can interact with the objects on the screen. Drag the ends of the *weight*, *wt*, and *Pull* vectors and notice what happens to other forces in order to maintain a static situation.

Answer the questions on pages 1.4–1.7 based on your observations and explorations on the diagram.

Answers:

1.4: If the ball is heavier, there must be more tension in the string.

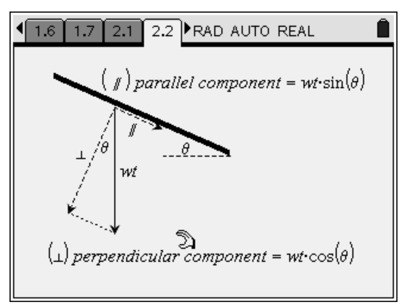
1.5: If the ball was heavier than the maximum tension of the string, the string would break and the ball would fall. This would no longer be a static situation.

1.6: If the pull was decreased, the value of friction would decrease. Friction provides the equilibrium force—up to the maximum value that friction can have in that situation.

1.7: If you pull harder than friction can oppose, there is a net force and the block will accelerate. The maximum amount of force that friction can apply depends on the coefficient of friction and the normal force. (This can be explored in another activity.)

Problem 2

In Problem 1, all forces are vertical or horizontal. On an incline, forces are not all perpendicular to each other. In order to understand what is going on, we need to resolve force vectors into perpendicular components. On an incline, it is easiest to resolve the weight vector into components perpendicular and parallel to the incline. This is done with basic trigonometry.



Study the diagram on page 2.2. The components of the weight vector form a right triangle, with *wt* as the hypotenuse. What trigonometric ratios relate the perpendicular and parallel components to the weight? Rewrite these in equation form to solve for each component.

Forces on an Incline

Teacher Tip: *Students may have this skill already and can skip through this section. If not, a discussion of "SOA CAH TOA" in this context may be useful.*

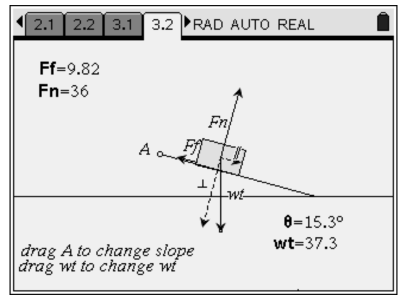
Answers:

Parallel component = *wt* × sin(θ)

Perpendicular component = *wt* × cos(θ)

Problem 3

In Problem 3, you will manipulate the diagram and observe how forces in the system change. You can change the weight of the block by dragging the end of the *wt* vector; you can change the slope of the incline by dragging point *A*. Experiment with the system and make observations to allow you to answer the questions that appear on the following pages on the handheld screen.



You will also capture data as you make changes. In problem 3, capture data by changing the *wt* only. The angle will be changed in problem 4. To capture data, press ctrl and then . (the decimal point). Adjust the weight to a different value, and then press ctrl . again.

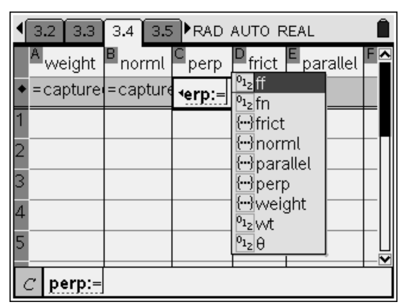
The captured data will appear in the spreadsheet on page 3.4. Study the spreadsheet to see how the normal (*fn*) and friction (*ff*) forces changed as the weight was changed.

Answers:

3.5: As the weight of the block changes, the normal force changes proportionately, since the ramp must exert more or less force to support the weight of the block.

3.6: Friction also changes proportionately to the change in weight because the system is static.

Calculate the perpendicular and parallel components of the weight by entering the formula for finding these components in the formula cells of Columns C and E. Start the formula with "=", and then select the variables by pressing sto→ var and choosing the appropriate variable. (Hint: Select variables with the variable key sto→ var; insert the ° symbol from the symbol template by pressing ctrl ∞β°.)



Teacher Tip: *The variables available are of two types: defined values (012) from the diagram on page 3.2 and list variables (…) from the spreadsheet. In the spreadsheet formula, you must use (…)weight to calculate with each value in Column A.*

This software has a default of radians for angle measure. You can change the document setting (home, System Info, Document Settings) or, more simply, just insert the ° symbol.

Answers:

3.8: Pairs of equal and opposite forces are the perpendicular components of weight and normal force, and the parallel components of weight and friction.

Forces on an Incline

Problem 4

Problem 4 is a repeat of the same process as problem 3, except that you will now change the angle of the slope, keeping the weight constant.

Again, capture data over a range of angle values, study the spreadsheet, and calculate the perpendicular and parallel components.

