



Exploring Middle Grades Science through Engineering Design with the TI-Innovator™ Hub

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Exploring Middle Grades Science through Engineering Design with the TI-Innovator™ Hub

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Introduction to the TI-Innovator™ System

TI PROFESSIONAL DEVELOPMENT

Participants will receive an overview of the TI-Innovator System.

Step 1: Overview of the TI-Innovator™ Hub's features

- Inputs and outputs
- On-Board sensors
- Data Port (Micro USB Port)
- Power
- LED Indicators



Step 2: Distinguishing the difference between inputs and outputs

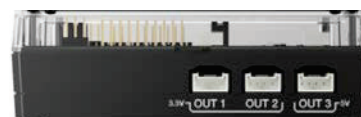
Left side - Three ports for collecting data or status from input modules:

- IN 1 and IN 2 provide 3.3 V of power
- IN 3 provides 5 V of power







Right side – 3 ports for controlling output modules:

- OUT 1 and OUT 2 provide 3.3 V of power
- OUT 3 provides 5 V of power



Sample sensors include:

Servo Motor	Output Device	
White LED	Output Device	
Vibration Motor	Output Device	
Analog Light Sensor	Input Device	

Introduction to the TI-Innovator™ System

TI PROFESSIONAL DEVELOPMENT

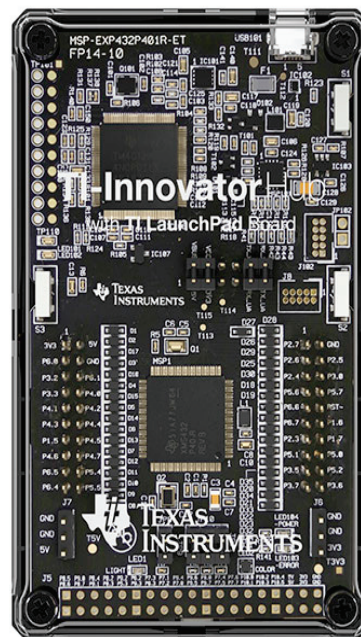
Step 3: Cables

1. USB Unit-to-Unit (Mini-A to Mini-B) - Connects the Hub to a TI-84 Plus CE Graphing Calculator or a TI-Nspire™ CX Handheld.
2. USB Standard A to Mini-B - Connects the Hub to a computer running TI-Nspire™ CX Software.
3. USB Standard A to Micro - Connects the **PWR** port of the Hub to a TI approved power source required by some peripherals.



Step 4: On-Board components and indicators

1. A Light Brightness Sensor at the bottom of the Hub can be read as "BRIGHTNESS" in Hub command strings.
2. Red LED is addressable as "LIGHT" in Hub command strings.
3. Speaker (at back of Hub, not shown) labeled as SOUND is addressable as "SOUND" in Hub command strings.
4. Red-Green-Blue LED is addressable as "COLOR" in Hub command strings.
5. I²C port connects to peripherals that use the I²C communication protocol.
6. DATA Mini-B port, used with the appropriate cable, connects to a compatible graphing calculator or computer for data and power.
7. USB-Micro connector (PWR) for auxiliary power required by some components. Also used for updating the Hub internal software.
8. Breadboard Connector with 20 labeled pins for communication with connected components. A breadboard and jumper cables are included with the TI-Innovator™ Breadboard Pack, sold separately.





Vocabulary and Useful Terms for the TI-Innovator

TI-Innovator System: The power supply, cables, sensors, TI-Innovator Hub, and all components.

TI-Innovator Hub: The main box “Hub” for the TI-Innovator System.

LED: Light emitting diode.

Servo Motor: A motor that rotates or pushes part of a machine with a high level of precision.

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







A Brief Introduction to the TI-Nspire™ CX Handheld

TI PROFESSIONAL DEVELOPMENT

Activity Overview


This activity provides a brief overview of the handheld and the Calculator and Graphs applications.

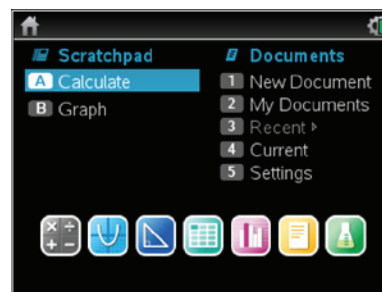
Key Name	Function
 Click Key	Selects an object on the screen. <code>ctrl</code> +  grabs an object on the screen.
 Touchpad	Press the arrow keys or swipe on the Touchpad to move the cursor/pointer.
 Escape Key	Removes menus or dialog boxes from the screen.
 Scratch Pad	Provides a temporary application (Calculator or Graphs).
 Tab Key	Moves to the next entry field.
The Big Three	
 Home Key	Displays the Home screen.
 Document Key	Controls document structure.
 Menu Key	Displays an application menu. (Press <code>ctrl</code> <code>menu</code> (“right click”) to display a context menu.)



The Document Model

The TI-Nspire™ handheld is “document based and menu driven.” This simply means that everything must be done in a *document* much like on a computer, and the tools for every application can be found in the *menus*.

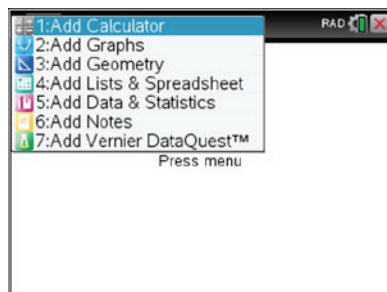
- Turn on the TI-Nspire™. If the screen shown is not displayed, press  for the Home screen.
- Open a new document by selecting **New Document**.





The Calculator Application

- Select **1:Add Calculator** to add a new Calculator application page.



Note: Screen shots for the CAS handheld may be different.

- Page 1.1 is a Calculator page.



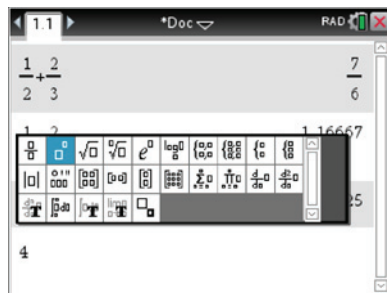
Note: To select a Menu option, highlight the option in the Menu, and press **enter** or . Or, press the number key for that option.

- To enter a fraction, type the fraction using the division key, or select the fraction template by pressing **ctrl** .
- For an approximate value, press **ctrl** **enter**.
Alternatively, add a decimal point in the fraction entry.



Note: An approximate value can be set as the default by pressing **Home > Settings > Document Settings**. Select **Calculation Mode: Approximate**, and click **OK**.

- To raise a number to a power, enter the base, then press , and then enter the power. Press **enter**.
- Alternatively, enter the base, press , and select the template option shown to the right. Enter the power, and press **enter**.
- If squaring a number, enter the base, press , and then press **enter**.



Note: To clear the Calculator screen, press **Menu > Actions > Clear History**.



The Graphs Application

Basic Graphing

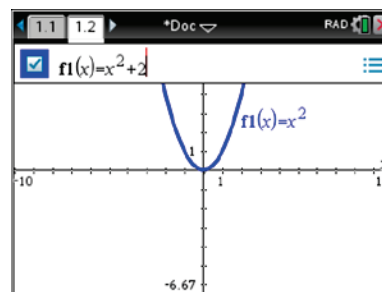
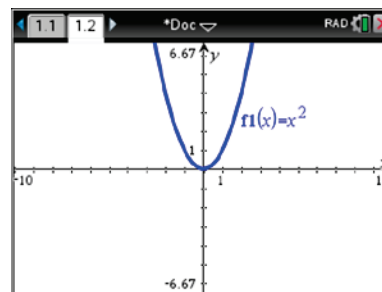
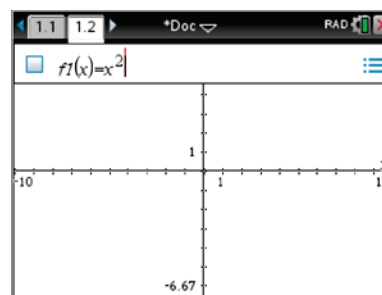
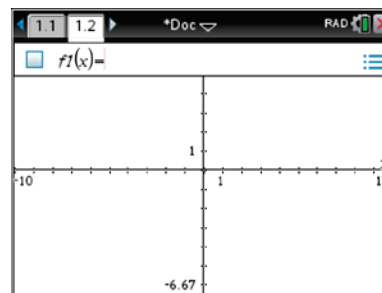
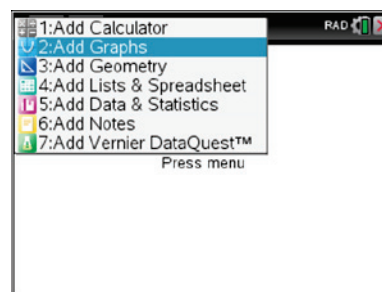
- To add a new page, press **ctrl** **doc**, and then select **Add Graphs**. (Alternatively, press **on** **↓**.)
- The Graphs application is now page 1.2 of the document.

Note: The graphing window shown is the default window setting with a screen aspect ratio of one.

- The function notation, $f1(x)$, is shown in the entry line.
- Type x^2 .
- To graph the function, press **enter**.

Note: The Entry line is hidden. To recall the Entry Line, press **ctrl** **G** or **tab**.

Note: To edit a function, recall the Entry line, and arrow up to the function to be edited. After editing, press **enter** to graph. Alternatively, “double click” on the function label shown on the screen. Edit, as desired, and press **enter**.



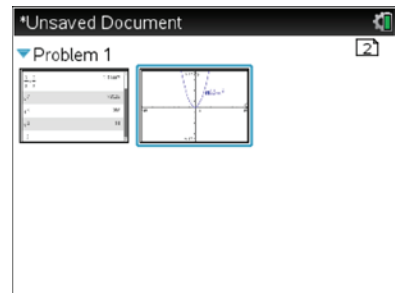


Moving Between Pages in a Document

- To move back one page in a document, press **ctrl** ◀. To move forward one page, press **ctrl** ▶.
- To view all of the pages of the document, press **ctrl** ▲.

Note: This screen allows movement from one page to another. To open a page, highlight the page by arrowing left or right. When the appropriate page is highlighted, press **enter**.

Note: To delete a page, highlight the page, and press **del**. To undo an action, press **ctrl** **Z** or **ctrl** **esc**.





Getting Started with the TI-Innovator™ Hub

TI PROFESSIONAL DEVELOPMENT

Activity Overview

This activity will focus on plugging the TI-Innovator Hub into the TI-Nspire™ CX and testing compatible accessories.

