



# Physics with TI-Nspire™ and TI-Nspire™ Navigator™ – Day 3

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# TI-Nspire™ and TI-Nspire™ Navigator™ “I Can” Statements – Day 3

## TI PROFESSIONAL DEVELOPMENT

I can...	TI-Nspire™ Handheld (HH) Data Collection (DC) TI-Nspire™ Navigator™ (Nav)
Download an activity from the Science Nspired website.	Nav
Analyze kinetic and potential energy relationships using the Energy Skate Park simulation.	Nav/HH
Design a roto-copter and use a motion detector to determine its terminal velocity.	HH
Make modifications to a design and use TI-Nspire™ to analyze its effectiveness.	HH
Collect data on the instructor computer and send it out to the class for analysis.	Nav/HH/DC
Use a TI-Nspire™ Lab Cradle with more than one sensor.	DC
Use and zero a force sensor.	DC
Use and zero an accelerometer.	DC
Create a document using the TI-Nspire™ CX Navigator™ Teacher Software.	Nav



Activity	Page #
1. Energy Skate Park	3–5
2. Roto-copter	3–19
3. What's the Mass with Newton's 2 <sup>nd</sup> Law?	3–27
4. Newton's 3 <sup>rd</sup> Law Interactive Lecture	3–33
5. Create a Science Activity	3–37
6. Discussion	3–39

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# Energy Skate Park

High School Student Activity

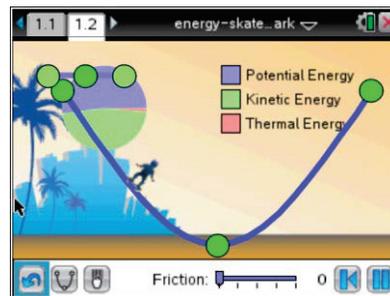


Name \_\_\_\_\_

Class \_\_\_\_\_

Open the TI-Nspire document *energy-skate-park.tns*.

In this simulation, you will observe the changing potential and kinetic energies of a skateboarder-celestial body system as she moves over a track with negligible friction. You will also explore the relationship between the system's potential and kinetic energy, and how they affect the total energy of the system. Finally, you will explore the impact of friction on these potential and kinetic energies.



Read the information on page 1.1.

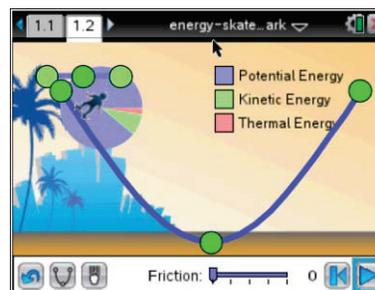
**Move to page 1.2.**

To start the simulation, select and drag the skateboarder up to the top left side of the track. Then, release him. You will see the skateboarder moving up and down along the skateboarding track on Earth. The skater's motion follows a predictable path:

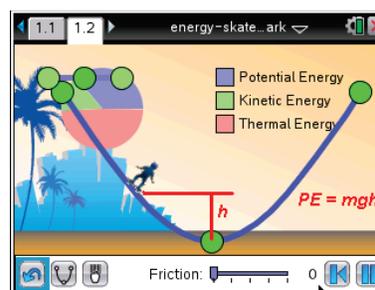
1. The skater starts from a stationary position.
2. The skater's direction of motion changes.
3. The downward motion of the skater momentarily becomes horizontal at the bottom of the skating ramp, and then changes direction in an upward direction.
4. The skater nears the top of the skating ramp on the other side, momentarily stops, then changes direction and starts moving again.
5. The downward motion of the skater momentarily becomes horizontal at the bottom of the skating ramp, and then changes direction in an upward direction.
6. The skater reaches the top of the skating ramp where he originally started, momentarily stops, then it resumes a new cycle of movement.

## Part 1: Exploring Potential Energy

1. Wait until the skateboarder reaches the top part of the ramp and select the Pause button . Your screen should now look like this. In this position the skateboarder isn't moving, but that doesn't mean the skateboarder doesn't have any energy. In fact, the skateboarder-celestial body system has **potential energy (PE)**.



Potential energy (PE) is based on the **mass ( $m$ )** of the skateboarder, the **height ( $h$ )** above the bottom of the ramp, and the **acceleration due to gravity ( $g$ )** for the celestial body he is on. The potential energy equation is  $PE = m \cdot g \cdot h$ .





# Energy Skate Park

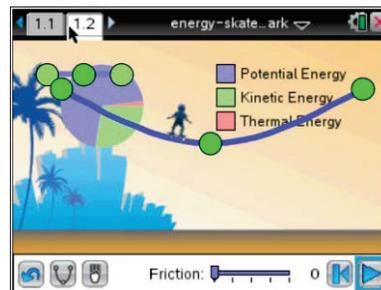
## High School Student Activity



Name \_\_\_\_\_

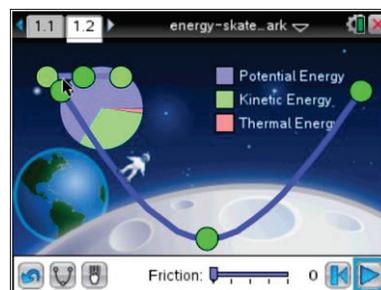
Class \_\_\_\_\_

2. Select the Play button  so the skateboarder starts moving. As the skateboarder moves, her potential energy is converted to **kinetic energy (KE)**, or the energy of motion as her position changes along the track and the velocity changes. The maximum amount of kinetic energy the skateboarder can have is entirely dependent on the amount of potential energy of the system. You saw in the equation for the PE that there are three variables, mass ( $m$ ), height ( $h$ ), and acceleration due to gravity ( $g$ ). In this simulation you can modify  $h$  and  $g$ . Grab and drag the bottom green point of the skating ramp and shorten its height to decrease the magnitude of  $h$ .



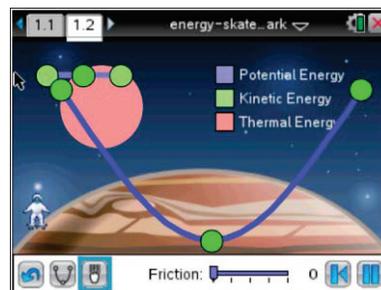
- Q1. How does shortening the height of the ramp change the potential energy of the system? How does the decreased height affect its kinetic energy? What happens when  $h = 0$ ?

3. Restore the original skating ramp by selecting the Undo button . Then start the simulation by dragging and dropping the skater at the top of the ramp. Now vary the acceleration due to gravity by changing celestial bodies for the system to see the effect on the potential energy. Select the Gravity button  once to change the force of gravity from the Earth to the Moon. The Moon has one-sixth the force of gravity of Earth, so the value of  $g$  will be different than that of the Earth.



- Q2. What happened to the skateboarder's motion when you switched from the Earth to the Moon? What does this tell you about the potential energy that skater has in the skater-Moon system? Compare the acceleration due to gravity  $g_E$  on Earth and  $g_M$  on the Moon.

4. Restore the original skater to Earth and restart the simulation. Quickly select the Gravity button  twice to change the scene from Earth to Jupiter. Jupiter's force of gravity is 2.5 times that of Earth.



