EXPLORATIONS

Activity 20

Treasure Trove

Objectives

- To understand the difference between mass and weight
- To determine the difference in weight an object on the moon, Mars, Saturn, and Jupiter

Materials

- TI-73
- Unit-to-unit cable
- CBL 2™
- Dual Range Force sensor
- Ring stand
- Styrofoam cup and string
- 100 pennies
- Data Collection and Analysis pages (p. 191 - 194)

In this activity you will

- Use the CBL 2™ with a force sensor to measure the weight of 100 pennies in Newtons.
- Calculate the weight of 100 pennies on the moon, Mars, Saturn, and Jupiter.

Problem

If you could keep all the treasure in pennies that you could lift, would you bury your treasure on Earth, the moon, Mars, Saturn, or Jupiter?

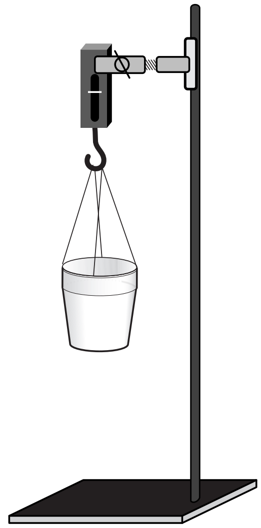
Introduction

The mass of an object stays the same no matter where it is located. The mass is the amount of matter measured in grams or kilograms. Weight on Earth is a measure of the gravitational pull between Earth and the object on Earth's surface. Weight on other celestial bodies is different from Earth due to their different masses and diameters (which changes the distance of the object being weighed on the surface from the center of the body).

Since weight is a result of the pull of gravity on a mass, the weight of 100 pennies would change depending on its location. The force sensor measures the weight of a mass in Newtons. If you know how much 100 pennies weigh on Earth, you can figure out how much they weigh on the moon, Mars, Saturn, and Jupiter.

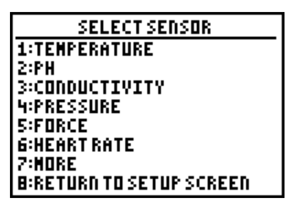
Hypothesis

Before testing, complete the **Hypothesis** on the **Data Collection and Analysis** page to predict where you could lift the most pennies.

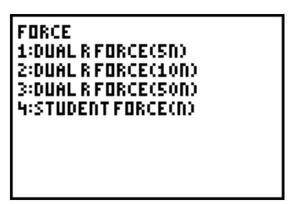


Procedure: Collecting the Data

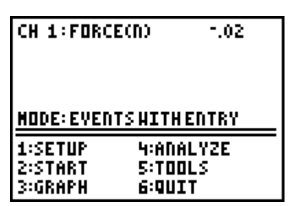
1. Using a Styrofoam cup and string, make a scale to hold the pennies. Hook your scale onto the force sensor.
2. Hold the force sensor on a table with your hand or attach it to a ring stand. The cup must swing free of the table or stand.
3. Plug the force sensor into Channel 1 (**CH 1**) on the CBL 2™ using the DIN adapter, if necessary.
4. Start the DATAMATE program.
5. The Main Screen is displayed. If **CH 1:FORCE (n)** is displayed at the top of the screen, go to step 10. If **CH 1:FORCE(n)** is not displayed, go to step 6.
6. Select **1:SETUP**.
7. Select **CH 1**. Select **5:FORCE**.



8. Select the type of force sensor you are using. If you are using the 10 or 50 range sensor, select **2:DUAL R FORCE 10(N).**



9. Select **1:OK** to return to the Main Screen.
10. If **MODE:EVENTS WITH ENTRY** is displayed, go to step 14. If not, got to step 11.



11. Select **1:SETUP**.

12. Select **MODE**, and then select **3:EVENTS WITH ENTRY**.
13. Select **1:OK** to return to the Main Screen.
14. Make sure that the Styrofoam cup scale is in position and is not moving.
15. When you are ready to begin, select **2:START**.
16. Press [ENTER] to get the force reading for the cup.
17. The program asks you to enter a value. This value is the number of pennies in the cup, NOT the force. Type the number of pennies and press [ENTER]. The program returns to the data collection screen, ready for the next test.
18. Add 10 pennies to the cup and wait for the cup to stop swinging.
19. Repeat steps 16 through 18 until you have 100 pennies in the cup. Use the number of pennies in the cup when the program asks for a value after you press [ENTER]. After you enter the first number, the last value you used is displayed at the bottom of the screen.
20. After you have collected the data for 100 pennies in the cup, press [STO▶]. A scatter plot is displayed showing the number of pennies and force reading for all of your test. Use [▶] and [◀] to move to each data point. Record the values in the table on the **Data Collection and Analysis** page.
21. On the **Data Collection and Analysis** page, sketch and label the graph.
22. To exit from the DATAMATE program, press [ENTER] to return to the Main Screen. Select **6:QUIT** and press [ENTER].
23. To display the lists showing the results, press [LIST]. The number of pennies is stored in **L1**. The force readings are stored in **L2**.