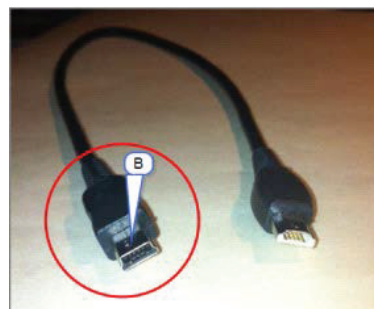
Connecting the TI-Innovator Hub

The TI-Innovator Hub connects by a USB cable to a graphing calculator or computer. The connection lets the Hub receive power and exchange data with the host.

Connecting to a graphing calculator

Step 1:

Identify the “B” connector of the USB Unit-to-Unit (Mini A to Mini B) cable. Each end of this cable is embossed with a letter. Insert the “B” connector into the USB-B port at the bottom of the TI-Innovator Hub.



Step 2:

Insert the free end of the cable (the “A” connector) into the USB port of the TI-Nspire CX.

Step 3:

If it is not already on, turn on the TI-Nspire CX. The RGB LED glows green to show that the Hub is receiving power.

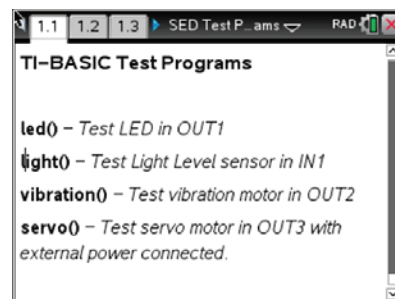


Testing the sensors with the Hub

Testing the Servo Motor

Step 1:

Open the .tns file **SED Test Programs** that was sent by the instructor. This is a simple testing program that allows you to test certain sensors that plug into the Hub for functionality.

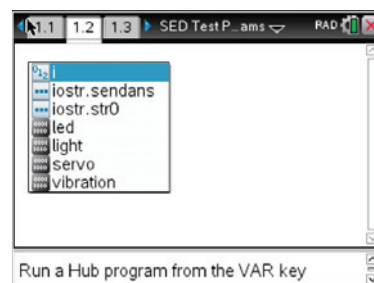


Step 2:

Plug in the external power supply into the Hub, making sure you have a second green light. Next, plug the Servo Motor in the **OUT3** port of the Hub.

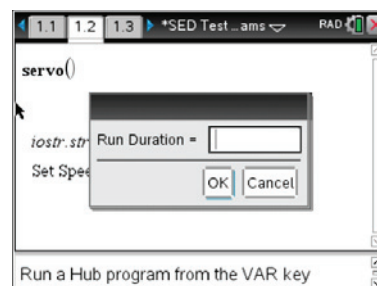
Move to page 1.2 of the .tns file by pressing **ctrl** and the right arrow of the Touchpad.

Press the **Var** key, and select **servo**.



Step 3:

Press **Enter** again. Enter a number between 5 and 10 for the speed. Press **Enter**, or click **Ok**. Enter a number for *Run Duration* (time in seconds). The number should be between 3 and 10 seconds. Press **Enter** again. The Servo Motor should run with the settings established.



Step 4:

Testing the other sensors

Plug the following sensors into their respective ports.

Press **Var** to choose a sensor program. Press **Enter** to run the program.

Testing the LED - Choose a number between 0 and 255, where 255 is the brightest setting.

Testing the light Sensor - When prompted, enter a time (in seconds) to gain a light reading.

Testing the Vibration Motor - The first input is a frequency and the second input is a time (in seconds).

Sensor	Port
LED	OUT1
Light	IN1
Vibration Motor	OUT2
Servo Motor	OUT3



Engineering Design Process

Student Activity

Name _____

Class _____

Engineers are problem solvers. The Engineering Design Process provides a path and organizational strategy to develop a solution to a problem.

There are many variations of the design process, and you might have to ask many questions to find a solution to a problem. In the chart below, develop a list of questions for each step in the process that you think would be useful in designing a solution to a problem.

Steps in the Design Process	Possible questions to be asked
IDENTIFY	<i>What is the need of the project?</i> <i>Who is the solution for?</i>
RESEARCH	
DESIGN	
CREATE	
EVALUATE	
COMMUNICATE	



Create a flow chart of how these terms might make a cycle, known as the Engineering Design Process

Why might an arrow point from Communicate back to Design?

The Engineering Design Process currently starts at Identify. Could the process restart at another location than in the cycle? Where?



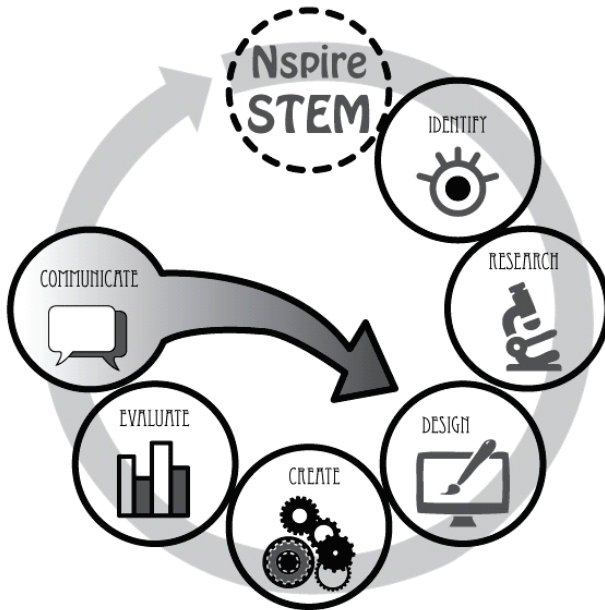
Engineering Design Process

Student Activity

Name _____

Class _____

Below is an example of the Engineering Design Process



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Exploring the Depths with Uniform Motion

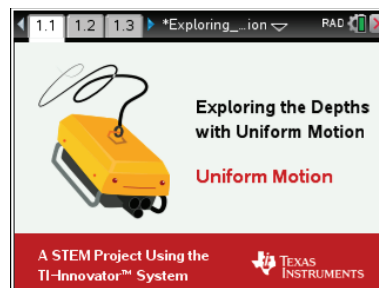
STUDENT ACTIVITY

Name _____

Class _____

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

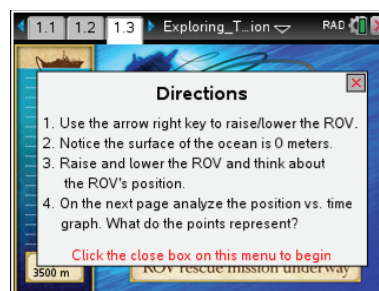
Sonja Sonar is an ROV (Remote Operation Vehicle) mechanical engineer and has designed an ROV that can go deep into the ocean, in search of the elusive Giant Squid thought to live deep in the Marianas trench. When she loses track of the ROV, she suspects it has become stuck under a shelf in the canyon. Sonja needs your help to free her ROV.



Move to pages 1.2 and 1.3 in TI-Nspire Document.

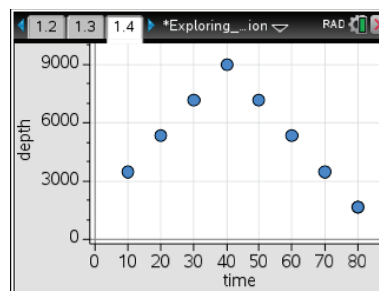
1. Read the background information on pages 1.2 and 1.3, summarized here:

You are tasked with designing and building a hoist to raise and lower a model of a rescue ROV to free the original ROV. You will conduct a simple experiment, using the scientific method, to understand how vertical motion can be represented by a graph or by a written description. You will build a physical system (a hoist) that will be used to explore position-time graphs while practicing your writing and mathematical skills to describe the rescue ROV's motion to another person.



Move to pages 1.4 in TI-Nspire Document.

2. Analyze the Graph on Page 1.4
 - A) What does the magnitude (size) of slope describe about the ROV's motion?



- B) What does the sign (+/-) of the slope represent about the ROV's motion?



Exploring the Depths with Uniform Motion

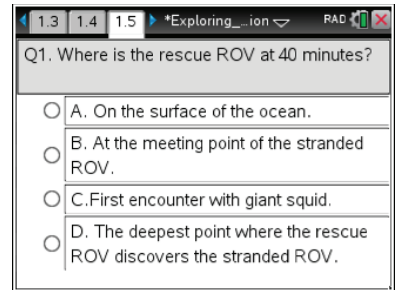
STUDENT ACTIVITY

Name _____

Class _____

Q1. Where is the rescue ROV at 40 minutes?

- A. On the surface of the ocean.
- B. At the meeting point of the stranded ROV.
- C. First encounter with giant squid.
- D. The deepest point where the rescue ROV discovers the stranded ROV.



3. **Identify:** You have an engineering goal and a science research question. The engineering goal is to design and build a hoist to lower or raise a rescue ROV. You will be selecting from several objects with different radii to build your hoist. Your science research question is to understand how the vertical motion of your ROV impacts the slope and y-intercept of the position vs. time graph.

- A) Predict the relationship between radius of the hoist and speed at which the rescue ROV can be raised/lowered.

- B) What is the impact of the motor direction on the motion of the rescue ROV?

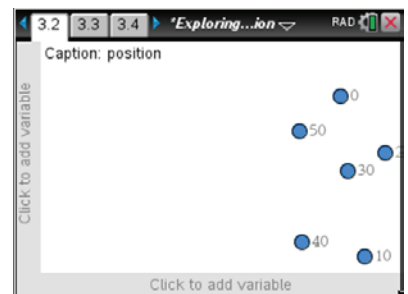
Move to pages 2.1 - 3.4 in TI-Nspire Document.

4. **Research:** Use the **Math Review** and **Practice** in Problems 2 & 3 to learn about position, change in position, and velocity in preparation to solving your engineering problem.

Answer the questions below:

One page 3.2, click to add the variables on the x (time) and y (position) axis.

Analyze the data in the graph with a moveable line (**Menu > Analyze > Add Moveable Line**).





Exploring the Depths with Uniform Motion

STUDENT ACTIVITY

Name _____

Class _____

Practice: Match the moveable line with data and record the slope and y-intercept.

Record the slope and y-intercept: _____

Q2. Calculate the change in position between time 2 and 4 seconds, and record it here.