- Q3. What happened to the skateboarder's motion when you switched from the Earth to Jupiter? What does this tell you about the potential energy that skater has in the skater-Jupiter system? Compare the acceleration due to gravity  $g_E$  on Earth and  $g_J$  on Jupiter.



# Energy Skate Park

## High School Student Activity

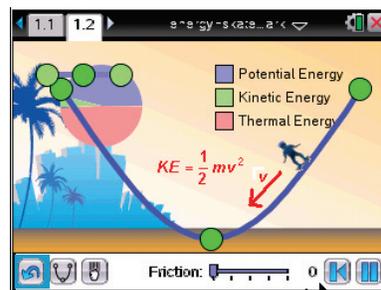


Name \_\_\_\_\_

Class \_\_\_\_\_

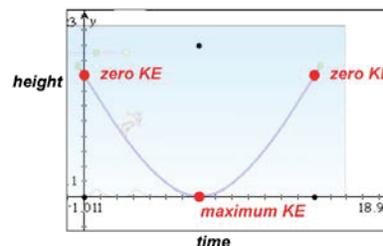
### Part 2: Exploring Kinetic Energy

5. Reset the simulation so that the ramp is in the standard shape and the acceleration due to gravity is for Earth. Start the simulation to observe the motion of the skateboarder.



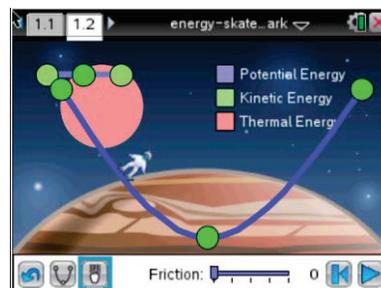
The **Kinetic Energy (KE)** of the skateboarder is based on two variables, the skateboarder's mass and her **velocity (v)**. The mass of the skateboarder doesn't change, but the speed does. This means that the KE changes, too.

6. This graph shows the changing KE for the skateboarder. At the top of the ramp, before he starts moving downward, the skateboarder has zero KE, due entirely to the fact that he is not moving. At the bottom of the ramp, the skateboarder has maximum KE because he is moving at the fastest speed.



- Q4. At the top of the ramp, where the skateboarder has zero KE, what is the potential energy of the system?
- Q5. At the bottom of the ramp, where the skateboarder has maximum KE, what is the potential energy of the system?
- Q6. At what part of the skateboarder's motion is KE converted back to PE?

7. Now change the setting from the Earth to the Moon and then to Jupiter. Note the changes to the speed in going from Earth to Moon and Earth to Jupiter.





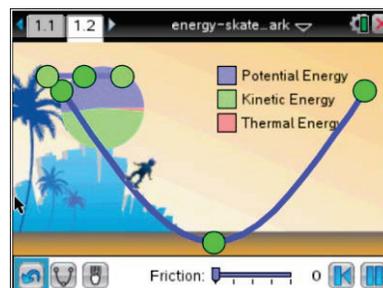
Q7. In which system is the maximum KE the greatest, the Earth, the Moon, or Jupiter?

Q8. In which system is the maximum KE the least, the Earth, the Moon, or Jupiter?

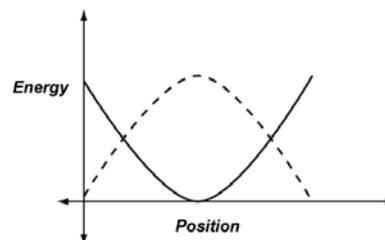
### Part 3: Exploring the Total Energy

8. You've seen how the potential and kinetic energies of the systems change for the skateboarder. The two main areas you've explored are the places where the potential energy is at a maximum and the kinetic energy is at a minimum, or the potential energy is at a minimum and the kinetic energy is at a maximum. But between these extremes are the places along the ramp where the **Total Energy (TE)** of the system is equal to the sum of the potential and kinetic energies.

$$TE = PE + KE$$



9. This graph shows the changing values for the potential energy (solid line) and the kinetic energy (dashed line) of the system. You can use this graph to find the Total Energy (TE) at any point on the ramp.



- Q9. Identify several different Position points and find the values of the corresponding Energy coordinates for both PE and KE. Use a ruler to measure the height of each Energy value. Add the two values for PE and KE to find TE. What do you notice about the TE for any positions along the curve?
10. The **law of conservation of energy** states that the total energy in a system is constant. At any point along the track, the skateboarder has varying values for PE and KE, but at all points along the ramp the sum of PE and KE is constant.
- Q10. Suppose that energy conservation didn't occur. Describe how this could affect the motion of the skateboarder.



# Energy Skate Park

## High School Student Activity

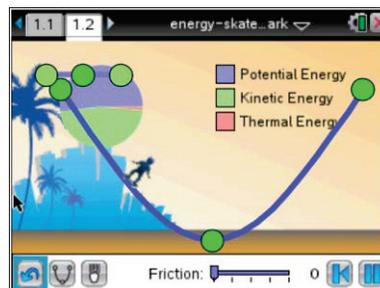


Name \_\_\_\_\_

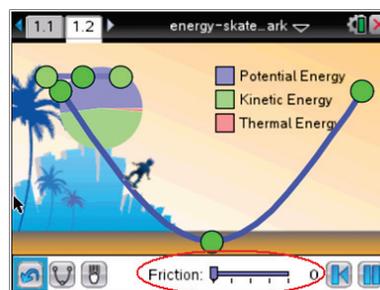
Class \_\_\_\_\_

### Part 4: Exploring the Impact of Friction

11. Restart the simulation with the standard ramp and acceleration of gravity for the Earth. You'll notice that the motion of the skateboarder goes back and forth continuously and would continue this way indefinitely. In reality, you know that a skater would eventually come to a stop because of the force of **friction** between the skateboard and the ramp. Friction is a **damping force** that, in effect, slows things down.



12. Select the slider that controls friction. It is in the bottom center of the screen. Drag the slider slowly to the right.



Q11. What happens to the motion of the skateboarder as the friction increases?

13. As the skateboarder goes down the ramp, potential energy is converted to kinetic energy. Because of friction, some of the energy in the system is converted to heat energy. Once the kinetic energy is converted to heat, the energy cannot be converted back to the potential or kinetic energy in the system.

Q12. Once the skateboarder comes to a stop due to friction, describe the energy needed to have the skateboarder resume moving up and down on the ramp.

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## Science Objectives

- Students will describe the variables that affect potential energy and kinetic energy
- Students will explore the conversion of potential energy to kinetic energy
- Students will describe the total energy as the sum of potential energy and kinetic energy
- Students will explore the effect of friction on kinetic energy and potential energy

## Vocabulary

- potential energy (PE)
- kinetic energy (KE)
- total energy (TE)
- mass
- velocity
- friction
- gravitational force
- acceleration due to gravity

## About the Lesson

- This lesson involves students simulating the motion of a skateboarder on a ramp under a number of different conditions that affect the potential and kinetic energies of the skateboarder- celestial body system.
- As a result, students will:
  - Describe the variables used to calculate potential energy;
  - Describe the variables used to calculate kinetic energy;
  - Explore conservation of energy;
  - Explore how potential energy, kinetic energy, and the energy from friction account for the total energy of the skateboarder.

