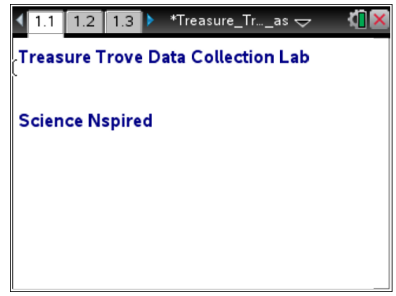
Science Objectives

- Students will understand the difference between the mass and weight of an object.
- Students will use a force sensor to measure the weight of an object on Earth.
- Students will calculate the weight of an object on different celestial bodies.



TI-Nspire™ Technology Skills:

- Download a TI-Nspire document
- Open a document
- Move between pages
- Grab and drag a point

Tech Tip:

Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials

Lesson Files:

Student Activity

- Treasure_Trove_Student.pdf
- Treausre_Trove_Student.doc

TI-Nspire document

- Treasure_Trove.tns

Vocabulary

- celestial body
- force
- force sensor
- gravity
- mass
- Newton
- weight

About the Lesson

- This lesson involves using a force sensor to measure the weight of an object.
- As a result, students will:
  - Measure the weight of 100 pennies in a cup.
  - Calculate the weight of the pennies of Earth's moon, Mars, Saturn, and Jupiter

TI-Nspire™ Navigator™ System

- Send *Treasure_Trove.tns* file.
- Monitor student progress using Screen Capture.
- Collect *Treasure_Trove.tns*.
- Use Live Presenter to spotlight student data.

Activity Materials

- TI-Nspire ™ Technology
- Vernier ® EasyLink ™ or TI-Nspire ™ Lab Cradle
- Vernier Dual Range Force Sensor
- Ring stand
- Styrofoam cup and string
- 100 pennies

Data Collection Set-Up

The Styrofoam cup needs to be large enough to hold 100 pennies. To save time in class, you can make the Styrofoam cup and string scales for the lab groups ahead of time. Make sure the string is tied securely and far enough down on the cup so that the scale does not break during testing. Ring stands are better for holding the scale and force sensor if you have them available.

Depending on the math level of your students, you might need to demonstrate how to get the reciprocal of the number from the gravity chart and then use that value to calculate the weight.

Discussion Points and Possible Answers

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1. Using a Styrofoam cup and string, have students make a scale to hold the pennies. They should hook the scale onto the force sensor.
2. Have students hold the force sensor on a table with their hand or attach it to a ring stand. The cup must swing free of the table or stand

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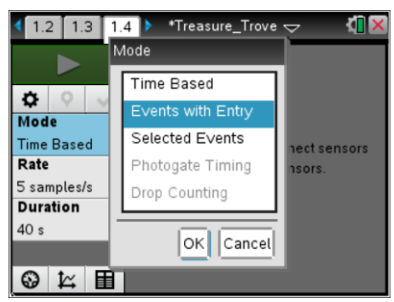
3. Have students plug the force sensor sensor into the Vernier EasyLink or TI-Nspire Lab Cradle and connect to the TI-Nspire technology. (They should make sure that the Styrofoam cup scale is in position and is not moving.)

4. Have students select **Mode: Events with Entry**. Then select the **Start** button.



5. When the reading has stabilized, have students select the **Keep** button.
6. The program asks students to enter a value. This value is the number of pennies in the cup, NOT the force. Have students type the number of pennies and select **OK**. The program returns to the data collection screen, ready for the next data point.
7. Instruct students to add 10 pennies to the cup and wait for the cup to stop swinging.
8. They should repeat steps 5 through 6 until they have 100 pennies in the cup. Students should use the number of pennies in the cup when the program asks for a value after they select the **Keep** button. After they enter the first number, the last value used

is displayed under the entry box.

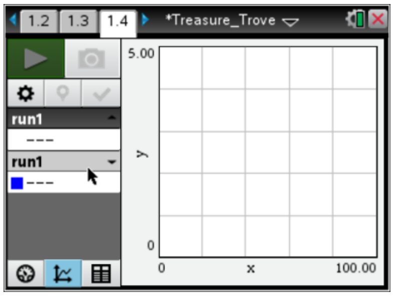
9. After students have collected the data for 100 pennies in the cup, they should select the **Stop** button. A scatter plot is displayed showing the number of pennies and force reading for all of the tests. Have students click **Table View** to display the data table on the handheld and record the values in the table below.

Sample data table. Note measured values of force may differ depending on the weight of the Styrofoam cup used.

Number of Pennies	Force (Newtons)	Force (pennies) – Force (cup)
0	0.05	0.00
10	0.3	0.25
20	0.55	0.50
30	0.80	0.75
40	1.05	1.00
50	1.30	1.25
60	1.55	1.50
70	1.80	1.75
80	2.05	2.00
90	2.30	2.25
100	2.55	2.50

10. Have students subtract the weight of the cup (number of pennies = 0) from each value in the table and record the actual weight of the pennies in the last column of the table.

11. Have students sketch and label the graph showing the number of pennies and the force readings.



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Have students answer questions 1 - 5 on their student activity sheets and/or in their .tns files.

Q1. Observe the graph showing the number of pennies and the force readings. What does the point on the *y*-axis where the number of pennies = 0 represent?

Answer: Force reading/weight of the empty cup. This point is called the *y*-intercept.

Q2. As the number of pennies increases, what happens to the force of gravity or their weight on Earth?

Answer: It increases.

Q3. What correlation does the graph show between force/weight in Newtons and the number of pennies?

Answer: If the number of pennies increases, then the force/weight increases.

Q4. What is the average rate of change in force for every 10 pennies added to the cup? How did you figure this out?