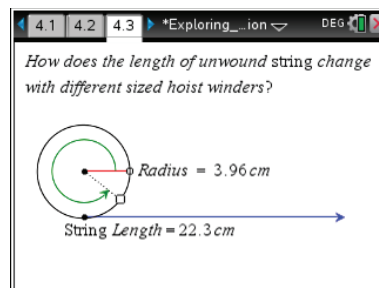
TI-Nspire calculator interface showing question Q2: "Below, calculate the change in position between time 2 and 4 seconds." The input field contains the text "Student: Type response here." and the output field is empty.

Q3. Calculate the velocity between time 2 and 4 seconds, and record it here.

TI-Nspire calculator interface showing question Q3: "Below, calculate the velocity between time 2 and 4 seconds." The input field contains the text "Student: Type response here." and the output field is empty.

Move to pages 4.1 - 4.4 in TI-Nspire Document.

5. **Task 1:** Read the task and research on Pages 4.1 and 4.2. On Page 4.3, try changing the length of the radius, and observe the impact. *How does the length of the unwound string change with different sized hoist winders?*



Q4. The greater the radius of the winder...

- A. the faster the motor spins.
- B. the less string wound up per revolution.
- C. the more string wound up per revolution.
- D. the slower the motor spins.

TI-Nspire calculator interface showing question Q4: "The greater the radius of the winder..." The input field contains four radio button options: A. the faster the motor spins., B. the less string wound up per revolution., C. the more string wound up per revolution., and D. the slower the motor spins.

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Exploring the Depths with Uniform Motion Reflection Questions

TI PROFESSIONAL DEVELOPMENT

Part A – Student Activity Pages 1 - 3

1. Discuss strategies on how to engage students in the design process prior to building their model.
2. What geometry concepts are being incorporated into the activity? What variables are involved and how are they affected?
3. Discuss different methods of mathematical analysis processes that can be used in the activity. How would you use these in your classroom?

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Exploring the Depths with Uniform Motion

Name _____

STUDENT ACTIVITY

Class _____

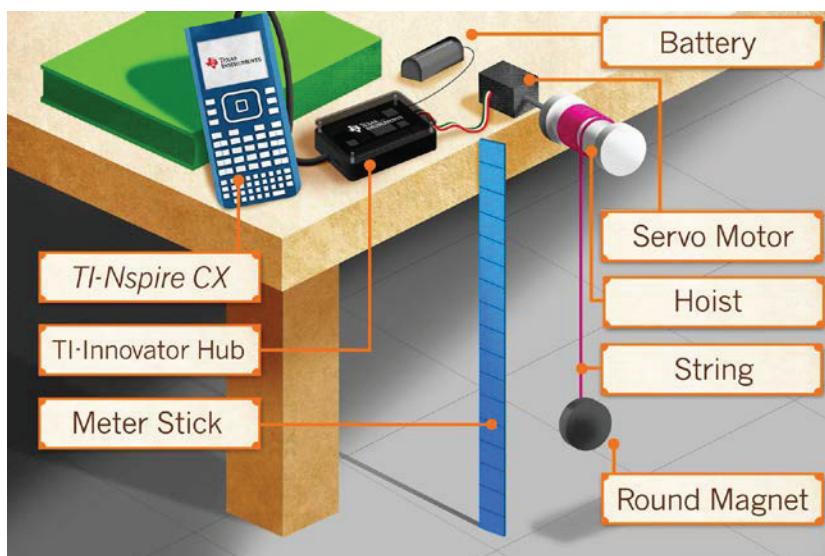
6. **Design/Prototype:** Design a hoist to rescue the stranded ROV in the deep trench. Create a plan for the building of your hoist. Label your sketch with the materials you will be using.

Move to pages 4.5 - 4.6 in TI-Nspire Document.

7. **Task 2:** Build your hoist: Use your design sketch and the materials and tools provided to build your hoist and model of the rescue ROV. Reference the image on Page 4.6 (also below).

Tips:

- The servo motor should be taped to the side of your table.
- Use the meter stick next to the hoist to measure the rescue ROV's position. The meter stick should be placed with the 0 centimeters measurement on the floor.
- Attach a washer, magnet, or paperclip to the string to represent the rescue ROV.





Exploring the Depths with Uniform Motion

STUDENT ACTIVITY

Name _____

Class _____

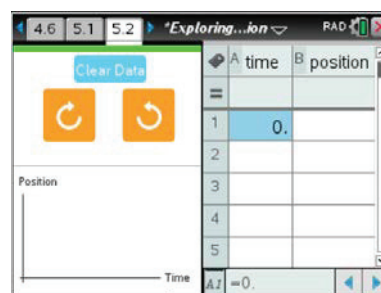
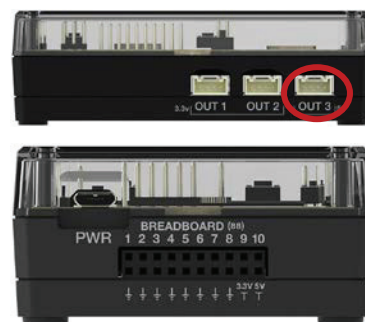
Move to pages 5.1 - 5.2 in TI-Nspire Document.

8. **Task 3:** Read the information on Page 5.1.

On Page 5.2, connect the servo motor to the TI-Innovator™ Hub.

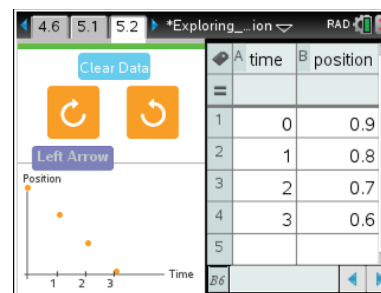
1. Connect the servo motor to OUT3 on the TI-Innovator Hub.
2. Connect the power supply to the TI-Innovator Hub where it says *PWR*.
3. Connect your TI-Innovator Hub to the TI-Nspire CX. Insert the “B” connector on the unit-to-unit cable into the DATA port at the bottom of the TI-Innovator™ Hub.

Note: You should note a green line appears at the top of TI-Nspire CX screen to show you are connected.



Each time you select the right or left button, the servo motor will run for exactly one second in that direction.

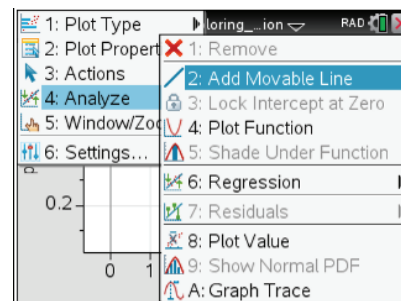
- When you are ready to start your trial, use a meter stick to measure the initial vertical position of your model ROV, and type the position in the table. *Note: The floor is position zero.*
- Select a direction, and record the next time and position. *Note: The time column is cumulative, and the values must be entered in sequential order, as shown in the screenshot.*
- Continue in the same direction for that trial.



Read pages 5.3 - 5.4 in TI-Nspire Document.

9. **Analyze:** Read the information on Page 5.3. Using the hoist and model rescue ROV that you’ve built and the control panel on the handheld, investigate the relationships between speed, direction, vertical position, and time.

Analyze the data in the graph on Page 5.4 with a moveable line (**Menu > Analyze > Add Moveable Line**).





Exploring the Depths with Uniform Motion

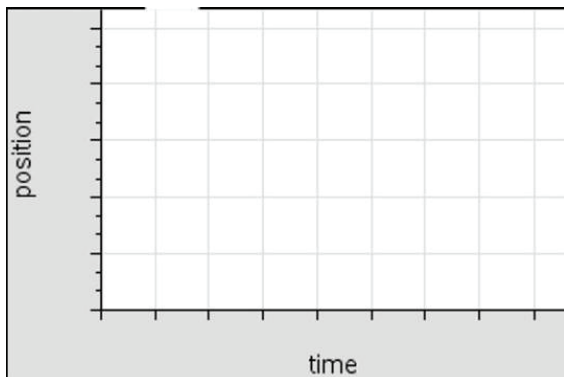
Name _____

STUDENT ACTIVITY

Class _____

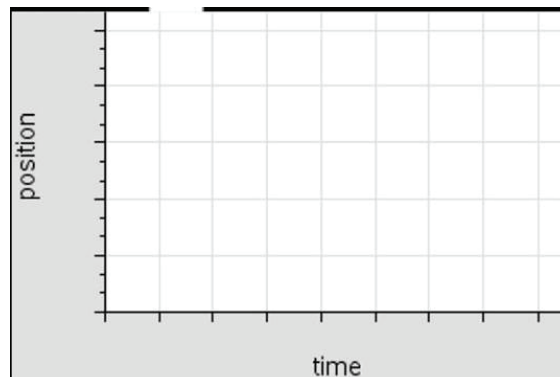
Now select the opposite direction, and record the times and positions in the table as you did for Trial 1. You will analyze the second trial on Page 5.4.

For each of the two different trials, draw the graph below (moveable line matched with data), and record the slope and y-intercept.



Trial 1 Direction: _____

Record the slope and y-intercept:



Trial 2 Direction: _____

Record the slope and y-intercept:

Move to pages 5.7 - 5.9 in TI-Nspire Document.

Q5. What effect does changing the rotation direction have on the slope of the line?

Q6. The slope of a position vs. time graph represents the...

- A. initial position of the model ROV.
- B. the speed of the hoist.
- C. the direction the hoist rotates.
- D. none of the above.



Exploring the Depths with Uniform Motion

STUDENT ACTIVITY

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Class _____

Q7. The y-intercept of a position vs. time graph represents the...

- A. initial position of the model ROV.
- B. the speed of the hoist.
- C. the direction the hoist rotates.
- D. none of the above.

Q8. What does the sign of the slope on a position vs time graph represent?

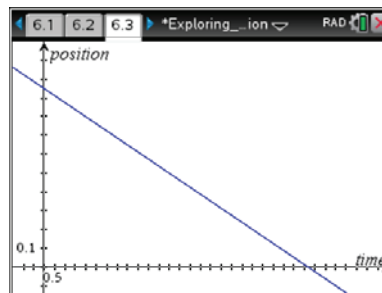
- A. initial position of the model ROV.
- B. the direction the ROV is moving.
- C. the speed the ROV is moving.
- D. none of the above.

Move to pages 6.1 - 6.6 in TI-Nspire Document.