Data Analysis

After testing, complete the questions on the **Data Collection and Analysis** page to find the weight of the pennies on other celestial bodies.

Application

- Write a linear equation that would be a close model for this data. Use the cup weight as the *y*-intercept and the average rate of increase as the slope. What do *x* and *y* represent? Enter the equation into the Y= editor. Set the window for a domain of 0 to 11 and a range to fit the force readings from **L2**.
- Algebra students: Run a linear regression on the data to find a model for the line that best models the data. What does the slope of this line represent?
- 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?

Extensions

- *Math:* How much would 100 million pennies weigh on Earth, the moon, Mars, Saturn, and Jupiter?
- *Language Arts:* Use what you know about the planets in our solar system, gravity, mass, and weight to write a treasure story. Include how many pennies (math) and how many you could lift due to the effect of the gravity on each body (science). Think of a problem that can be solved in the treasure story by scientific reasoning.
- *Science:* Measure how high each class member can jump. Multiply the height by the reciprocal of the number used for the gravity relative to Earth (1.0 = Earth's gravity) to see how high each person would jump on the moon, Mars, Saturn, and Jupiter. Would you jump higher on bodies having smaller or larger masses? As the mass of the planet increases, what happens to your jumping height?

Data Collection and Analysis

Name ______________________

Date ______________________

Activity 20: Treasure Trove

Problem

If you could keep all the treasure in pennies that you could lift, would you bury your treasure on Earth, the moon, Mars, Saturn, or Jupiter?

Hypothesis

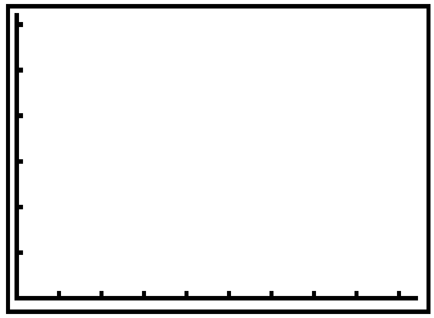
If I could keep all the treasure in pennies that I could lift, I would bury my treasure on ____ .

Data Collection

1. After weighing all of the pennies, record the weights in the table below. Then subtract the weight of the cup (number of pennies = 0) from each value and record the actual weight of the pennies in the last column of the table.

Number of pennies	Force (Newtons)	Force (pennies) – Force (cup)
0		
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		

2. Sketch and label the graph showing the number of pennies and the force readings, or print the graph on the computer and attach it to this page.



Data Analysis

Using the table and graph, answer the following questions to find the weight of the pennies on other celestial bodies.

1. What does the point on the *y*-axis where the number of pennies = 0 represent?

____

____

____

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

____

____

____

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

____

____

____

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

____

____

____

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

____

____

____

6. Use the gravity conversion factors to complete the table of how much the pennies would weigh on the moon, Mars, Saturn, and Jupiter. (Use your answers from question 5 to complete the data for the Earth.)

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					
Earth's moon	0.17					
Mars	0.38					
Saturn	0.92					
Jupiter	2.36					

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.

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

____

____

____

8. The mass of 100 pennies will be ________________ 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 ___________ depending on its location. Weight on Earth is a measure of the ___________ force between the Earth and the 100 pennies and the distance of the pennies from the center of the ________________. 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 ________________ on the moon.

9. The weight of 100 pennies will __________________ in different locations. __________________ 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 __________________ pull on the pennies. The pennies also pull back on the large bodies.

Conclusion

1. 100 pennies weigh the least on ____________________. This is because the ____________________ and diameter are ____________________ so the gravitational pull on the pennies is _________________________________ .
2. 100 pennies weigh the most on ____________________. This is because the ____________________ and diameter are ____________________ so the gravitational pull on the pennies is _________________________________ .
3. If you could lift 100 pounds 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?

Celestial Body	**Number of Pennies You Could Lift**	**Amount of Money You Could Lift**
Earth's moon		
Mars		
Saturn		
Jupiter		

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

Application

- 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.)