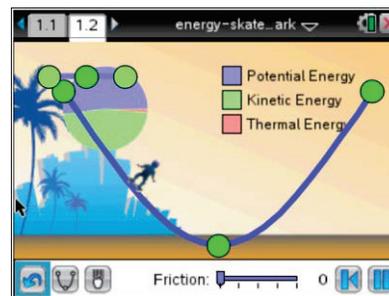


## TI-Nspire™ Navigator™

- Send out the *energy-skatepark.tns* file.
- Monitor student progress using Class Capture.
- Use Live Presenter to allow students to show how they manipulate variables that effect results.

## Activity Materials

- Compatible TI Technologies:  TI-Nspire™ CX Handhelds,  TI-Nspire™ Apps for iPad®,  TI-Nspire™ Software



## Tech Tips:

- This activity includes screen captures taken from the TI-Nspire CX handheld. It is also appropriate for use with the TI-Nspire family of products including TI-Nspire software and TI-Nspire App. Slight variations to these directions may be required if using other technologies besides the handheld.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at <http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials>

## Lesson Files:

### Student Activity

- Energy\_Skate\_Park\_Student\_HS.doc
- Energy\_Skate\_Park\_Student\_HS.pdf
- TI-Nspire document
- energy-skate-park.tns



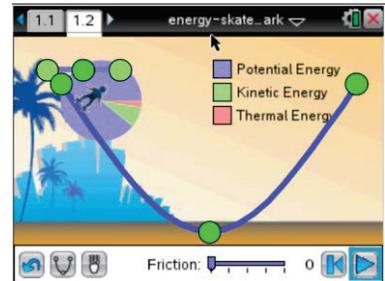
## Discussion Points and Possible Answers

Allow students to read the information on page 1.1.

Move to page 1.2.

### Part 1: Exploring Potential Energy

In this part of the lesson students explore the skateboarder's potential energy as he moves up and down the ramp. They investigate how potential energy is converted to kinetic energy.



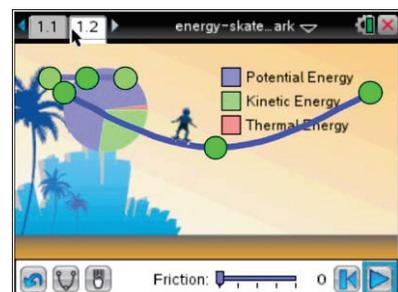
**Tech Tip:** Make sure students are familiar with the different buttons of the simulation. They can:

- select  to change the track shape
- select the Gravity button  to change the force of gravity
- select  to reset the skateboarder, press  to stop the motion of the skateboarder, press  to start the motion of the skateboarder
- select  to reset the skateboarder, track, and gravity
- grab and drag the slider  25 next to "Friction" to change the amount of friction between the skateboard and the track
- grab and drag  to change the shape of the track

1. Start the simulation with the skateboarder at the top of the ramp. Make sure the skateboarder is stationary. Reinforce that the skateboarder, even while stationary, has energy. Potential energy is based on position.

As the skateboarder moves along the ramp focus on how the potential energy changes, since the **height ( $h$ )** along the ramp changes. The change in potential energy affects the skateboarder's motion, turning the potential energy into kinetic energy.

2. To more fully explore the potential energy's dependence on the variable  $h$ , have the students vary the depth of the skateboarding ramp. Having them change the ramp to a flat line brings the skateboarder to a stop. Because potential energy is based on the value of  $h$ , in a situation in which  $h$  is zero, then the skateboarder has no potential energy when the ramp is flat. With less potential energy, there is less kinetic energy available, which affects the skateboarder's motion.

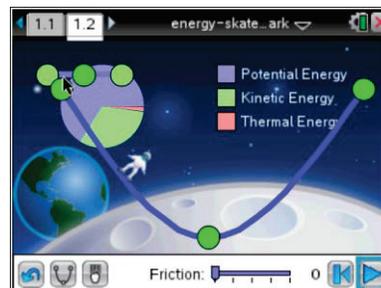




- Q1. How does shortening the height of the ramp change the potential energy of the system? How does the decreased height affect its kinetic energy? What happens when  $h = 0$ ?

**Answer:** Decreasing the value of  $h$  decreases the potential energy of the system. With less potential energy, there is less kinetic energy available to the skateboarder. When  $h = 0$ , there is no potential energy.

3. To more fully explore the potential energy's dependence on the variable  $g$ , have the students change the location of the ramp from Earth to the Moon and from Earth to Jupiter using the Gravity button . The Moon's gravity is less than Earth's, and Jupiter's gravity is greater than Earth's. Changing the value of  $g$  changes the potential energy and therefore the available kinetic energy.



- Q2. What happened to the skateboarder's motion when you switched from the Earth to the Moon? What does this tell you about the potential energy that skater has in the skater-Moon system? Compare the acceleration due to gravity  $g_E$  on Earth and  $g_M$  on the Moon.

**Answer:** The skateboarder slowed down. This means the amount of potential energy available on the Moon is less because  $g_M < g_E$ .

4. Help students see that once they quickly change to Jupiter, the skateboarder's speed increases.
- Q3. What happened to the skateboarder's motion when you switched from the Earth to Jupiter? What does this tell you about the potential energy that skater has in the skater-Jupiter system? Compare the acceleration due to gravity  $g_E$  on Earth and  $g_J$  on Jupiter.

**Answer:** The skateboarder went faster. This means the amount of potential energy available on Jupiter is more because  $g_J > g_E$ .



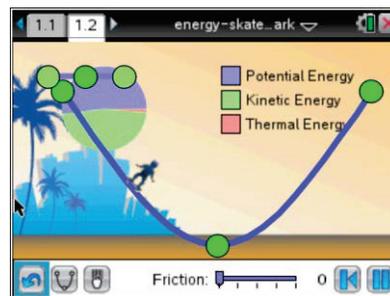
#### TI-Nspire Navigator Opportunities

Allow students to volunteer to be the Live Presenter and demonstrate how to adjust the parameters of height, gravity, and friction.

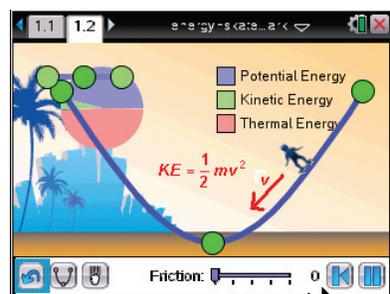


### Part 2: Exploring Kinetic Energy

In this part of the lesson students explore the skateboarder's kinetic energy as she moves up and down the ramp. They investigate how kinetic energy is converted to potential energy.



5. Reinforce that the KE for the skateboarder varies throughout the trip back and forth along the ramp. In fact, the KE cycles through values ranging from zero to a maximum and back to zero. Also, because the amount of KE is dependent on the amount of PE, changing gravitational acceleration from the Earth to the Moon and to Jupiter has a marked effect on the skateboarder's speed.



6. Ensure students understand the variables shown in the diagram and discuss various points along the curve.

- Q4. At the top of the ramp, where the skateboarder has zero KE, what is the potential energy of the system?

**Answer:** The skateboarder has maximum PE.

- Q5. At the bottom of the ramp, where the skateboarder has maximum KE, what is the potential energy of the system?

**Answer:** The skateboarder has zero PE.

- Q6. At what part of the skateboarder's motion is KE converted back to PE?

**Answer:** As the skateboarder is moving from the bottom of the ramp to the top, the KE is converted to PE, as the skateboarder begins to slow down and come to a momentary stop at the top of the ramp.