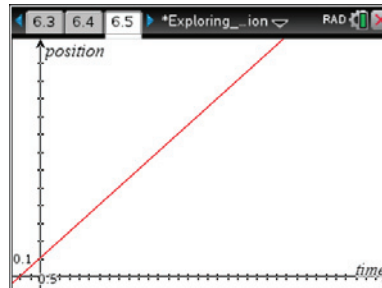
9. **Application 1:** Read the information on Pages 5.1 – 5.2, summarized here:

Sönja Sonar needs your help again. She has found some old position-time graphs and needs your help to understand their meaning. On the next few pages, you will find two graphs to interpret for her. Use the graph trace tool on each to find the position and time of the ROV along the graph. Then, write a description of the ROV's motion in the space provided.

Q9. Analyze the graph, and write a description.



Q10. Analyze the graph, and write a description.





Exploring the Depths with Uniform Motion

STUDENT ACTIVITY

Name _____

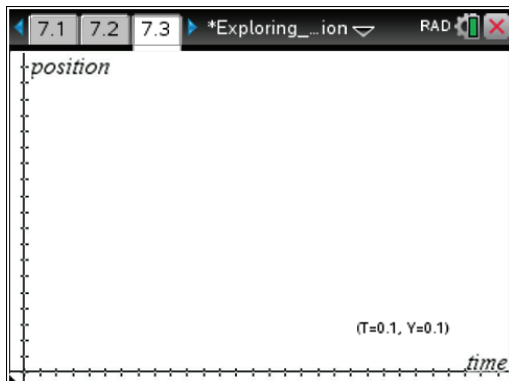
Class _____

Move to pages 7.1 – 7.4 in TI-Nspire Document.

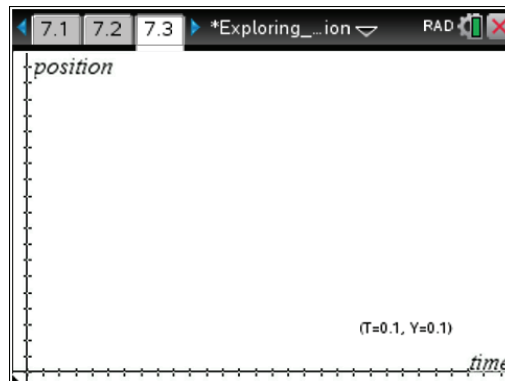
10. **Application 2.** Read the information on pages 6.1 – 6.2, summarized here:

Sönja Sonar needs your help... again. She now needs your math powers to predict a graph of the rescue ROV's motion in the ocean. Please read her two descriptions, and make a sketch of the graphs (below).

A) Graph 1: The rescue ROV starts at .20 meters above the floor and rises to 1.8 meters in 24.5 seconds.



B) The rescue ROV starts 1.5 meters above the floor and lowers to the floor in 14.0 seconds.



11. **Conclusion:** Write a conclusion stating the impact that hoist speed, direction, and initial position have on the appearance of a position vs. time graph.

What additional modifications might need to be made if you were designing a real hoist?

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Exploring the Depths with Uniform Motion Reflection Questions

TI PROFESSIONAL DEVELOPMENT

Part B – Student Activity Pages 4 - 8

1. Discuss strategies on how to engage students in the drawing of their design before building. How much time should be required for students to complete this part of the activity?

2. Discuss the benefits of having students create their own models, setting up their own data collection, and analyzing it.

3. Discuss different methods of mathematical analysis processes that can be used in the activity. How would you use these in your classroom?

4. How best do you evaluate designs when developing a solution? Discuss importance of the materials, placement and availability.

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Science, Technology, Engineering and Math

Objectives

- Students will research **science** topics including:
 - Uniform (non-accelerated) motion
 - Change in position
 - Speed
 - Velocity
- Students will **engineer** and build a small hoist to raise or lower an object 1 vertical meter.
- Students will use appropriate **technology** to enable and evaluate their design, collaborate with colleagues, and present their findings.
- Students will use **mathematical** processes of:
 - Slope of a line
 - Y-intercept of a line
 - Interpreting graphs
 - Proportional reasoning

Vocabulary

- | | |
|----------------------------------|---------------|
| • ROV (remote operation vehicle) | • speed |
| • hoist | • velocity |
| • change in position | • y-intercept |
| | • slope |

About the Lesson

- This is a project-based STEM activity that will engage your students in the engineering design process while using TI-Nspire technology.

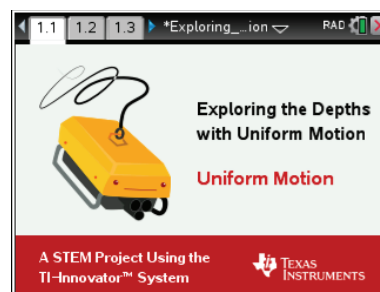
Activity Materials

- Water bottles or sewing thread spools
- Thread, string, dental floss or fishing line
- Paper clips, fishing sinker or washer
- Meter stick
- Scissors
- Tape

Technology Requirements

- TI-Nspire™ CX handheld
- TI-Innovator™ Hub with USB Cable
- Servo Motor from TI-Innovator™ I/O Modules Pack
- TI-Innovator™ Battery Pack *

*Can alternatively plug in the TI-Innovator™ Hub into a power outlet using the TI Wall Adapter.



Tech Tips:

- This activity includes screen captures taken from the TI-Nspire™ CX. It could also be used with the TI-Nspire™ CX Software.
- This activity will use the TI-Innovator™ Hub with TI LaunchPad™ Board.
- Watch for additional Tech Tips throughout the activity.

Suggested Grade Level: 6-8

Lesson Files:

Student Activity

- Exploring_The_Depths_with Uniform_Motion_Student .doc
- Exploring_The_Depths_with Uniform_Motion_Student.pdf
- Exploring_The_Depths_with Uniform_Motion.TNS



Teacher Tip: The above materials are listed as suggestions. The goal is to have a variety of materials available for the students to create the model hoist. Students should work in groups of two. Building time should be limited to one class period.

Teacher Tip: If you are using the I/O Modules Pack for the first time, you will need to assemble the Servo Motor before distributing to students. For help with the initial assembly of this device, view the videos on <https://education.ti.com/en/tisciencespired/us/stem>

Prerequisite Content Knowledge and Skills

- This activity incorporates many of the process skills and cross-cutting principles of the Next Generation Science Standards (NGSS):
 1. *Disciplinary Core Ideas* - PS2.A: Forces and Motion
 2. *Science and Engineering Practices* - Planning and Carrying Out Investigations
 3. *Crosscutting Concepts* - Systems and System Models
Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.
(MS-PS2-1),(MS-PS2-4),

Teacher Tip: The use of this activity is designed to be flexible. It can be used as part of a project-based classroom or problem-based learning environment.

The Situation

Sonja Sonar is an ROV (Remote Operation Vehicle) mechanical engineer and has designed an ROV that can go deep into the ocean, in search of the elusive Giant Squid thought to live deep in the Marianas trench. When she loses track of the ROV, she suspects it has become stuck under a shelf in the canyon. Sonja needs your help to free her ROV.

Your students will be tasked with designing and building a hoist to raise and lower a model of the rescue ROV. Students will conduct a simple experiment using the scientific method to understand how vertical motion may be represented by a graph or written description. Students will build a physical system (a hoist) that will be used to explore position-time graphs while practicing their writing and mathematical skills to describe the rescue ROV's motion to another person.

Related STEM Career – ROV Mechanical Design Engineer

A mechanical engineer is a career that uses physical and mathematical principles to design and build mechanical devices, such as remote operated vehicles (ROV), automobiles, robots, airplanes, and enabling devices. Mechanical engineers are paid well and work in a stimulating work environment that is in demand in our technological society.



Teacher Tip: Students might find it valuable to explore this STEM career after completing the activity.

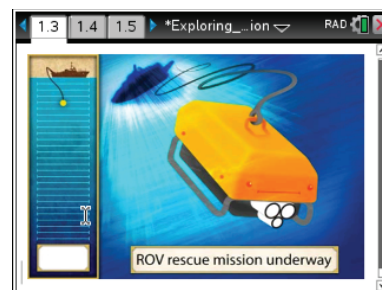
Overview of the Activity

Students will build a hoist to raise and lower a model of a rescue ROV (sinker) one meter and collect position vs time data. Students will then analyze their data and investigate velocity (slope) and initial height (y-intercept). During the investigation, students will change the hoist's speed and winding direction to explore the impact on slope.

Move to pages 1.2 - 1.5 in TI-Nspire Document.

In Problem 1, students are asked to read the storyline that sets the context of the tasks they are about to complete. Give students time to read this section. You could choose to have students do additional research on the following topics:

- different kinds of hoists and their purposes
- ROV technology
- underwater research
- ROV search and rescue
- discovery and research missions of Dr. Bob Ballard, such as the discovery of oceanic thermal vents, or locating famous sunken ships such as the battleship Bismarck or ocean liner Titanic.
- Jules Vern's classic *20,000 Leagues under the Sea* which includes the mythology of giant squid attacks.



The students will also analyze the graph that story animation produces on Page 1.4. On the student activity sheet for question 3 "Identify", students should write two hypothesis statements that predict the relationships between the *independent* variable (radius of the hoist) and the *dependent* variable (speed of the ROV).

Move to pages 2.1 - 3.4 in TI-Nspire Document.

Problem 2 consists of a **Math Review** for students. You might want to remind students of the following:

- Position is the location of an object relative to a reference point that is arbitrarily labeled as position zero.
- Change in position is the difference between the final and initial positions. Change in position has a sign of positive or negative.
- Distance is how far apart two positions are and has no sign or direction.
- Velocity has a direction since it is calculated by dividing change in position by time. Speed has no sign or direction.

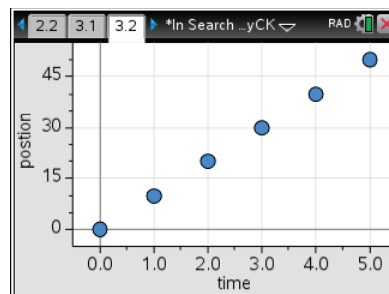
Teacher Tip: Velocity is different from speed in that velocity has a sign or direction. Speed on the other hand does not have direction. Velocity is always relative to a starting point (zero position). A positive velocity is motion away from zero while a negative velocity is motion toward zero.



In Problems 2 and 3, students are tasked with learning about position, change in position, and velocity. Students will practice graphing measurements of position vs. time and then use the data on Page 3.1. to build and analyze a graph on Page 3.2.

They will investigate the difference between change in position and distance as well as the difference between velocity and speed.

Students will answer questions Q2 and Q3 in the TNS and on the student activity sheet.