  50 pounds on Earth

  __________ pounds on Earth's moon

  __________ pounds on Mars

  __________ pounds on Saturn

  __________ pounds on Jupiter

Teacher Notes

Activity 20

Treasure Trove

Objectives

- To understand the difference between mass and weight
- To determine the difference in weight an object on the moon, Mars, Saturn, and Jupiter

NSES Standards

- Earth and Space Science: Earth in the solar system

Preparation

- 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.

Management

- Assign these student jobs for this lab:
  - Materials/setup person (sets up samples, sensor)
  - Tech person (operates CBL 2™ and TI-73)
  - Data recorder (reads force readings from the TI-73 at each collection interval)
  - Runner (brings CBL 2 and TI-73 to the computer to print graphs with TI-GRAPH LINK™ or TI™ Connect and brings **Data Collection and Analysis** pages to the teacher)
- Clear covered plastic shoeboxes will hold the CBL 2™, temperature sensors, and other equipment neatly at each station.
- Students can record data points in their lab journals as they are displayed on the TI-73. This keeps them engaged throughout the data collection period and if they lose the data/graph later, they can still write up their lab reports. Students can also access the data in the TI-73 lists after data collection. You can send lists to all students' calculators using [APPS] **1:Link**.

a. Press [APPS].

b. Press [ENTER] to select **1:Link.**

c. Select **4:List** and press [ENTER].

d. Press [▼] to move the ▶ beside the list you wish to send. Press [ENTER].

e. Repeat step **d** for each list you wish to send.

f. Set the receiving unit by pressing [APPS] [ENTER] [▶] to select **RECEIVE**. Press [ENTER]. **Waiting…** displays on the TI-73 screen.

g. On the sending unit, press [▶] to select **TRANSMIT** and press [ENTER].

For more permanent storage of data, use TI-GRAPH LINK™ or TI™ Connect to save the lists in a computer folder. However, students may inadvertently lose their data or overwrite it in the next trial, so recording data in journals is a good option.

- Students can assess each other using a teamwork rubric after the lab. Provide a checklist of positive and negative behaviors. Copy these on quarter sheets of paper.
- Students can collect data in science class and analyze it in math class to emphasize interdisciplinary connections.

Selected Answers

Data Analysis

1. What does the point on the *y*-axis where the number of pennies = 0 represent?

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

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

   It increases.

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

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

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

   $$\text{Slope} = \frac{\Delta\ \text{force}}{\Delta\ \text{number of pennies}}$$

   The average rate of change in force is the slope of the line that best fits this data.

   There are two possible methods for solving:

   – *Find the mean of the differences in the y-list (force) using the ΔList option on the TI-73.*

– *Find the slope of the line of best fit for this scatter plot. Slope equals the rate of change.*

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

Use your CBL 2 force readings to find the mean weight in Newtons of ten pennies. Use mental math to multiply by powers of ten to calculate the weights.

6. Use the gravity conversion factors to complete the table of how much the pennies would weigh on the moon, Mars, Saturn, and Jupiter.

Answers will vary based on experimental data.

Procedure for Table 2:

Enter the experimental data for the weight of 100 pennies on Earth into the table. 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 bodies, multiply by the conversion factor. Use mental math and powers of 10 to fill out the weights for the other amounts of pennies.

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					
Earth's moon	0.17					
Mars	0.38					
Saturn	0.92					
Jupiter	2.36					

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

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.

8. 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 as much* on the moon.

9. 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.

Conclusion

1. 100 pennies weigh the least on *Earth's moon*. This is because the *mass* and diameter are *less than the other bodies* so the gravitational pull on the pennies is *smaller*.

2. 100 pennies weigh the most on *Jupiter*. This is because the *mass* and diameter are *greatest of the given bodies* so the gravitational pull on the pennies is *greater*.

3. If you could lift 100 pounds 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?

   Procedure:

   Use your experimental data to calculate the number of pennies weighing 100 lbs. on Earth. Multiply the number of pennies you could lift on Earth by the reciprocal of the gravity conversion factor. Divide by 100 to calculate the amount of money in dollars. (Answers will vary slightly.) Round to the nearest penny.

4. If I could keep all the treasure in pennies that I could lift, I would bury my treasure on *the Earth's moon*.

Application

50 pounds on Earth

≈ *294* pounds on Earth's moon

≈ *132* pounds on Mars

≈ *54* pounds on Saturn

≈ *21* pounds on Jupiter