Answer: $\text{Slope} = \dfrac{\Delta \text{ force}}{\Delta \text{ number of pennies}}$

The average rate of change in force is the slope of the line that best fits this data. For the sample data provided, this value is 0.025 N/penny.

Q5. On Earth, how much would 1,000, 10,000, 100,000, and 1,000,000 pennies weigh in Newtons?

Answer: Students should use the force sensor readings to find the mean weight in Newtons of ten pennies. They should use mental math to multiply by powers of ten to calculate the weights. For the sample data provided, the mean weight of ten pennies is 0.25 N. Thus, 1,000 pennies = 250 N; 10,000 pennies = 2,500 N; 100,000 pennies = 25,000 N; 1,000,000 pennies = 250,000 N.

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14. Have students use the gravity conversion factors to complete the table of how much the pennies would weigh on the moon, Mars, Saturn, and Jupiter. (Students should use the answers from Question 5 to complete the data for the Earth.) For example, a treasure hunter could lift six times the weight on the moon as on Earth. This is because the moon has a smaller mass and diameter so the weight in Newtons of the treasure is only 1/6 as much as on Earth.

    Answer: Students answers will vary based on experimental data. To complete the table, students should enter the experimental data for the weight of 100 pennies on Earth into the table. They should use mental math to fill in the weights of the other amounts of pennies on Earth by multiplying by powers of 10 (or just insert answers from Question 5). For weights of 100 pennies on each of the other celestial bodies, students should multiply by the conversion factor. Then, students should use mental math and powers of 10 to fill out the weights for the other amounts of pennies.

    Sample data table.

Celestial Body	**Gravity Conversion Factor**	**Weight of Pennies in Newtons**				
		100 pennies	1,000 pennies	10,000 pennies	100,000 pennies	1,000,000 pennies
Earth	1.00	2.5 N	25 N	250 N	2,500 N	25,000 N
Earth's moon	0.17	0.425 N	4.25 N	42.5 N	425 N	4,250 N
Mars	0.38	0.95 N	9.5 N	95 N	950 N	9,500 N
Saturn	0.92	2.3 N	23 N	230 N	2,300 N	23,000 N
Jupiter	2.36	5.9 N	59 N	590 N	5,900 N	59,000 N

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Have students answer questions 6 - 10 on their student activity sheets and/or in their .tns file.

Q6. For every 10 pennies you lift on Earth, you can only lift about 4 pennies on Jupiter. Explain why this statement makes sense.

Answer: Jupiter's greater mass and diameter cause it to exert more gravitational pull than Earth on the pennies. The Earth exerts only about 42% of the gravitational force of Jupiter.

Q7. Fill in the blanks: The mass of 100 pennies will be **CONSTANT** at every location in the universe. The weight of 100 pennies is different. Since weight is a result of the pull of gravity on a mass, the weight of 100 pennies would **DIFFER/CHANGE** depending on its location. Weight on Earth is a measure of the **GRAVITATIONAL** force between the Earth and the 100 pennies and the distance of the pennies from the center of the **EARTH**. Since the mass of Earth's moon is smaller, it exerts only 1/6 of the Earth's gravity on the pennies. Therefore, 100 pennies should weigh **1/6** on the moon.

Q8. Fill in the blanks: The weight of 100 pennies will **VARY** in different locations. **WEIGHT** is a measure of the gravitational force between the mass of Earth, the moon, Mars, Saturn, or Jupiter and the pennies. The different masses and diameters of these celestial bodies cause different amounts of **GRAVITATIONAL** pull on the pennies. The pennies also pull back on the large bodies.

Q9. Fill in the blanks: 100 pennies weigh the *least* on **EARTH'S MOON**. This is because the **MASS** and diameter are **LESS THAN OTHER CELESTIAL BODIES** so the gravitational pull on the pennies is **SMALLER** .

Q10. Fill in the blanks: 100 pennies weigh the *most* on **JUPITER**. This is because the **MASS** and diameter are **GREATEST OF THE GIVEN CELESTIAL BODIES** so the gravitational pull on the pennies is **GREATER**.

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Have students answer question 11 by completing the table below and/or in their .tns file.

Q11. If you could lift 100 pounds (approximately 450 N) of pennies on Earth, how many pennies could you lift on each of the other celestial bodies? How much money would that be in each case?

Answer: Answers will vary. Students should use their experimental data to calculate the number of pennies weighing 450 N on Earth. From the sample data given, this would be 18,000 pennies, or $180. Then they should multiply the number of pennies you could lift on Earth by the reciprocal of the gravity conversion factor. Then, have them divide by 100 to calculate the amount of money in dollars. (Answers will vary slightly.) Students should round to the nearest penny.

Celestial Body	Number of Pennies You Could Lift	Amount of Money You Could Lift
Earth's moon	105,882	$1,058.82
Mars	47,368	$473.68
Saturn	19,565	$195.65
Jupiter	7,627	$76.27

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Have students answer questions 12 - 13 on their student activity sheets and/or in their .tns file.

Q12. If I could keep all the treasure in pennies that I could lift, I would bury my treasure on:

Answer: Earth's moon

Q13. If a treasure hunter can lift 50 pounds of pennies on Earth, what is the maximum number of pounds this person can lift on each of the other celestial bodies? (Round to the nearest pound.)

294 pounds on Earth's moon

132 pounds on Mars

54 pounds on Saturn

21 pounds on Jupiter

Wrap Up

After the students have finished the lab, look back at their answers, and discuss the differences in their results. If they didn't obtain similar values for the weight of 100 pennies, discuss reasons that the values might not be the same (calculation error, some pennies might have different masses, etc).