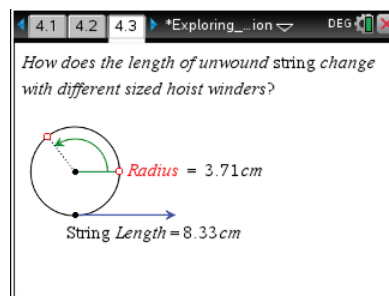


Teacher Tip: Be sure students select “position” for the vertical axis and “time” for the horizontal axis.

Move to pages 4.1 - 4.6 in TI-Nspire Document.

Student Task 1: Researching and Designing the Hoist

In Problem 4, students research how the radius of the winder will impact the string length. This will inform their design in question #6 in the student activity sheet. They should make a detailed sketch of their model with appropriate labels and material lists before they begin construction. This is a good checkpoint for the teacher to ensure students are on task.



Student Task 2: Build the Hoist

Then they will build their hoist using the servo motor and the materials provided. Encourage student groups to build a variety of winders using various sizes of cylindrical objects that can be affixed to the motor like a soda bottle, a towel roll, or thread spool. String, dental floss, fishing line, or thread should be attached to the winder to serve as the hoist cable. They will set it up using the diagram provided on Page 4.6 in the TI-Nspire document. It also provided on the next page.

Teacher Tip: Discussion questions to help guide student design:

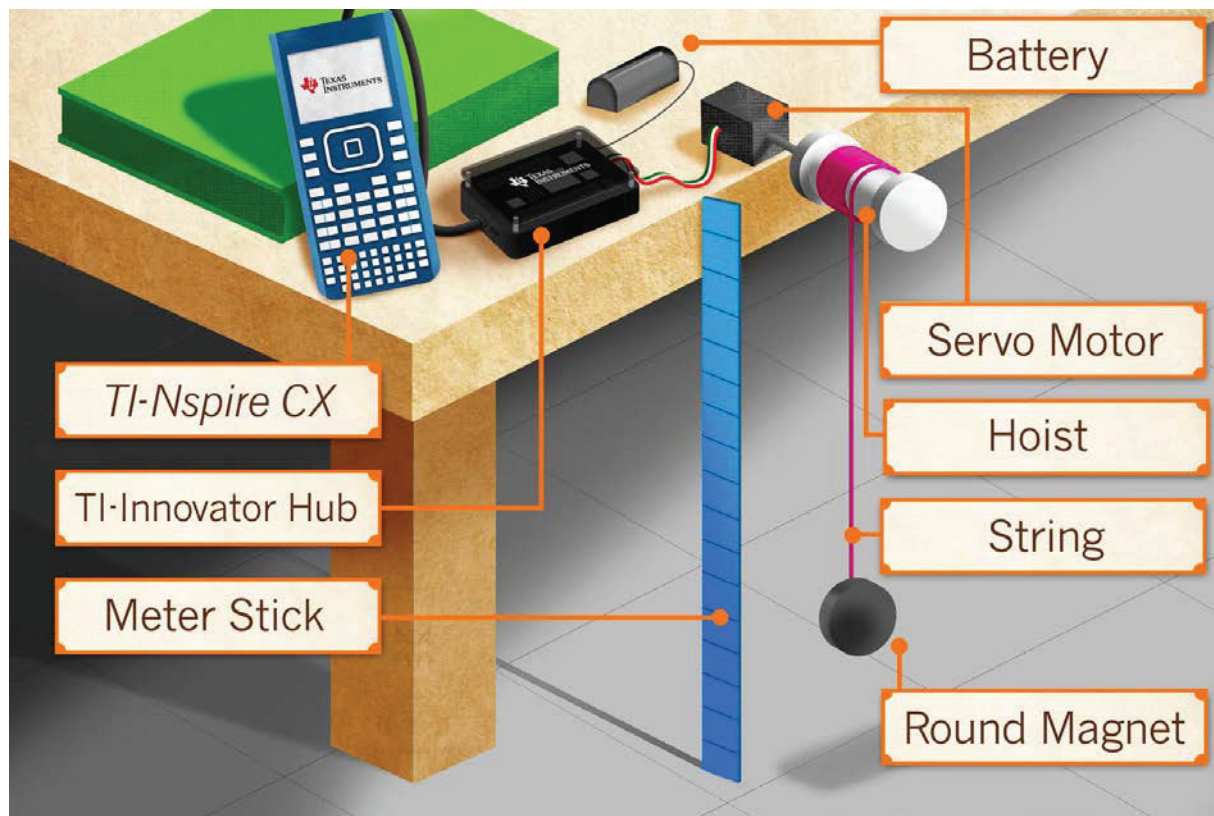
- How do you think the size of your winder will impact your design?
- How can the winder be mounted to the motor to allow free rotation?
- How will you attach the line to the winder? (Hot glue works well here and can be removed to use materials again.)
- How might you stabilize the motor so it doesn't move during the experiment? (The motor should not move during an experiment as it might inadvertently change the position.)

The goal is to make a physical system that can raise and lower a “sinker” using the turning of the servo motor. The model ROV (“sinker”) should be attached to the end of the winding string. Alternatively, a washer or paper clip could be used.



Teacher Tip: Different cylinder diameters will have different changes of the position of the model ROV.

$$\Delta X = \pi \times \text{diameter} \times \text{revolutions}$$



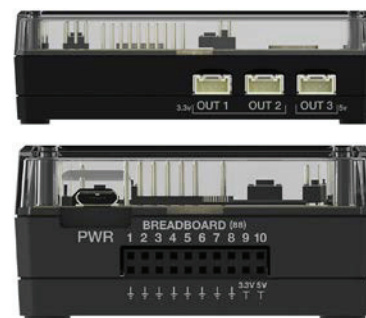
Move to pages 5.1 - 5.2 in TI-Nspire Document.

Student Task 3: Connecting to the TI-Innovator Hub

In Problem 5, students will connect the hoist they built to the TI-Innovator Hub. Students will use the control panel on Page 5.2 to move the hoist. Students will use a meter stick to measure the vertical position of the model ROV as the hoist raises or lowers at one second intervals. Remind students to stay on one setting for the duration of a single trial. They will complete two trials, running the hoist both up and down.

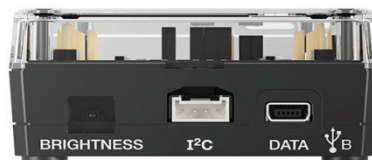
On Page 5.2, connect the servo motor to the TI-Innovator Hub.

1. Connect the servo motor to OUT3 on the TI-Innovator Hub.
2. Connect the power supply to the TI-Innovator Hub where it says *PWR*.

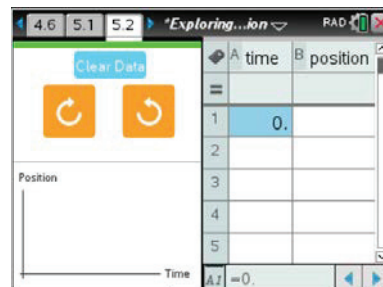




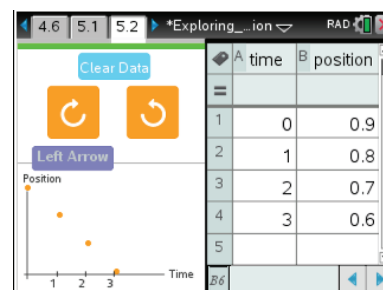
3. Connect the TI-Innovator Hub to the TI-Nspire CX. Insert the “B” connector on the unit-to-unit cable into the DATA port at the bottom of the TI-Innovator™ Hub.



Note: You should note a green line appears at the top of the TI-Nspire CX screen to show you are connected.



Students will use a meter stick to measure their initial position of the ROV above the floor. Remind students that the floor is position zero. Students will select a direction button to move the hoist. The hoist’s motor will rotate for approximately one second. They will record their time and measurements in the table as shown. Note that the time column is cumulative. Students must enter the time values sequentially (Ex: 0, 1, 2, 3....) for the data to be displayed properly in the graph.



Students must analyze their data on Page 5.4 for each trial before changing the hoist direction. This is very important because students need to reset their data after each trial. If students reset their data without doing the analysis first, they will need to repeat their trial.

Teacher Tip: Suggest each student take on a specific role within the group to ensure consistency within the trial. For example, have one student be the “measurer”, or “stabilizer” (holding the meter stick and/or motor) while the other student enters in the data.

Teacher Tip: Note that the time column is cumulative, and students must enter the values in sequential order. If students enter values that are not in the expected order (Ex: 0, 1, 2, 3....) their data will not be displayed properly in the graph.



Teacher Tip: Over time, the Servo Motor may not operate correctly and will need to be recalibrated. Go to **menu > Calibrate Servo > Calibrate Servo**. If the Servo does not move, then it's already calibrated, If the servo is moving, use a screwdriver to move the potentiometer in the back of the motor until it stops. If you need more assistance, contact Customer Support education.ti.com/support.

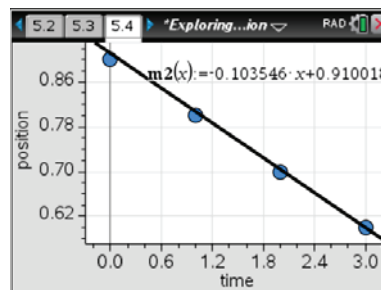
Move to pages 5.3 - 5.5 in TI-Nspire Document.

Finally, they will analyze the graphs of their data and make conclusions on how changing the control settings relates to the slope and y-intercept of the line.

On Page 5.4, students will choose “time” on the horizontal axis and “position” on the vertical axis and see a graph of the vertical position of the ROV vs. time.

They should add a movable line (**menu > Analyze > Add Moveable Line**) and match it with their data. The slope and y-intercept are calculated and displayed for the line.

Students should record the slope and y-intercept on the student activity sheet and make sketches of their graphs for each of the four graphs.



Move to pages 5.4 - 5.5 in TI-Nspire Document.

Student Task 4: Measuring, Graphing and Analyzing the Opposite Direction

The sign of the slope will change from positive to negative when the students switch directions.

Counterclockwise and clockwise are relative to frame of reference and the ROV motion is dependent on which side of the spool the string is attached. These are not absolutes and will vary within the class.

Teacher Tip: Students can also change the y-intercept depending on how many loops of string are initially on the winding spool before the motor is turned. Typically, when the ROV is to be lowered (- slope), the ROV string is wound onto the spool, so that it has an initial position about one meter above the floor. Alternatively, when the ROV is raised (+ slope), the string is unwound, so that the ROV has an initial position on the floor.