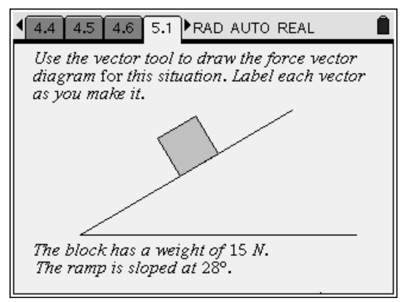
Teacher Tip: *Stress that problem 3 involved changing the weight, whereas problem 4 involves changing only the slope angle.*

Answers:

4.5: Changing the slope angle does affect the pairs of opposite forces because the components of weight change with the angle.

4.6: Changing the angle has a bigger effect on forces than changing the weight. When horizontal, friction becomes 0; when vertical, normal force becomes 0.

Problem 5



Page 5.1 contains a diagram of a block on a ramp. The weight and slope angle are given. Draw vectors for all the forces and components that relate to the situation. Estimate lengths. To access the Vector tool, select **MENU > Points & Lines > Vector**. To make the component vectors dashed lines, select **MENU > Actions > Attributes**. Select the vector, and then arrow down to "Line style is continuous" and press the right arrow to the command that says "Line style is dotted." Press esc when finished.

After you have added to the diagram, proceed to the next page and then insert a new *Calculator* page by selecting **HOME > Calculator**. Use the values given to calculate the actual values of all the forces in the system. Your teacher may have special instructions for saving this file. Please follow the teacher's directions.

Teacher Tip: *This problem tests the understanding of all the other parts of the activity. Note that the slope is in the other direction. Students should have five vectors in total when completed.*

When calculating the forces on the Calculator page of the TI-Nspire CAS, an exact value in terms of radians will be given, even with the degree symbol. To get the approximate numeric value, press ctrl enter.

Answers:

Weight = 15 N

Normal = *wt* perpendicular = *wt* × cos(θ) = 13.24 N

Friction = *wt* parallel = *wt* × sin(θ) = 7.04 N

Teacher Tip: *You may want students to save this file as "Incline_name" and submit it for marking electronically through Connect-to-Class or Computer Link.*

Friction

Physics – Student Activity

Name ________________________

Class ________________________

Activity Overview:

In is activity you will explore the frictional force acting on a block and determine what that frictional force depends upon.

Materials:

- *TI-Nspire™ CAS handheld*
- *Vernier™ EasyLink*
- *Vernier Dual Force Sensor*
- *Block with a hook*
- *String*
- *Set of masses*
- *Balance*

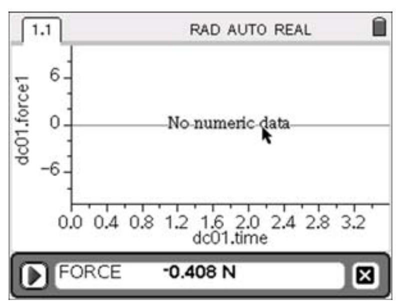
Preliminary Questions:

1. Describe the force needed to move a heavy box across the floor from the time the box is at rest and after it is moving.

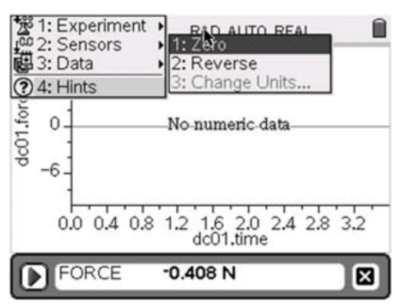
2. Sketch a prediction of the graph of force as a function of time.

Procedure:

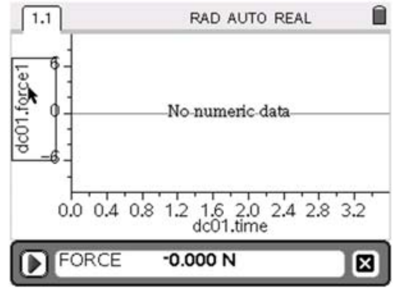
1. Open a new document on your TI-Nspire handheld.
2. Set the force probe switch to ± 10 and plug the force probe into an EasyLink. Connect the EasyLink to the USB port of the TI-Nspire. Choose to add a *Data & Statistics* page.



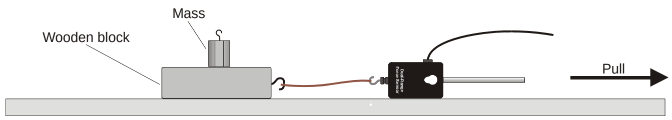
3. If the force probe does not read a force of zero, lay the force probe on the table so that no force is acting on it and press the (menu) key. To access the zero function, choose **Menu > Sensors > Zero**. The force values should now read close to zero.