- Q7. In which system is the maximum KE the greatest, the Earth, the Moon, or Jupiter?

**Answer:** Because Jupiter has the greatest acceleration due to gravity,  $g$ , then the skateboarder has the greatest KE on this planet.

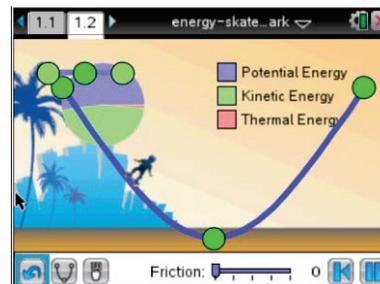


Q8. In which system is the maximum KE the least, the Earth, the Moon, or Jupiter?

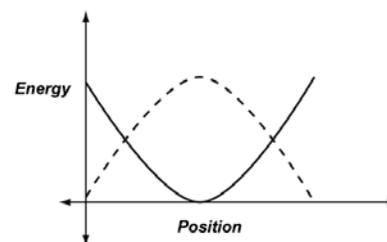
**Answer:** Because the Moon has the least acceleration due to gravity,  $g$ , then the skateboarder has the least KE on the Moon.

### Part 3: Exploring the Total Energy

8. In this part of the lesson students explore the total energy of the system and that this encompasses the sum of the KE and PE. In fact, because of the law of conservation of energy, the sum of KE and PE is constant throughout the skateboarders trek along the ramp.



9. Have students take a number of measurements of the values of KE and PE using a ruler. Have students add these measurements. Gather data for different measurements and among different groups of students. Show that the values are consistently close to each other, and barring slight measurement errors, the sums of PE and KE are constant.



Q9. Identify several different Position points and find the values of the corresponding Energy coordinates for both PE and KE. Use a ruler to measure the height of each Energy value. Add the two values for PE and KE to find TE. What do you notice about the TE for any positions along the curve?

**Answer:** The sum of PE and KE are about the same for different positions along the ramp.

10. Discuss the included diagram and have students explain the relationship between PE, KE and skateboarder's location on the ramp.

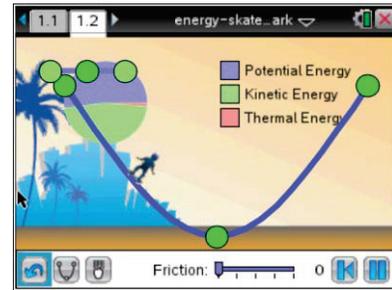
Q10. Suppose that energy conservation didn't occur. Describe how this could affect the motion of the skateboarder.

**Answer:** If the skateboarder's total energy was not constant, then the motion of the skateboarder would be unpredictable, and not the steady back and forth shown in the simulation.

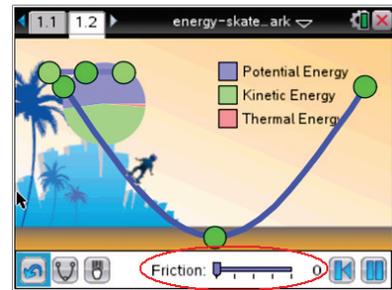


#### Part 4: Exploring the Impact of Friction

11. In this part of the lesson students see the effect of friction on the skateboarder's motion. While the total energy of the system is constant, the energy from friction cannot be converted back to KE or PE.



12. In the frictionless scenario, students saw that PE is converted to KE and KE is converted to PE, as the motion of the skateboarder is like a pendulum swinging back forth. Friction changes this scenario. PE is converted to KE and some of the KE is converted to heat energy due to friction. This heat energy is lost to the system and cannot be converted to PE or KE. Eventually, the skateboarder comes to a stop. But even in this scenario, the total energy is conserved.



Q11. What happens to the motion of the skateboarder as the friction increases?

**Answer:** Eventually, the skateboarder comes to a stop.

13. Discuss the included diagram and have students explain the relationship between PE, KE and skateboarder's location on the ramp.

Q12. Once the skateboarder comes to a stop due to friction, describe the energy needed to have the skateboarder resume moving up and down on the ramp.

**Answer:** Once the skateboarder stops, she is at the bottom of the ramp. To get her moving again, a new source of KE is needed to move the skateboarder back to the top of the ramp, where she will once again have maximum PE.



#### TI-Nspire Navigator Opportunities

Allow students to volunteer to be the Live Presenter and demonstrate how to adjust the parameters of height, celestial body, and friction. Use Quick Poll to check for understanding during the course of the activity.



## Wrap Up

When students are finished with activity, collect students' worksheets.

## Assessment

- Formative assessment will consist of questions embedded in the student worksheet. Analyze questions in the student worksheet with the students.
- Summative assessment will consist of questions/problems on the chapter test.
- In groups, have students construct another example of where PE is converted to KE and back. Some examples could include a ball rolling off a table and bouncing, bungee jumping, or a yo-yo.

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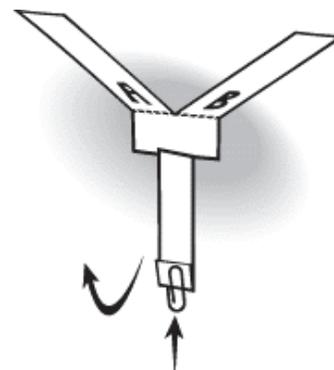
## Roto-copter Student Activity

Name \_\_\_\_\_

Class \_\_\_\_\_

### Activity Overview

In this activity, you will explore the motion of a roto-copter using a CBR 2™ motion sensor. After determining the terminal velocity from a position-versus-time graph, you will explore how the design of the roto-copter can be reengineered to minimize its terminal velocity.

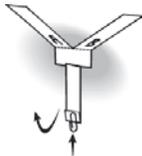


### Materials

- CBR 2™ motion sensor
- Scissors
- Paper clips
- Tape

- Use the roto-copter template to cut out the roto-copter and attach the paperclip. Drop the roto-copter and watch its motion. Make a sketch of the roto-copter along with the forces acting on the roto-copter as it falls.

Individually, predict the graph of position versus time if the roto-copter is dropped over a CBR 2. Make a sketch and compare it with the graphs of your partners.

Prediction of the position graph	Draw the forces acting on the roto-copter
	

- Connect the CBR 2 to the TI-Nspire™ handheld and place it on the floor. Collect data as you drop the roto-copter toward the CBR2. How does the graph compare with your prediction? What does the shape of the position graph indicate about the motion of the roto-copter?
- The roto-copter reaches terminal velocity quickly. Use the position-versus-time graph to determine the terminal velocity of the roto-copter. Select the region of the graph where the roto-copter has a constant velocity by clicking on the left side of the region and dragging the cursor with double arrows across to the right edge of the region you want to analyze. **Select Menu > Data > Strike Data > Outside Selected Region.** The remaining section shows the constant terminal velocity.
- From the Analyze Menu, find the equation of the linear data using the Model feature. To use the model feature, choose the default  $mx+b$  and enter values for  $m$  and  $b$  that make sense for your data. These values can be adjusted using the arrows on the left side of the screen or by clicking on the number value and typing a new value. Record the equation that best fits the data.

You may want to also calculate the linear regression for the data using the Analyze menu and selecting Curve Fit rather than Model. Compare this equation with the model that you developed.