Key takeaways for students:

- Associate value of the slope or steepness of the line with the speed of the hoist.
- Associate the sign (positive or negative) of the slope with direction of the hoist (clockwise or counterclockwise).
- Associate the y-intercept with the initial position of the ROV before operating the hoist.

Teacher Tip: After students have collected their data, compare the graphs of groups with different winder diameters. Students with a larger diameter will have a steeper slope than those with smaller diameters.



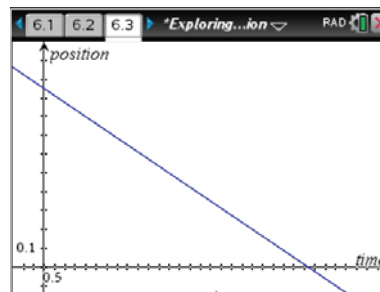
On Pages 5.6 through 5.9, there are questions to help students analyze the data and draw conclusions. Questions and answers are included on the student activity sheet answer key.

Teacher Tip: Additional discussion questions to help guide student conclusions:

- Encourage students to explore different initial positions and different hoist movement direction. Challenge them to predict and describe the graph in writing before they actually do the experiment.
- Additionally, challenge your students to consider how the diameter of their winder impacts the graph (greater diameter produces a steeper slope).
- What does the slope of your graph tell you about the motion of the ROV?
- **Answer:** The speed the ROV is raising or lowering in cm/s
- Why are some slopes negative and some positive?
- **Answer:** The slopes are opposite in sign depending on if the winder is rotating clockwise or counterclockwise.
- What is the difference between speed and velocity?
- **Answer:** Velocity indicates the speed AND direction of travel, which is indicated by the positive/ negative sign (direction is clockwise or counterclockwise). Speed has no direction.
- How would changing the servo motor to be position zero (instead of the floor) change the graph?
- **Answer:** The sign of the slopes on all graphs would be opposite.

Further Analysis: Exploring Multiple Representations of Motion

Application 1: In Problems 6 and 7, students will apply what they learned about uniform motion. In Problem 5, students are tasked with writing a description of two graphs provided.



Application 2: In Problem 7, students will take two written description and draw a graph using the simulation provided.

**Assessment**

Students will complete the Student Activity sheet which will contain design sketches, data analysis, answers to the questions included in the TNS file, and finally their conclusions.

You can also have students prepare a brief presentation explaining their design and findings using a dry erase board, poster board, or multimedia. They should include pictures of their design and findings from their experiment. You might also have your students compare their designs.

- Formative assessment consists of questions posed to students throughout the design process to determine if they understand the concepts presented in the lesson.
- Summative assessment will consist of the overall quality of the design and student explanation of their model and findings.

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Exploring the Depths with Uniform Motion

STUDENT ACTIVITY ANSWER KEY

Name _____

Class _____

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

Sonja Sonar is an ROV (Remote Operation Vehicle) mechanical engineer and has designed an ROV that can go deep into the ocean, in search of the elusive Giant Squid thought to live deep in the Marianas trench. When she loses track of the ROV, she suspects it has become stuck under a shelf in the canyon. Sonja needs your help to free her ROV.

Move to pages 1.2 and 1.3 in TI-Nspire Document.

1. Read the background information on pages 1.2 and 1.3, summarized here:

You are tasked with designing and building a hoist to raise and lower a model of a rescue ROV to free the original ROV. You will conduct a simple experiment, using the scientific method, to understand how vertical motion can be represented by a graph or by a written description. You will build a physical system (a hoist) that will be used to explore position-time graphs while practicing your writing and mathematical skills to describe the rescue ROV's motion to another person.

Move to pages 1.4 in TI-Nspire Document.

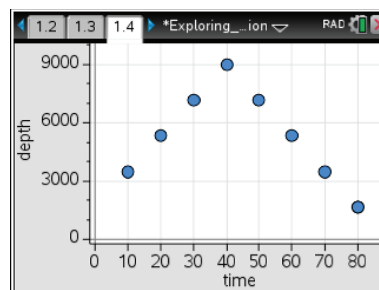
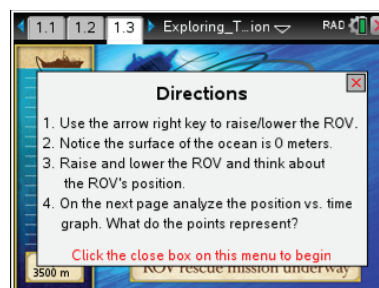
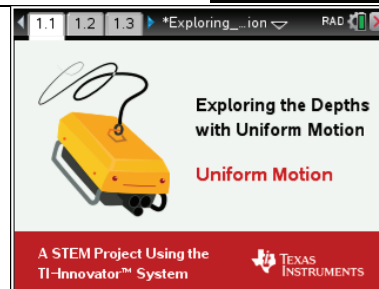
2. Analyze the Graph on Page 1.4

A) What does the magnitude (size) of slope describe about the ROV's motion?

Sample Answer: When speed is slow, the slope is shallow (small); when the speed is fast, the slope is steep (large).

B) What does the sign (+/-) of the slope represent about the ROV's motion?

Sample Answer: The sign of the slope will change from positive to negative when the students switch directions. Counterclockwise and clockwise are relative to frame of reference and the ROV motion is dependent on which side of the spool the string is attached.





Exploring the Depths with Uniform Motion

STUDENT ACTIVITY ANSWER KEY

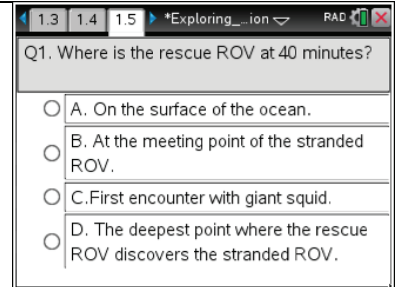
Name _____

Class _____

Q1. Where is the rescue ROV at 40 minutes?

- A. On the surface of the ocean.
- B. At the meeting point of the stranded ROV.
- C. First encounter with giant squid.
- D. The deepest point where the rescue ROV discovers the stranded ROV.

Answer: D. The deepest point where the rescue ROV discovers the stranded ROV.



3. **Identify:** You have an engineering goal and a science research question. The engineering goal is to design and build a hoist to lower or raise a rescue ROV. You will be selecting from several objects with different radii to build your hoist. Your science research question is to understand how the vertical motion of your ROV impacts the slope and y-intercept of the position vs. time graph.

A) Predict the relationship between radius of the hoist and speed at which the rescue ROV can be raised/lowered.

Answers May Vary: The larger the radius of the hoist, the quicker the ROV can be raised or lowered.

B) What is the impact of the motor direction on the motion of the rescue ROV?

Sample Answer: Depending on which direction for the hoist is selected, the rescue ROV will either move up or down.

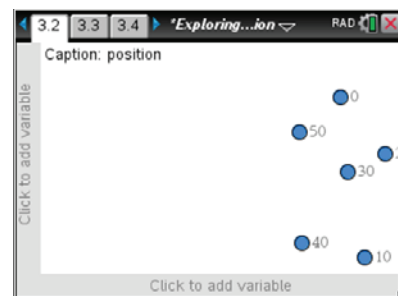
Move to pages 2.1 - 3.4 in TI-Nspire Document.

4. **Research:** Use the **Math Review** and **Practice** in Problems 2 & 3 to learn about position, change in position, and velocity in preparation to solving your engineering problem.

Answer the questions below:

One page 3.2, click to add the variables on the x (time) and y (position) axis.

Analyze the data in the graph with a moveable line (**Menu > Analyze > Add Moveable Line**).





Exploring the Depths with Uniform Motion

STUDENT ACTIVITY ANSWER KEY

Name _____

Class _____

Practice: Match the moveable line with data and record the slope and y-intercept.

Record the slope and y-intercept: **Answers May Vary**

Q2. Calculate the change in position between time 2 and 4 seconds, and record it here.

Answer: $\Delta X = 40\text{m} - 20\text{m} = 20\text{m}$

Q2. Below, calculate the change in position between time 2 and 4 seconds.

Student: Type response here.

Q3. Calculate the velocity between time 2 and 4 seconds, and record it here.

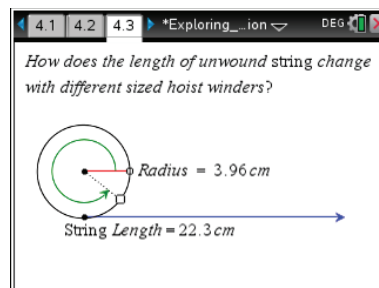
Answer: $V = \Delta X / \Delta t = (40\text{m} - 20\text{m}) / (4\text{sec} - 2\text{sec}) = 10\text{m/sec}$

Q3. Below, calculate the velocity between time 2 and 4 seconds.

Student: Type response here.

Move to pages 4.1 - 4.4 in TI-Nspire Document.

5. **Task 1:** Read the task and research on Pages 4.1 and 4.2. On Page 4.3, try changing the length of the radius, and observe the impact. *How does the length of the unwound string change with different sized hoist winders?*



Q4. The greater the radius of the winder...

- A. the faster the motor spins.
- B. the less string wound up per revolution.
- C. the more string wound up per revolution.
- D. the slower the motor spins.

Answer: C. the more string wound up per revolution.

Q4. The greater the radius of the winder...

- A. the faster the motor spins.
- B. the less string wound up per revolution.
- C. the more string wound up per revolution.
- D. the slower the motor spins.



6. **Design/Prototype:** Design a hoist to rescue the stranded ROV in the deep trench. Create a plan for the building of your hoist. Label your sketch with the materials you will be using.