4. Record the mass of your block. ____________________



5. Connect the string on the block to the hook on the force sensor. You will begin with no additional mass on the block and then add mass to the top of the block for each additional trial.



   You will pull the block by pulling on the force probe. <u>Be sure that the string is horizontal the entire time.</u> You should gradually increase the force until the block moves and then try to keep it moving at a constant speed. Click the Play button to begin collecting data. Then, pull the block.

6. If the graph is what you expect, use the tab key to close out the *Data Collection* console (box). If not, collect the data again and discard the first set of data.

7. Sketch the graph or print a copy for your lab report.

Analysis:

8. Locate the maximum static frictional force and record that value in the data table. (Move the cursor to that point and press the key.)

9. Select **MENU > Analyze > Add Moveable Line**.

10. Adjust the line to go through the horizontal section of the graph, and record the horizontal value as the tension in the string.

11. Now you will add a weight to the top of the block and repeat the process at least five more times. For the each trial, have a different person collect the data on his or her TI-Nspire. Rotate the person collecting the data each time a different mass is added to the block. Record all values in the table.

Data and Analysis (complete at least six trials):

Trial	Mass (kg)	Weight (N)	Normal (N)	Maximum Friction (N)	Tension (N)	Kinetic Friction (N)
1						
2						
3						
4						
5						
6						

Friction

1. Draw a free-body diagram for the block. Show how you used it to determine the values of the normal force and kinetic friction force.

2. Add a *Lists & Spreadsheet* page to your document. Name columns for normal, maximum friction, and kinetic friction. Enter the names in the top cell of each column. Enter the data from your table into the spreadsheet.

3. Add a *Data & Statistics* page and plot maximum friction as a function of the normal. What kind of relationship exists? Find the equation.

4. Add another *Data & Statistics* page and graph kinetic friction as a function of the normal. What kind of relationship exists? Find the equation.

5. What do you notice about the equations for Questions 3 and 4?

6. What factors do you think affect the slopes of the lines?

7. The slope of the line is called the coefficient of friction and has the symbol μ_s for static friction, which is your maximum frictional force, and μ_k for kinetic friction. Write an equation for the kinetic friction (f_k) as a function of the normal (N).

8. The static friction is written as an inequality rather than as an equation. Explain why and write the inequality for static friction (f_s) as a function of the normal (N).

9. Describe how the data would change if you dragged the block over a rough surface like sandpaper. What would happen to the coefficients of friction?

10. In this activity, you plotted friction as a function of the normal force instead of the weight, but the weight and normal are the same. Under what conditions is the normal not equal to the weight? Why do you think the friction is related to the normal instead of to the weight?

11. What factors affect the frictional force on an object?

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Friction

Physics– Teacher Notes

Activity Overview: Friction

In this activity, students use a force probe to pull a block across a table. The probe measures the tension in the string attached to the block. Students will pull with increasing force until the block begins to move and then will pull so that the block moves at a constant speed. They will analyze a graph of force versus time to find the maximum static frictional force and the force of kinetic friction. They will then add mass to the top of the block and repeat the experiment with at least five additional masses. They will record the maximum frictional force and force of kinetic friction for each trial in a data table. Students will create graphs of maximum static friction as a function of the normal and kinetic friction as a function of the normal. They will obtain these values by analyzing graphs of data.

Teacher Preparation and Notes:

- *Estimated time for activity is 50 minutes. Preliminary questions can be done ahead of time to give more time on the lab day.*
- *Students should be able to draw free-body diagrams and should understand equilibrium.*
- *Students should be working in lab groups with a maximum of 4 students per group.*
- *If computers are available, students can use the Computer Link software to print graphs for their lab reports.*

Materials:

- *TI-Nspire™ handheld technology or TI-Nspire CAS handheld technology*
- *Vernier™ EasyLink™*
- *Vernier Dual Range Force Sensor*
- *Block with a hook*
- *String*
- *Set of masses up to 500 g*
- *Balance*
- *If available, TI-Nspire Computer Link software*
- *Student worksheet Friction_Student_Physics.doc*

Suggested Related Activities (optional):

To download any activity listed, go to tiphysics.com/activities and find the activity in the list.

- *Friction and Inclined Planes*
- *Friction: Your Friend or Your Enemy?*

Friction

Preliminary Questions:

1. Describe the force needed to move a heavy box across the floor from the time the box is at rest and after it is moving.

   Answers will vary here. The idea is to get students thinking about what prior knowledge they have about friction. Hopefully, they will discuss the fact that it takes more force to get the box moving and that the force required to keep the box moving is smaller.

2. Sketch a prediction of the graph of force as a function of time.

   This is a prediction only. It should not be graded as being correct or incorrect. Making predictions prior to conducting the experiment increases a student's understanding of the concepts.

