Bell Ringer: Charge Decay – ID: 13721

Based on an activity by Irina Lyublinskaya

Time required
15 minutes

Topic: Electricity and Magnetism

- *Describe the decay of induced charge over time.*

Activity Overview

In this activity, students use a precompiled data set to explore the process of discharging or “leakage” of charge over time and compare that with an exponential decay model.

Materials

To complete this activity, each student will require the following:

- *TI-Nspire™ technology*
- *pen or pencil*
- *blank sheet of paper*

TI-Nspire Applications

Data & Statistics, Lists & Spreadsheet, Notes

Teacher Preparation

Before carrying out this activity, review with students the concepts of charge transfer by contact and electric discharge. Students should be familiar with static electricity, charge polarity, electric conductors, and dielectric materials.

- *A good resource for teachers is the article “Electrostatics with Computer-Interfaced Charge Sensors” by Robert A. Morse, published in the journal* The Physics Teacher, *Vol. 44, November 2006, p. 498–502.*
- *The screenshots on pages 2–5 demonstrate expected student results. Refer to the screenshots on page 6 for a preview of the student TI-Nspire document (.tns file).*
- ***To download the student .tns file and solution .tns file, go to education.ti.com/exchange and enter “13721” in the search box.***
- *This activity is related to activity 10542: Charge Transfer. If you wish, you may extend this bell-ringer activity with the longer activity. You can download the files for activity 10542 at education.ti.com/exchange.*

Classroom Management

- *This activity is designed to be* ***teacher-led*** *with students following along on their handhelds. You may use the following pages to present the material to the class and encourage discussion. Note that the majority of the ideas and concepts are presented only in* ***this*** *document, so you should make sure to cover all the material necessary for students to comprehend the concepts.*
- *Students may answer the questions posed in the .tns file using the Notes application or on blank paper.*
- *In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.*

The following questions will guide student exploration during this activity:

- Does induced or transferred charge change over time? Why? What factors affect this process?

The purpose of this activity is for students to explore the process of discharging, also known as leakage. The data set used in this activity was collected using a charge sensor. A piece of cellophane tape was charged and placed inside a metal can. The induced charge on the can was measured over time.

Step 1: Students should open the file **PhysBR_week28_Charge_decay.tns** and read the first two pages. They should then answer questions 1–3.

Q1. What happens over time to the charge of an object that has been charged by rubbing?

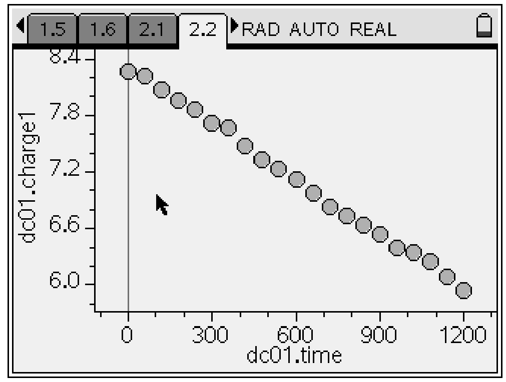
A. *In general, the charge “leaks off” onto water molecules in the air. This is because the water molecules are polar. Thus, the extra electrons, for example, are attracted to positive ends of water molecules.*

Q2. How does humidity affect static electricity?

A. *On a dry day, static electricity is more noticeable because air contains fewer water molecules to allow leakage. On a humid or rainy day, it is hard to make any object hold a net charge for long.*

Q3. A student placed a charged object inside a metal can, inducing a charge on the can. The student then recorded how the charge on the can changed over time. What functional form do you think the data will have? Explain your answer.

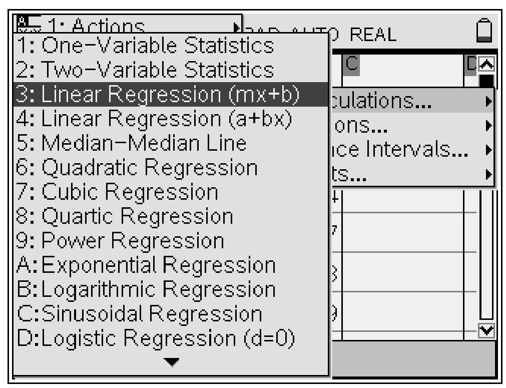
A. *Student answers will vary. Students should reason that the charge will leak off the can over time, so they should predict some form of inverse curve. The rate of discharge is proportional to the initial charge on the can, so some students may be able to reason that the discharge should follow an exponential curve.*



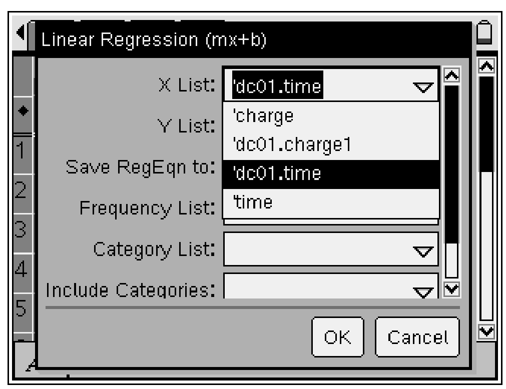
Step 2: Next, students should move to page 2.1, which shows the data collected during the experiment. Students should study the data and then move to page 2.2, which contains an empty *Data & Statistics* application. Students should make a plot of **dc01.charge1** vs. **dc01.time** on the *Data & Statistics* page. To make the plot, students should click (press) on the area just below each axis. A list of available variables will pop up. They should choose **dc01.time** for the *x*-variable and **dc01.charge1** for the *y*-variable. Alternatively, they can add the *x*- and *y*-variables using the **Plot Properties** menu (**Menu > Plot Properties > Add X Variable** or **Add Y Variable**). Students should study the graph and then answer question 4.