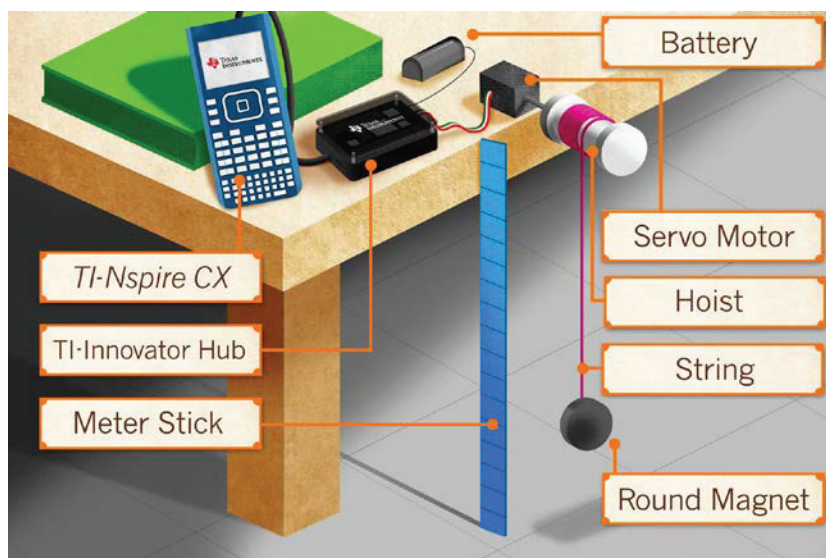
Answers May Vary

Move to pages 4.5 - 4.6 in TI-Nspire Document.

7. **Task 2:** Build your hoist: Use your design sketch and the materials and tools provided to build your hoist and model of the rescue ROV. Reference the image on Page 4.6 (also below).

Tips:

- The servo motor should be taped to the side of your table.
- Use the meter stick next to the hoist to measure the rescue ROV's position. The meter stick should be placed with the 0 centimeters measurement on the floor.
- Attach a washer, magnet, or paperclip to the string to represent the rescue ROV.





Exploring the Depths with Uniform Motion

STUDENT ACTIVITY ANSWER KEY

Name _____

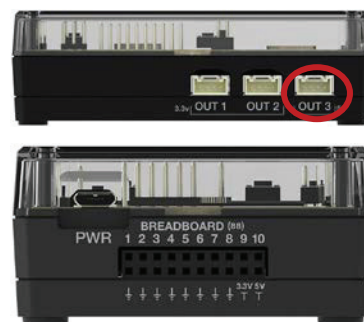
Class _____

Move to pages 5.1 - 5.2 in TI-Nspire Document.

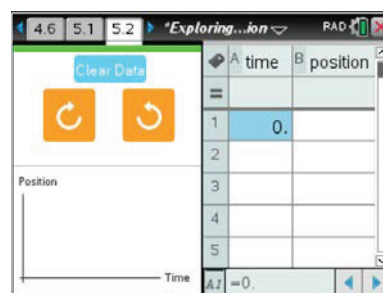
8. **Task 3:** Read the information on Page 5.1.

On Page 5.2, connect the servo motor to the TI-Innovator™ Hub.

1. Connect the servo motor to OUT3 on the TI-Innovator Hub.
2. Connect the power supply to the TI-Innovator Hub where it says *PWR*.
3. Connect your TI-Innovator Hub to the TI-Nspire CX using the USB.

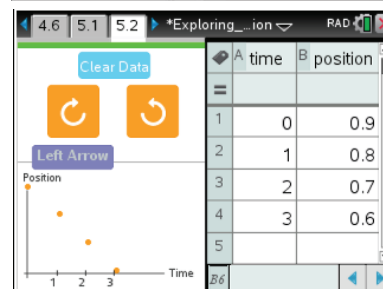


Note: You should note a green line appears at the top of TI-Nspire CX screen to show you are connected.



Each time you select the right or left button, the servo motor will run for exactly one second in that direction.

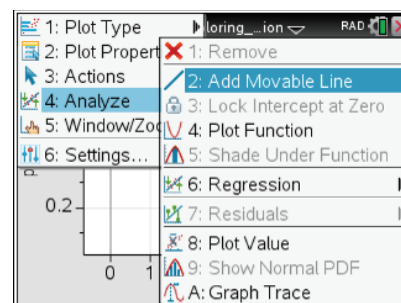
- When you are ready to start your trial, use a meter stick to measure the initial vertical position of your model ROV, and type the position in the table. *Note: The floor is position zero.*
- Select a direction, and record the next time and position. *Note: The time column is cumulative, and the values must be entered in sequential order, as shown in the screenshot.*
- Continue in the same direction for that trial.



Read pages 5.3 - 5.5 in TI-Nspire Document.

9. **Analyze:** Read the information on Page 5.3. Using the hoist and model rescue ROV that you've built and the control panel on the handheld, investigate the relationships between speed, direction, vertical position, and time.

Analyze the data in the graph on Page 5.4 with a moveable line (**Menu > Analyze > Add Movable Line**).





Exploring the Depths with Uniform Motion

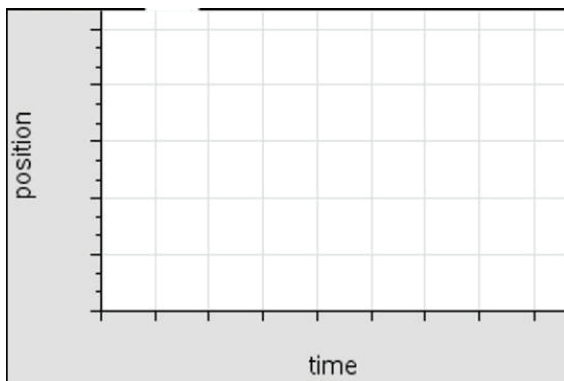
Name _____

STUDENT ACTIVITY ANSWER KEY

Class _____

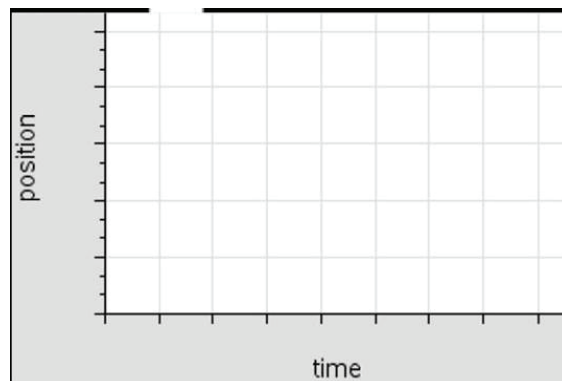
Now select the opposite direction, and record the times and positions in the table as you did for Trial 1. You will analyze the second trial on Page 5.4.

For each of the two different trials, draw the graph below (moveable line matched with data), and record the slope and y-intercept.



Trial 1 Direction: _____

Record the slope and y-intercept:



Trial 2 Direction: _____

Record the slope and y-intercept:

Answers may vary**Answers may vary**

Move to pages 5.6 - 5.9 in TI-Nspire Document.

Q5. What effect does changing the rotation direction have on the slope of the line?

Sample Answer: The sign of the slope will change from positive to negative or vice versa when the students switch directions.

Q5. What effect does changing the rotation direction have on the slope of the line?

Student: Type response here.

Q6. The slope of a position vs. time graph represents the...

- A. initial position of the model ROV.
- B. the speed of the hoist.
- C. the direction the hoist rotates.
- D. none of the above.

Answer: B. the speed of the hoist.

Q6. The slope of a position vs. time graph represents the...

- A. initial position of the model ROV.
- B. the speed of the hoist.
- C. the direction the hoist rotates.
- D. none of the above.



Exploring the Depths with Uniform Motion

STUDENT ACTIVITY ANSWER KEY

Name _____

Class _____

Q7. The y-intercept of a position vs. time graph represents the...

- A. initial position of the model ROV.
- B. the speed of the hoist.
- C. the direction the hoist rotates.
- D. none of the above.

Answer: A. initial position of the model ROV.

Q7. The Y-intercept of a position vs. time graph represents the...

- A. initial position of the model ROV.
- B. the speed of the hoist.
- C. the direction the hoist rotates.
- D. none of the above.

Q8. What does the sign of the slope on a position vs time graph represent?

- A. initial position of the model ROV.
- B. the direction the ROV is moving.
- C. the speed the ROV is moving.
- D. none of the above.

Answer: B. the direction the ROV is moving.

Q8. What does the sign of the slope on a position vs time graph represent?

- A. initial position of the model ROV.
- B. the direction the ROV is moving.
- C. the speed the ROV is moving.
- D. none of the above.

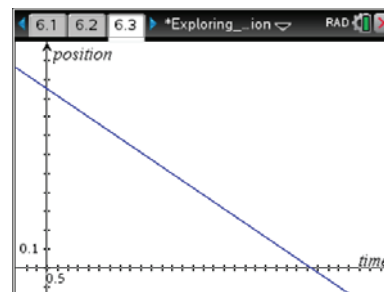
Move to pages 6.1 - 6.6 in TI-Nspire Document.

9. **Application 1:** Read the information on Pages 6.1 – 6.2, summarized here:

Sönja Sonar needs your help again. She has found some old position-time graphs and needs your help to understand their meaning. On the next few pages, you will find two graphs to interpret for her. Use the graph trace tool on each to find the position and time of the ROV along the graph. Then, write a description of the ROV's motion in the space provided.

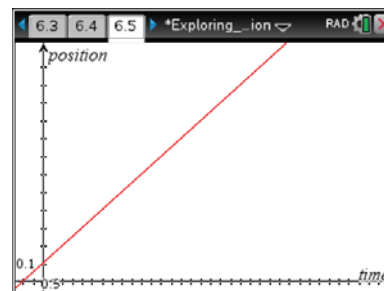
Q9. Analyze the graph, and write a description.

Sample Answer: The ROV starts .95 m above the floor and then slowly goes down and reaches the floor in 12.7 seconds.



Q10. Analyze the graph, and write a description.

Sample Answer: The ROV starts .10 m above the floor and then slowly rises above the floor and reaches 1.0m in 9 seconds.



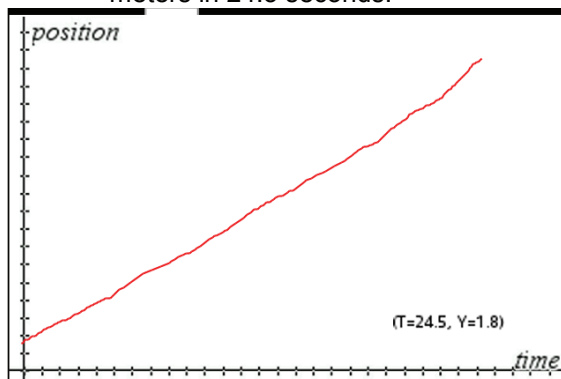


Move to pages 7.1 – 7.4 in TI-Nspire Document.

10. **Application 2.** Read the information on pages 7.1 –7.2, summarized here:

Sönja Sonar needs your help... again. She now needs your math powers to predict a graph of the rescue ROV's motion in the ocean. Please read her two descriptions, and make a sketch of the graphs (below).