## Roto-copter Student Activity

Name \_\_\_\_\_

Class \_\_\_\_\_

- 
5. How can you use the equation to determine the terminal velocity of the roto-copter?  
Explain your reasoning clearly. Record your terminal velocity.
  
  6. What factors affect how the roto-copter falls? Make a list.
  
  7. Team Competition: Work with your team to design a roto-copter with the lowest terminal velocity.  
Write a paragraph to explain the reasoning for modifications that you make. Include a sketch.
  
  8. Each team will now drop their roto-copter and calculate the new terminal velocity. Make a presentation to show your terminal velocity and evidence of the terminal velocity. The team with the lowest terminal velocity wins the competition.
  
  9. State Newton's 1<sup>st</sup> and 2<sup>nd</sup> Laws of Motion and describe how they apply in this activity.



# Roto-copter

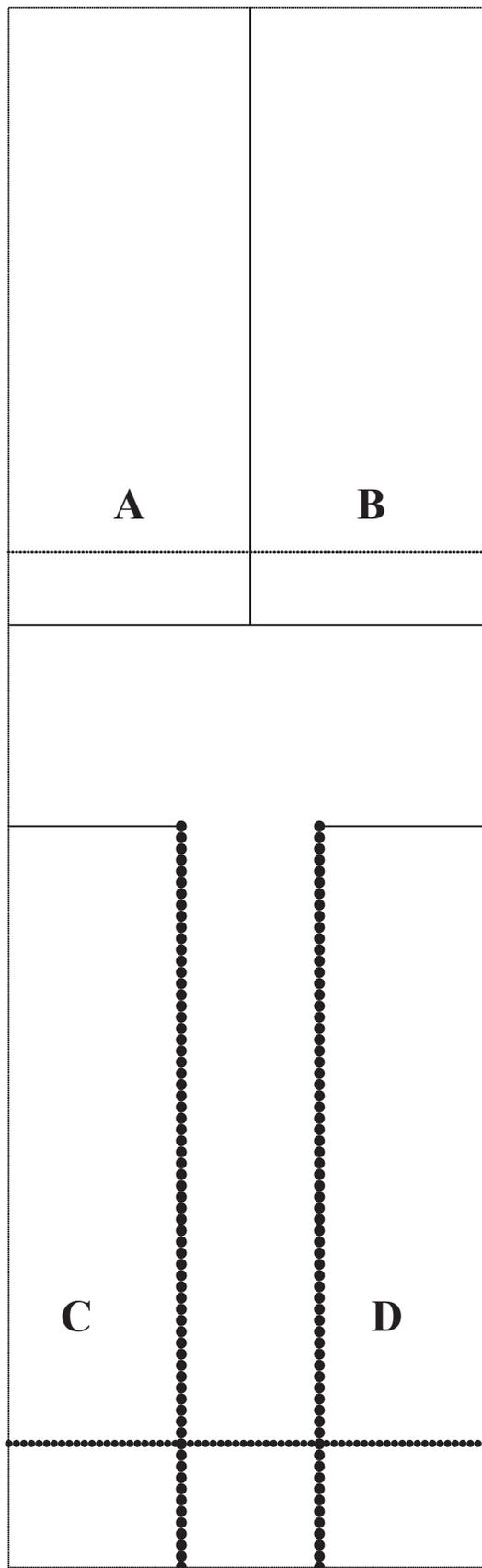
## Student Activity

Name \_\_\_\_\_

Class \_\_\_\_\_

The template for the roto-copter is shown to the right.

1. Cut along the solid lines and fold along the dotted lines.
2. Fold parts C and D over each other to overlap.
3. Fold the bottom up and put a paperclip on it to hold the roto-copter together.
4. Hold the roto-copter from the paperclip when you drop it over the CBR 2.

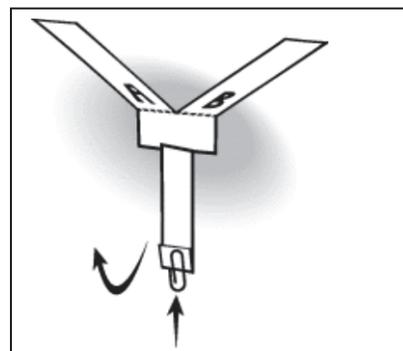


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## Science and Engineering Objectives

- Students will use a roto-copter with a CBR 2™ motion sensor to calculate terminal velocity
- Students will analyze the forces on the roto-copter and apply Newton's Laws of Motion
- Students will calculate the slope of a position-versus-time graph to calculate the terminal velocity of the roto-copter.
- Students will modify their original roto-copter to decrease the terminal velocity.



## Vocabulary

- velocity
- terminal velocity
- net force

## About the Lesson

- This lesson has students create a roto-copter from a template and calculate its terminal velocity.
- Students will apply Newton's 1<sup>st</sup> and 2<sup>nd</sup> Laws of Motion.
- Once the students calculate the terminal velocity for the roto-copter, they will engineer their own roto-copter, making adjustments to the template. They can make changes to length, mass, width of wings, etc with the goal being to have the smallest terminal velocity. Students will compete with other students/teams to engineer a roto-copter with the smallest terminal velocity as measured with the CBR 2™.

## TI-Nspire™ Navigator™ System

- Use the TI-Nspire Navigator System to show student graphs and find the slope of the position-versus-time graph to calculate the terminal velocity.
- Students can display their graphs and calculations in the competition using the TI-Nspire Navigator System.

## Activity Materials

- CBR 2™ motion sensor
- Paper clips
- Scissors
- Tape
- Various types of paper
- Prizes for winners if desired

### TI-Nspire™ Technology Skills:

- Use the Vernier DataQuest™ Application
- Collect data for position and time with a CBR 2™
- Calculate the velocity of a position versus time graph by modeling and by linear regression.

### Tech Tips:

- Change the default screen with two graphs to only one graph of position versus time.

### Lesson Files:

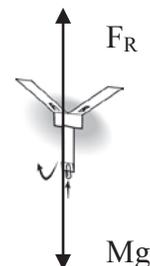
#### Student Activity

- Roto-copter\_Student.pdf
- Roto-copter\_Student.doc



## Discussion Points and Possible Answers

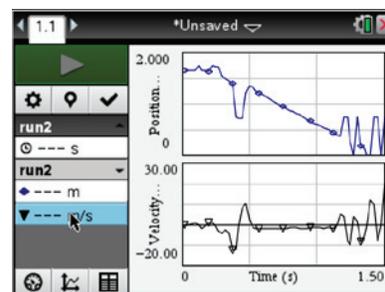
1. Use the roto-copter template to cut out the roto-copter and attach the paperclip. Drop the roto-copter and watch its motion. Make a sketch of the roto-copter along with the forces acting on the roto-copter as it falls. Individually, predict the graph of position versus time if the roto-copter is dropped over a CBR2™. Make a sketch and compare it with the graphs of your partners.



**Answer:** Sketches of predictions will vary and should not be marked as incorrect. Since the roto-copter is approaching the CBR 2, the graph should be linear with a negative slope like the graph shown to the right.

The free body diagram of the forces is shown to the right.  $F_R$  is the resistive force due to air resistance and can be labeled with a variety of names but should be directed upward.  $Mg$  is the weight of the roto-copter and must be directed downward.