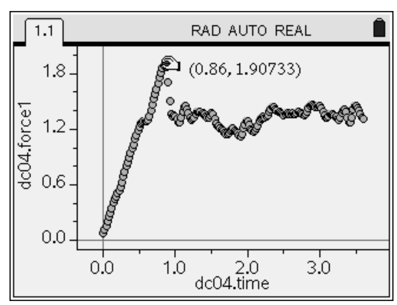
You may want to have students share their predictions and discuss them prior to conducting the lab. This will help students get good data by knowing what the graph should look like.

Procedure:

1. Be sure that students zero the probe, as instructed on the student handout.
2. Remind students that they must pull on the probe so that the string is horizontal. Students often pull at an angle without realizing it. Pulling at an angle causes the tension to be greater than the frictional force rather than equal to it.
3. Having computers available allows students to print a copy of at least one graph of friction as a function of time for their lab report.

Answers supplied use sample data:

4. Record the mass of your block. ***M* = 0.2515 kg**
5. See the sample data graph.

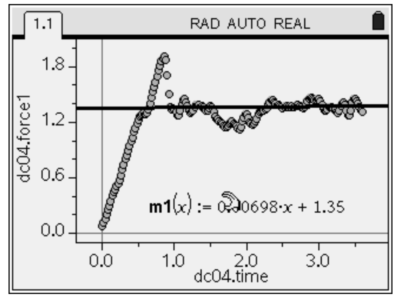


Analysis:

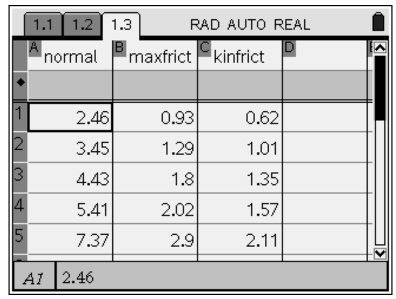
8. Locate the maximum static frictional force and record that value in the data table. (Move the cursor to that point and press the key.)
9. Select **MENU > Analyze > Add Moveable Line**.
10. Adjust the line to go through the horizontal section of the graph, and record the horizontal value as the tension in the string.

Friction

11. Now you will add a weight to the top of the block and repeat the process at least five more times.



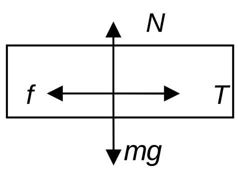
For the each trial, have a different person collect the data on his or her TI-Nspire. Rotate the person collecting the data each time a different mass is added to the block. Record all values in the table.

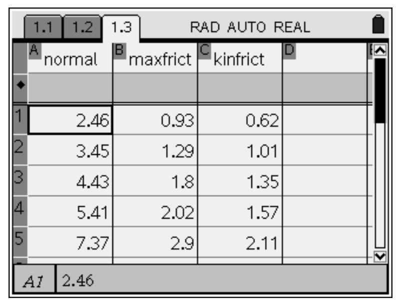


Data and Analysis:

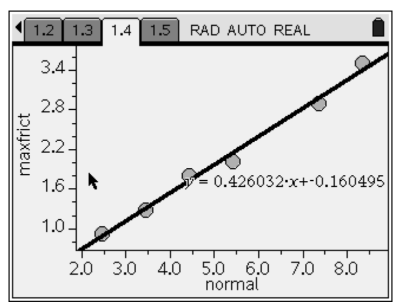
See the data table for the TI-Nspire to the right.

1. Free-body diagram:

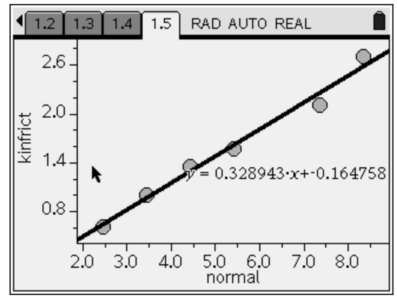




2. See spreadsheet to the right.
3. See the plot of maximum frictional force versus normal force with the linear regression.



Friction



4. See the plot of kinetic frictional force versus normal force with the linear regression.
5. Both are linear. The slope of the maximum static frictional force is greater than the slope of the kinetic frictional force.
6. The slope is affected by the surfaces between the block and the table.
7. $f_k = \mu_k N$
8. $f_s \leq \mu_s N$ because the static frictional force can be less than the maximum frictional force.
9. The slope would increase, as the surface is rougher.
10. The normal is less than the weight of the block when the block is on an incline or when it is accelerating upwards. The frictional force depends on how much weight is exerted **on a surface** (or, in other words, how much the surface pushes on the object). This is why the frictional force depends on the normal force and not the weight of the object.
11. Friction is affected by the normal and the surfaces between the surfaces.