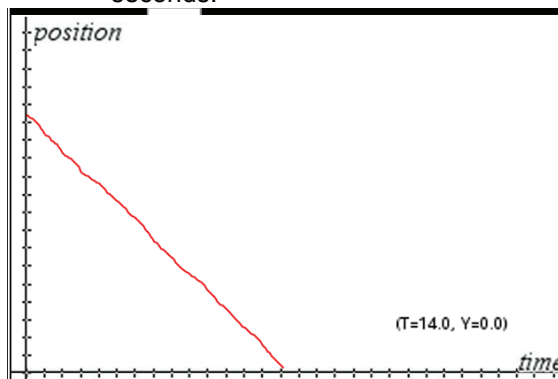
A) Graph 1: The rescue ROV starts at .20 meters above the floor and rises to 1.8 meters in 24.5 seconds.



Sample Answer:

The smoothness of the line is not critical, It should however begin at $(0, .2)$ and end at $(24.5, 1.8)$ and attempt to be smooth and straight between.

B) The rescue ROV starts 1.5 meters above the floor and lowers to the floor in 14.0 seconds.



Sample Answer:

The smoothness of the line is not critical, It should however begin at $(0, 1.5)$ and end at $(14, 0)$ and attempt to be smooth and straight between.

11. **Conclusion:** Write a conclusion stating the impact that hoist speed, direction, and initial position have on the appearance of a position vs. time graph.

Sample Answer: The vertical position will increase proportionately when speed increases while direction and time are held constant. The vertical position will change from rising to dropping when the direction of the hoist is changed, while the speed and time are held constant.

What additional modifications might need to be made if you were designing a real hoist?

Answers May Vary

T3 Ticket Outta Here

I have learned ...

My next steps are ...

T3 Ticket Outta Here

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Transferring Documents Using the TI-Nspire™ CX Teacher Software TI PROFESSIONAL DEVELOPMENT

Activity Overview

In this activity, you will use the Documents and Content Workspaces of the TI-Nspire™ CX Teacher Software to transfer TI-Nspire™ documents between the computer and the handheld.

Materials

- TI-Nspire™ CX Teacher Software (v4.2) if using TI-Nspire™ CX handhelds
- TI-Nspire™ Teacher Software (v3.9) if using TI-Nspire™ CX, TI-Nspire™ with Touchpad, or TI-Nspire with Clickpad
- TI-Nspire™ handheld and standard-A to Mini-B USB cable

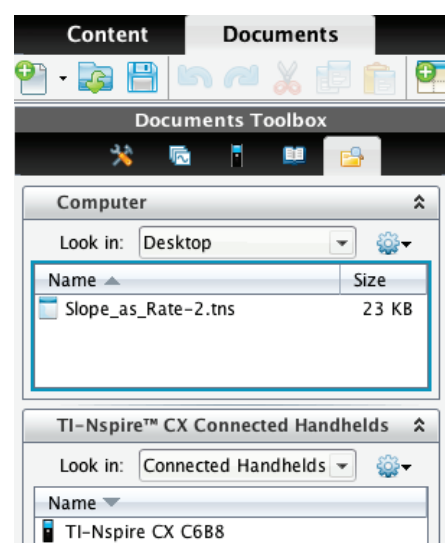
Transferring Documents in the Documents Workspace

Step 1:


Open the Teacher Software. Go to the Documents Workspace by clicking the **Documents** tab.

Step 2:

Connect a TI-Nspire™ handheld to the computer using the USB connection cable. Multiple handhelds can be connected using multiple USB ports, USB hubs, or the TI-Nspire™ Docking Station. If multiple handhelds are connected, then multiple handhelds appear in the Connected Handhelds panel.



Step 3:

Documents can be transferred between the computer and connected handhelds using the Content Explorer in the Documents Toolbox. Open the Content Explorer by clicking the  **Content Explorer** tab.

Step 4:

To transfer a TI-Nspire™ document from the computer to the handheld, locate the document in the Computer panel. Click, drag, and drop it into the handheld in the Connected Handhelds panel.

Step 5:

To transfer a TI-Nspire™ document from the connected handheld to the computer, locate the document in the Connected Handhelds panel. Click, drag, and drop it into the desired folder in the Computer panel.

TI PROFESSIONAL DEVELOPMENT

Transferring Documents Using the TI-Nspire™ CX Teacher Software

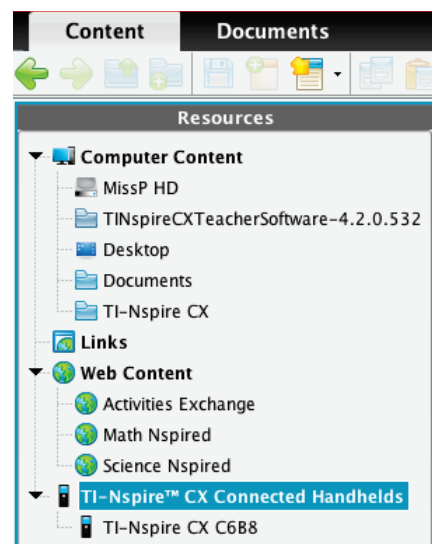
Transferring Documents in the Content Workspace

Step 6:

Go to the Content Workspace by clicking the **Content** tab. In the Resources panel select **TI-Nspire™ CX Connected Handhelds**.

Step 7:

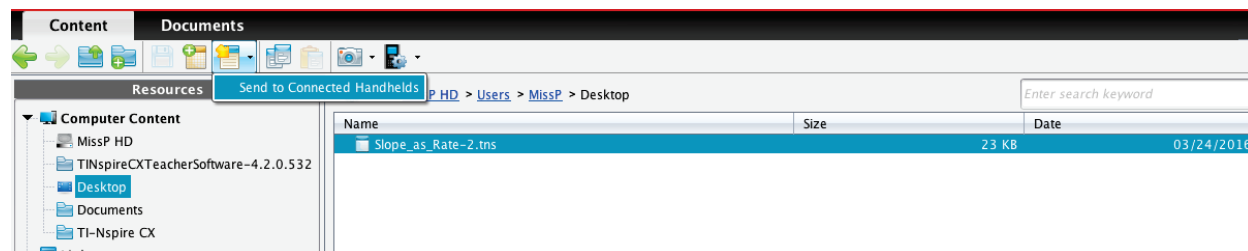
The connected handheld appears in the Content window, along with battery, storage, and OS information. To view the documents on a connected handheld, click the name of the handheld.



Name	Battery (Li-ion)	Battery (AAA)	Storage / Size	OS version
TI-Nspire CX C6B8	10%	--	96.8/115.2 MB	4.2.0.532

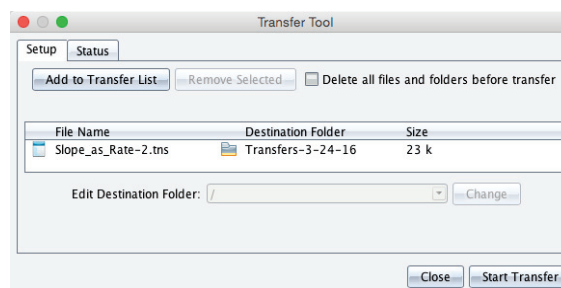
Step 8:

Locate a TI-Nspire™ document on your computer by browsing Computer Content in the Resources panel. Send the document by dragging and dropping it to the connected handheld. The document can also be sent by right-clicking it and selecting **Send to Connected Handhelds**.



Step 9:

The Transfer Tool window appears with the current document. Documents can be added to or removed from the transfer list, and the destination folder on the handheld(s) can be edited or changed. To send the document to the handheld(s), click **Start Transfer**. Once the Status tab indicates that the transfer is complete, click **Stop Transfer**.





Transferring Documents Between Handhelds

TI PROFESSIONAL DEVELOPMENT

Activity Overview

In this activity, you will learn how to transfer a document from one TI-Nspire™ CX handheld to another.

Materials

- Two TI-Nspire™ CX handhelds
- Unit-to-unit connection cable (Mini-A to Mini-B USB)

Transferring a Document or a Folder

Documents can be transferred between two TI-Nspire™ CX handhelds by connecting them with the unit-to-unit mini USB cable. The USB A port is located at the top of the handheld on the right side.



Step 1:

Firmly insert the ends of the mini USB unit-to-unit cable into the USB A ports of the handhelds. The handhelds will automatically turn on when the cable is plugged in.

Step 2:

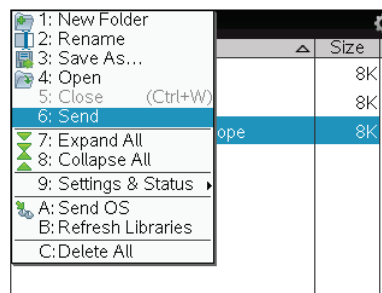
Open **My Documents** on the sending handheld.

Step 3:

Press the ▲ and ▼ keys to highlight the document or folder to send.

Step 4:

Press **menu** and select **Send**. No action is required by the user of the receiving TI-Nspire™ CX handheld. Once the transfer begins, a progress bar displays the status of the transfer. When the transfer is complete, a message displays on the receiving handheld. If the document was renamed on the receiving handheld, the new document name appears.





Transferring Documents Between Handhelds

TI PROFESSIONAL DEVELOPMENT

Note: When sending a folder from one handheld to another, the file structure in the sending folder is retained. If the folder does not exist on the receiving handheld, it will be created. If the folder does exist, files will be copied into it, with appended names added to any duplicate files.

Note: To cancel a transmission in progress, select **Cancel** in the dialog box of the sending handheld. To cancel a transfer from the receiving handheld, press . The receiving handheld, however, cannot cancel a transfer of folders. If an error message appears, press or to clear it.

Guidelines for Transferring Documents or Folders

The guidelines for sending an individual document also apply to documents within folders that are sent.

- If you send a document with the same name as an existing document on the receiving TI-Nspire™ CX handheld, the system renames the sent document by appending a number to the name. For example, if you send a document named *Mydata* to another TI-Nspire handheld that already contains a document named *Mydata*, the document you send will be renamed *Mydata(2)*. Both the sending and receiving units display a message that shows the new name.
- There is a 255-character maximum length for a document name, including the entire path. If a transmitted document has the same name as an existing document on the receiving handheld and the document names contain 255 characters, then the name of the transmitted document will be truncated to allow the software to follow the renaming scheme described in the previous bullet.
- All variables associated with the document being transmitted are transferred with the document.
- Transmissions will time out after 30 seconds.