2. Connect the CBR 2 to the TI-Nspire™ handheld and place it on the floor. Collect data as you drop the roto-copter over the CBR 2. How does the graph compare with your prediction? What does the shape of the position graph indicate about the motion of the roto-copter?



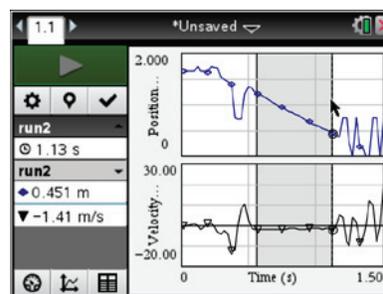
**Answer:** See the sample graph to the right.

**Tech Tip:** Students might need to try a few times to get a good data set and might see a spike where the motion detector missed the roto-copter due to the spinning. Decreasing the time to 1 or 2 seconds should help students to see the section of constant velocity a little easier.

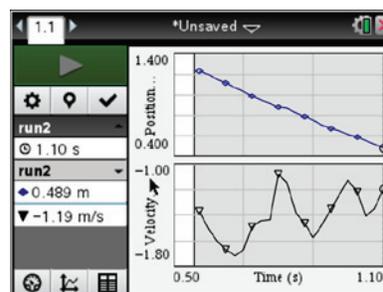
**Tech Tip:** Using the Model feature for analysis allows student to enter values that make sense with the data. This forces students to analyze the data and find an equation rather than just run a regression. The Model feature also allows a student to overlook a spike and discount it, which the regression feature will not do. The regression can be used after the model is found to compare.



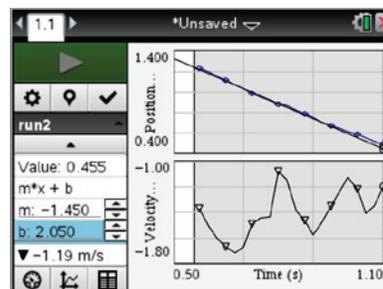
3. The roto-copter reaches terminal velocity quickly. Use the position-versus-time graph to determine the terminal velocity of the roto-copter. Select the region of the graph where the roto-copter has a constant velocity by clicking on the left side of the region and dragging the cursor with double arrows across to the right edge of the region you want to analyze. Press Menu→2:Data→5: Strike Data→2: Outside Selected Region. The remaining section shows the constant terminal velocity.



**Answer:** The student should select the data as shown above and then strike the data to obtain a graph like the one shown to the right. Students may keep both graphs on the screen or change to show graph 1 only.



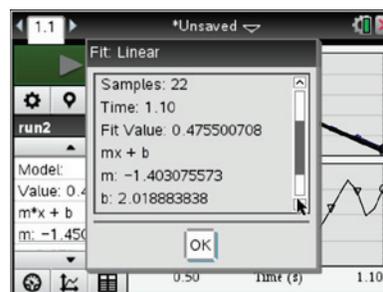
4. From the Analyze menu, find the equation of the linear data using the Model feature. To use the Model feature, choose the default  $mx+b$  and enter values for  $m$  and  $b$  that make sense for your data. These values can be adjusted using the arrows on the left side of the screen or by clicking on the number value and typing a new value. Record the equation that best fits the data.



**Answer:** The equation for the sample data is  $y = -1.45x + 2.05$  from the model.

You may want to also calculate the linear regression for the data using the Analyze menu and selecting Curve Fit rather than Model. Compare this equation with the model that you developed.

**Answer:** The regression equation for the sample data is displayed to the right. Arrow down to see the regression values.



5. How can you use the equation to determine the terminal velocity of the roto-copter? Explain your reasoning clearly. Record your terminal velocity.

**Answer:** The slope is the terminal velocity. For the sample data, the terminal velocity is  $-1.4$  m/s.



6. What factors affect how the roto-copter falls? Make a list.

**Answer:** The answers will vary, but could include: the mass of the paperclip, the length or width of the propellers, the overall mass of the roto-copter, the length of the body, the shape of the propellers, etc.

7. Team Competition: Work with your team to design a roto-copter with the lowest terminal velocity. Write a paragraph to explain the reasoning for modifications that you make. Include a sketch.

**Answer:** The answers will vary. They should include a sketch and well written paragraph with complete sentences to describe the changes that the group made.

8. Each team will now drop their roto-copter and calculate the new terminal velocity. Make a presentation to show your terminal velocity and evidence of the terminal velocity. The team with the lowest terminal velocity wins the competition.

9. State Newton's 1<sup>st</sup> and 2<sup>nd</sup> Laws of Motion and describe how they apply in this activity.

**Answer:** Newton's 1<sup>st</sup> Law states that an object at rest or moving at constant velocity will remain at rest or moving at constant velocity unless acted upon by an unbalanced force. Newton's 2<sup>nd</sup> Law states that the net force acting upon an object produces an acceleration and the force and acceleration are directly proportional if the mass is held constant. Often, the 2<sup>nd</sup> Law is summarized with an equation  $\Sigma F = ma$ , where  $\Sigma F$  represents the net force acting on the object,  $m$  represents mass, and  $a$  represents acceleration. In this activity, the weight or force due to gravity is the only force at the start so the object accelerates according to Newton's 2<sup>nd</sup> Law. The air resistance force increases with velocity and quickly becomes equal to the weight but directed upward. The net force now becomes zero and the roto-copter now moves with constant velocity as indicated in Newton's 1<sup>st</sup> Law. This constant velocity is referred to as terminal velocity.

**TI-Nspire Navigator Opportunity:** Students can use the TI-Nspire Navigator System to show their data and explain their reasoning.

## Wrap Up

Discussion of how forces affect the roto-copter's motion and what factors affected a design of a roto-copter with a lower terminal velocity.

## Assessment

Equations and competition are the assessment in this activity along with the ability to justify from evidence.



# What's the Mass with Newton's 2<sup>nd</sup> Law?

Name \_\_\_\_\_

Student Activity



Class \_\_\_\_\_

---

## Activity Overview

*This activity will introduce the Dual-Range Force Sensor, an accelerometer, and TI-Nspire™ Lab Cradle with the Vernier DataQuest™ application. You will analyze data that has been collected by your teacher.*

---

## Background Information

Newton's 2<sup>nd</sup> Law states that:

*The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object.*

---

**Q1:** What two variables were tested and collected by your teacher during the experiment? Make a prediction of what the graph would like when you graph those variables together. Determine which variable to put on the y-axis and x-axis.

### Step 1:

When you receive the document press **Open**. The document should open with the stored data that was collected by your teacher.

### Step 2:

Once you have opened the document, insert a Data & Statistics page by pressing  and selecting **Insert > Data & Statistics**.

**Q2:** What do you notice about the data after you enter the Data & Statistics page?

### Step 3:

In order to organize the data, hover over the box on the y-axis. It should bring up some options. What variable needs to be graphed on the y-axis? Why?

### Step 4:

Now you need to assign a variable to the x-axis. Repeat the same procedure in Step 3 to do so. Which variable did you assign on the x-axis and why?

**What's the Mass with Newton's 2<sup>nd</sup> Law?**

Name \_\_\_\_\_

**Student Activity**

Class \_\_\_\_\_

**Q3:** Now that your data is organized, what type of relationship does it represent? How does this graph compare to your prediction?

