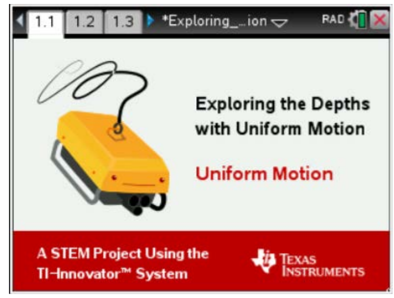
Science, Technology, Engineering and Math Objectives

- 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



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

Vocabulary

- ROV (remote operation vehicle)
- hoist
- change in position
- speed
- velocity
- 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.

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/tisciencenspired/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 anaylze 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).

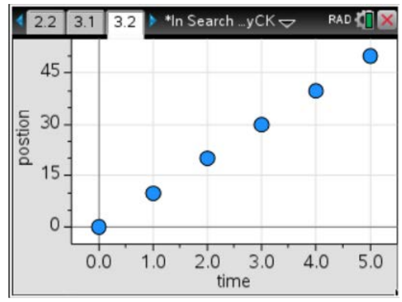
Move to pages 2.1 - 3.4 in TI-Nspire Document.

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

- 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 anaylze 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.

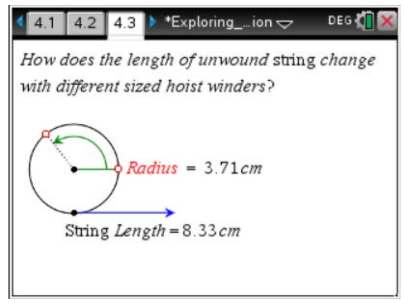


Teacher Tip: Be sure students select "position" for the vertical axis and "time" for the horizontal axis.

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.

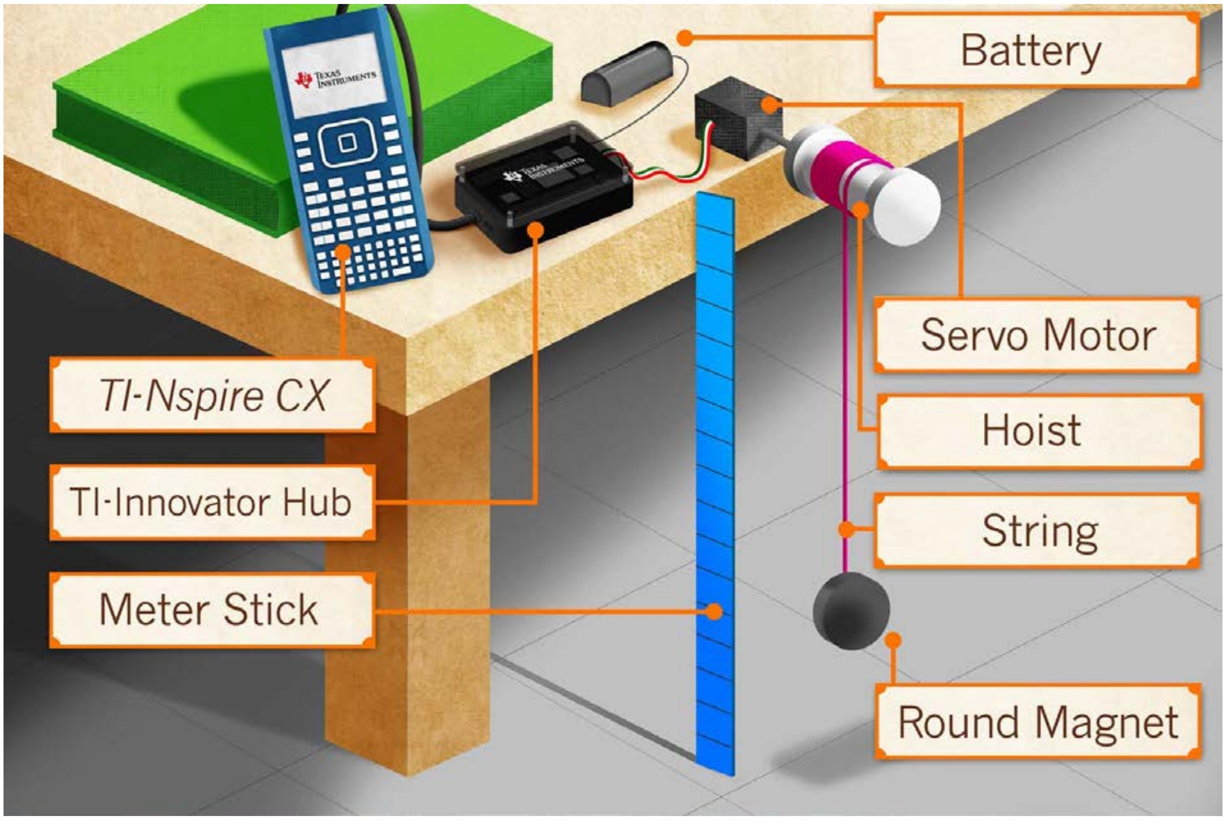
Teacher Tip: Discussion questions to help guide student design:

- 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.

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



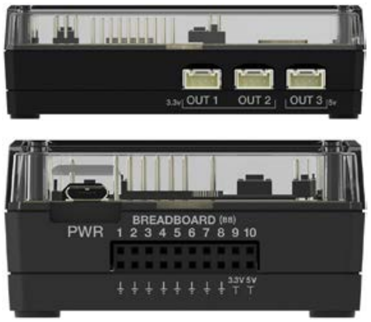
Move to pages 5.1 - 5.2 in TI-Nspire Document.

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.

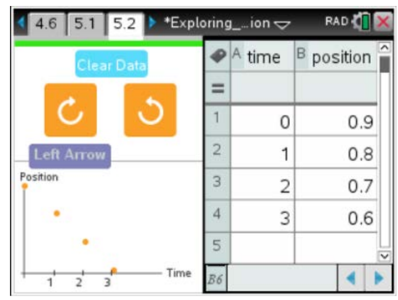
On Page 5.2, connect the servo motor to the TI-Innovator Hub.

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.

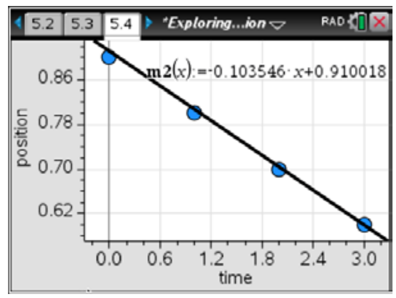
Teacher Tip: Note that the time column is cumulative, and students must enter the values in sequential order. If students enter values that are not in the expected order (Ex: 0, 1, 2, 3....) their data will not be displayed properly in the graph.

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.

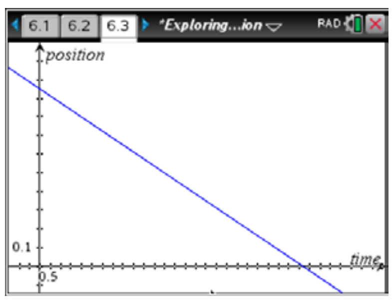
On Pages 5.6 through 5.9, there are questions to help students analyze the data and draw conclusions. Questions and answers are included on the student activity sheet answer key.

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

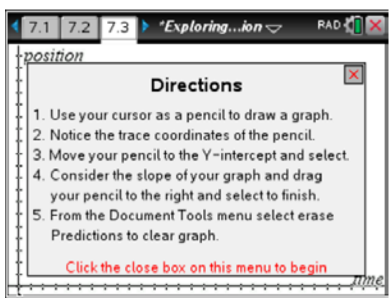
- Encourage students to explore different initial positions and different hoist movement direction. Challenge them to predict and describe the graph in writing before they actually do the experiment.
- Additionally, challenge your students to consider how the diameter of their winder impacts the graph (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.