Q4. What mathematical function appears to best fit the data that describe the change of charge over time?

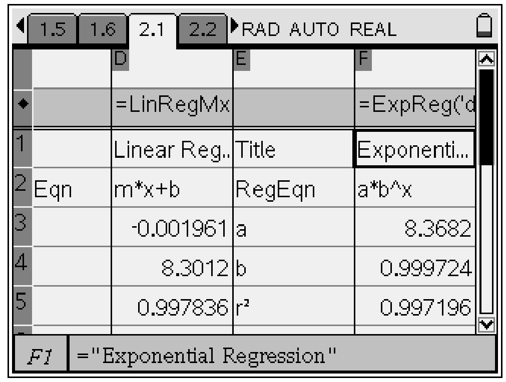
A. *Answers will vary. Students should be able to justify their answers.*



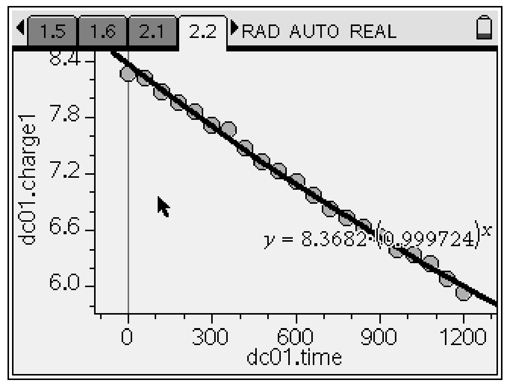
Step 3: Next, students should move back to page 2.1. They should use the **Regression** tool (**Menu > Statistics > Stat Calculations**) to calculate the regression equation for the data. They should use whatever equation form they think best fits the data. In the **Regression** dialog boxes, they should use the data in column A (**dc01.time**) for the X List and the data in column B (**dc01.charge1**) for the Y List. They should save the data to column C.



Step 4: Students should repeat Step 3 using a different type of regression, saving the data to column E. They should compare the r^2 values of the regressions to determine which provides the best fit to the data.



Step 5: Next, students should move to page 2.2 and plot the regression equation that best fits the data. They should use the **Regression** tool (**Menu > Analyze > Regression**) to plot the regression. Then, they should answer questions 5 and 6.



Q5. Write the mathematical equation for the best-fit line for your data.

A. *For the sample data, the best-fit exponential line has the equation $y = 9.5 \cdot (0.9998)^x$. Note that this is extremely close to a linear function. Students may also choose to perform a linear regression on the data. Encourage students to compare the r^2 values for these two functions. You may wish to discuss these results with students. The “true” decay relationship should be exponential in form. However, if the sampling time is short relative to the decay rate, then students will see only a small portion of the decay curve. This portion can be approximated by a linear function. You should also discuss with students the importance of thinking about the physical implications of a mathematical model. For example, in this case, although a linear equation appears to fit the data, the physical implications of the linear model are not realistic. A linear model suggests that as time increases, electric charge eventually becomes negative—that is, that the object continues to lose charge even after it has lost all of its excess positive charge. This is not a physically plausible model.*

Q6. Do your results agree with the prediction you made in question 3? If not, identify any errors in reasoning that you made.

A. *Answers will vary. Encourage metacognitive thinking to help students identify their errors in reasoning.*

Suggestions for Extension Activities: If you wish, you may have students plot both regression equations and compare the fits visually. They can discuss the meaning of the r^2 value and why a mathematical regression analysis is a more reliable way than visual matching to calculate a best-fit line.

Charge Decay – ID: 13721

(Student)TI-Nspire File: *PhysBR_week28_Charge_decay.tns*

1.1

CHARGE DECAY

Physics

Electrostatics

1.2

In this activity, you will explore how induced charge "leaks" over time.

1.3

1. What happens over time to the charge of an object that has been charged by rubbing?

1.4

2. How does humidity affect static electricity?

1.5

3. A student placed a charged object inside a metal can, inducing a charge on the can. The student then recorded how the charge on the can changed over time. What functional form do you think the data will have? Explain your answer.

1.6

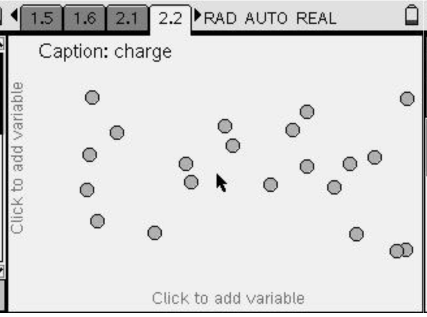
The data on the next page show how an induced charge on an object changed over time.

2.1

	A dc01.time	B dc01.charge1
1	0.	8.26005
2	60.	8.21244
3	120.	8.06367
4	180.	7.96548
5	240.	7.86729

A1 0.

2.2



2.3

4. What mathematical function appears to best fit the data that describe the change of charge over time?

2.4

5. Write the mathematical equation for the best-fit line for your data.

2.5

6. Do your results agree with the prediction you made in question 3? If not, identify any errors in reasoning that you made.