**Q4:** Run a regression on your data by selecting **Menu > Analyze > Regression**.

Write down the regression equation: \_\_\_\_\_

What does the slope of your line represent?

**Q5:** Write a general equation that represents the relationship between force, acceleration and mass. Which of Newton's Laws does this relationship model?

**Step 5:**

Obtain the actual mass of the system that was used from your teacher. Record that mass below.

Actual Mass of System \_\_\_\_\_

**Q6:** How does the actual mass of the system compare to the experimental value obtained during the experiment?

**Q7:** Calculate the relative error by subtracting the *Actual mass of System* from the *experimental mass*.

**Q8:** Calculate the percent error by taking the Relative Error and dividing by the actual mass of system, multiply by 100%. What does the error value tell you about the experiment? What factors can contribute to the error in the experiment?

**Discussions/Explorations**

Write a summary of what you learned in this activity. Use at least two complete sentences.



# What's the Mass with Newton's 2<sup>nd</sup> Law?

## TEACHER NOTES

TI PROFESSIONAL DEVELOPMENT



### Math and Science Objectives

- Students will graph the relationship between force and acceleration.
- Students will run a regression to determine the relationship between force and acceleration.

### Vocabulary

- force
- mass
- acceleration
- relative error
- percent error
- slope

### About the Lesson

- This lesson involves the teacher collecting a set of data as the Live Presenter and sending it out to students to analyze.
- As a result, students will:
  - Insert a data and statistics page and graph the data.
  - Run a regression.
  - Determine the mass of the system.
  - Calculate percent error.



### TI-Nspire™ Navigator™

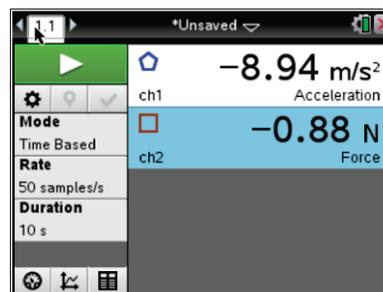
- Use the TI-Nspire™ Navigator System to send out the data.
- Use the Class Capture feature to monitor student progress and check for understanding.

### Activity Materials

Compatible TI Technologies:  TI-Nspire™ CX Handhelds,

TI-Nspire™ Software.

- Dual-Range Force Sensor
- TI-Nspire™ Lab Cradle
- Low-g Accelerometer
- Electronic scale or balance.



### Tech Tips:

- This activity includes screen captures from the TI-Nspire CX handheld. It is also appropriate for use with the TI-Nspire family of products including TI-Nspire software. Slight variations to these directions may be required if using other technologies besides the handheld.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at <http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials>



## Introduction

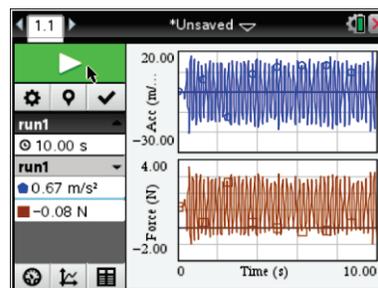
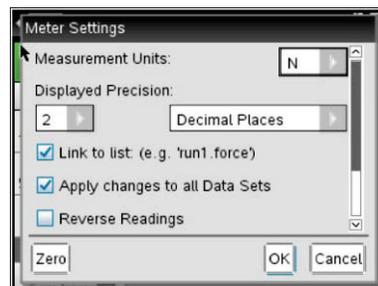
Before you begin the activity, show the class what the sensors look like while taped together. Show students how you will conduct the experiment and asks them to make a prediction as instructed on their lab sheets. This prediction step is important in helping students to connect the ideas and enhance conceptual understanding.

## Data Collection

1. Open the TI-Nspire™ CX Navigator™ Teacher Software and connect the TI-Nspire™ Lab Cradle to the computer using the standard-A to mini-B USB connection cable.
2. With masking tape, secure the accelerometer to the force probe. Make sure the arrow is pointing opposite the hook or downward.
3. Set the force probe to 10 N.
4. Measure the mass of the accelerometer and force probe together. Do not include the cables. This will cause for a large amount of error in the results.
5. Plug both sensors into the TI-Nspire™ Lab Cradle. The Vernier DataQuest™ application should automatically open up and detect both sensors.
6. Zero both sensors. Stand them on end with the hook pointing upward on the force sensor, the accelerometer arrow should be pointing down. In order to zero, click on the meter itself and a menu should show up. Click zero at the bottom of the page. Do this for both sensors.
7. To begin collecting data, click the green **Start Collection**  arrow in the upper-left corner of the screen, or press **Tab** until the start arrow is highlighted and press **Enter**.
8. Holding the hook between your fingers, shake the force probe gently for the entire run time.
9. Once you have collected the data, send the data set out to all the students using the TI-Nspire™ CX Navigator™ System.



**Tech Tip:** Make sure students are logged in ahead of time before starting the experiment.





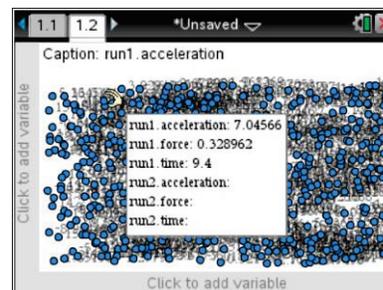
## Student Questions and Answers

**Q1.** What two variables were tested and collected by your teacher during the experiment? Make a prediction of what the graph would like when you graph those variables together. Determine which variable to put on the y-axis and x-axis.

**Answer:** Student answers will vary because this is a prediction

**Q2:** What do you notice about the data after you enter the Data & Statistics page?

**Answer:** Students should notice that there is NO organization to the data. They may even notice that theirs looks different from their neighbors.

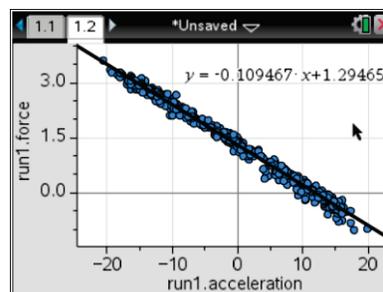


**Teacher Tip:** Use the Live Presenter feature of the TI-Nspire™ Navigator™ System to show how they all are different

Students will have the discussion about what variable to graph on the x-axis and y-axis. You can guide them if you like or let them choose. This opens the discussion for which answer is better later in the activity. Essentially, if they graph force on the y-axis and acceleration on the x-axis, their results make more sense.

**Q3:** Now that your data is organized, what type of relationship does it represent? How does this graph compare to your prediction?

**Answer:** Students should notice that the relationship tends to be linear when organized.



**Q4:** What does the slope of your line represent?

**Answer:** The slope of the line represents the mass of the system. If they graphed the acceleration on the y-axis and force on the x-axis, they will get the inverse of the mass.

**Q5:** Write a general equation that represents the relationship between force, acceleration and mass. Which of Newton's Laws does the relationship model?

**Answer:**  $F = m \cdot a$



**Q6:** How does the actual mass of the system compare to the experimental value obtained during the experiment?

**Answer:** They should be comparable.

**Q7:** Calculate the relative error by subtracting the *Actual mass of System* from the *experimental mass*.

**Answer:** Answers will vary.

**Q8:** Calculate the percent error by taking the Relative Error and dividing by the actual mass of system, multiply by 100%. What does the error value tell you about the experiment? What factors can contribute to the error in the experiment?

**Answer:** The percent should be small. Discussion can lead to how hard you shake the device, cables getting in the way when measuring the mass of the system, etc...

### Discussions/Explorations

Write a summary of what you learned in this activity. Use at least two complete sentences.

**Answer:** Answers will vary. It is important to encourage students to explain their thinking using complete sentences.

### Wrap Up

- You can have students add a model line to see if their results change. If so, this opens up the discussion of “why.” Which is better, a regression or model line?

# Newton's 3<sup>rd</sup> Law Interactive Lecture

## TEACHER NOTES

TI PROFESSIONAL DEVELOPMENT



### Science Objectives

- Understand graphically the representation of Newton's 3<sup>rd</sup> Law.
- Analyze and interpret data (NGSS).
- Engage in argument from evidence (NGSS).

### Vocabulary

- force

### About the Lesson

- This lesson is an interactive lecture demonstration. Students will make predictions and discuss them with their group and the class. The teacher or a group of students will perform the demonstration for the class and students will draw a conclusion.
- As a result, students will:
  - State Newton's 3<sup>rd</sup> Law of equal and opposite forces.
  - Describe the relationship of Newton's 3<sup>rd</sup> Law graphically.



### TI-Nspire™ Navigator™

- Use the TI-Nspire™ CX Navigator™ Teacher Software to conduct the demonstration.

### Activity Materials

Compatible TI Technologies :  TI-Nspire™ CX Handhelds,



TI-Nspire™ Software

- 2 Dual-Range Force sensors
- TI-Nspire™ Lab Cradle
- String



### Tech Tips:

- This activity includes screen captures from the TI-Nspire CX handheld. It is also appropriate for use with the TI-Nspire family of products including TI-Nspire software. Slight variations to these directions may be required if using other technologies besides the handheld.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at <http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials>

### Lesson Files:

#### Student Activity

- Newton's\_3<sup>rd</sup>\_Law\_Teacher.pdf
- Newton's\_3<sup>rd</sup>\_Law\_Teacher.doc

#### TI-Nspire document

- Newtons\_3<sup>rd</sup>\_Law.tns



## Discussion Points and Possible Answers

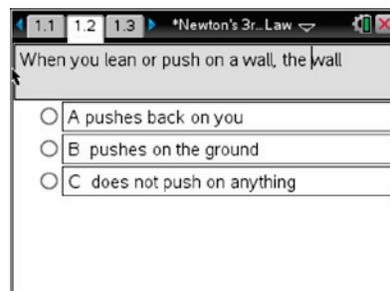


**Tech Tip:** This activity is designed as an interactive lecture demonstration and presented through the teacher computer with software. The activity can also be done as a student activity. Data can also be collected from the student handhelds using Live Presenter for the class.

### Move to page 1.2

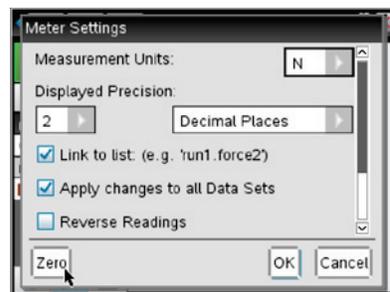
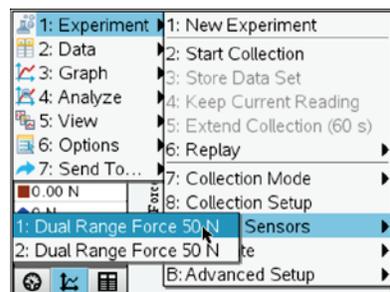
Begin the lesson with a quick poll included in the document.

**Answer:** No correct answer should be given yet. This is a question to get students thinking. They should be able to correctly answer the question at the end of the activity.



1. Set the range switches of the Dual-Range Force Sensors to 50 N. Connect the two force sensors to the TI-Nspire™ Lab Cradle.

2. Zero the forces sensors. Set the sensors horizontally on the table with no force acting on them. Select **Menu > Experiment > Set up Sensors > Zero**. You must do this for both sensors.



# Newton's 3<sup>rd</sup> Law Interactive Lecture

## TEACHER NOTES

TI PROFESSIONAL DEVELOPMENT

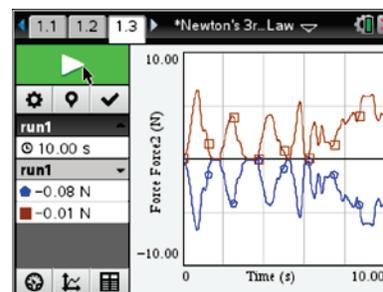


3. Create a loop of string and use it to connect the two force sensors. Pull horizontally on one sensor while holding the other sensor. Vary the force as you collect the data for the class. You may want to repeat in various ways, having the other object pull, etc. See a sample graph to the right.



**Teacher Tip:** (Optional) Because you will be comparing the readings of two different force sensors, it is important that they both read force accurately.

To increase the accuracy of the sensors, you may want to calibrate them. This is only necessary if the forces do not appear equal and opposite when you perform the demonstration. See the Vernier website if you want to learn to calibrate a sensor.



4. Ask the class to discuss the resulting graph showing the force on each sensor. What does this mean?

**Answer:** Develop the idea that if one object pulls on an object, the other object exerts an equal and opposite force on it. Newton's 3<sup>rd</sup> Law states, "If Object A exerts a force on Object B, Object B exerts an equal and opposite force on Object A."

### Assessment

Go back and send the Quick Poll from the beginning of the activity to see if students change their responses. Discuss the correct answer A.



TI-Nspire™ Navigator™

This activity uses the TI-Nspire™ Navigator System as a tool to demonstrate an idea and make a lecture interactive. This process can also be utilized in classrooms where the teacher may have only a few sensors. Data can be collected and sent to the class if desired.

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## About the Activity

- You have seen a number of sources for TI-Nspire™ activities. To allow you to make the most relevant use of the remainder of this workshop, you will have time to explore activities that are of particular interest to you for your classroom use.
- Some activities are contained in your workshop binder, some are available online through the Teacher Software, or you might have found something on your own that you would like to explore. You will share your findings with the whole group.

### Sources for Activity Materials:

- Workshop binder
- TI-Nspire™ Teacher Software content links

## TI-Nspire™ Navigator™ System

If you want, you can use the TI-Nspire™ Navigator™ System to practice enhancing your activity presentation, engage your fellow participants, and share any TI-Nspire documents you found useful. The T<sup>3</sup>™ Instructor will be happy to help you with the system.

## Discussion Points

Please work through an activity or two in the time provided. While completing the activity, consider:

- How does it add new TI-Nspire skills to your repertoire?
- What are some pedagogical implications of the activity and its technology use?
- What is the content relevance?
- How might it engage and motivate your students?
- You are encouraged to work in small groups and discuss as you go.
- Each group will give a short presentation on an activity and the results of the discussions surrounding it.

**Tech Tip:** Try using any TI-Nspire documents on both the TI-Nspire Teacher Software and the TI-Nspire handheld. Transfer any documents from one to the other and back again.

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**T3 Ticket Outta Here**

I have learned ...

My question is ...

My next steps are ...

**T3 Ticket Outta Here**

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