

Let's explore the science of thermal runaway

Learning Target: I can ask questions and begin to define a design problem about the causes and effects of thermal runaway in lithium-ion powered devices.

Watch the intentional e-scooter overcharge video featuring research by the Fire Safety Research Institute on the hazards of thermal runaway.



List 4-5 things that you **noticed** in the video:

List 4-5 things that you are **wondering** about after watching the video

What is thermal runaway?

Considering the information on this page, organize your thinking in your own words on the following questions:

What is thermal runaway? Where does thermal runaway occur? What are the impacts of thermal runaway? Do you have initial ideas for preventing thermal runaway?

In order to solve the problem, I need to know:

Brainstorm any logistic or technical questions that you'll need to answer in order to fully understand the problem and deliver a safe enclosure.

Model thermal runaway

Develop a model of your device here (or on poster paper). Add important labels, like where the battery is located. Throughout your investigation, you will return to and update this model. Draw a model of a lithium-ion battery-powered device experiencing thermal runaway. We will continue to add to this model as we learn more about the problem of thermal runaway.

Tips for drawing a model:

- A model is a representation of an experiment or phenomenon
- Begin with a simple image, picture, or even outline. It does not need to be a perfect, life-like reproduction
- Models bring important features into focus and ignore less important features. Only include features you think are important in your model

How does a lithium-ion battery work?

I can plan and carry out an investigation as I begin to identify criteria and constraints of the design problem as it relates to the interactions of matter and energy associated with energy transformations in lithium-ion battery-powered devices.

Develop a model of a lithium-ion battery. (Label all components of the system.) You may come back to this model and refine it as you learn more about lithium-ion batteries.

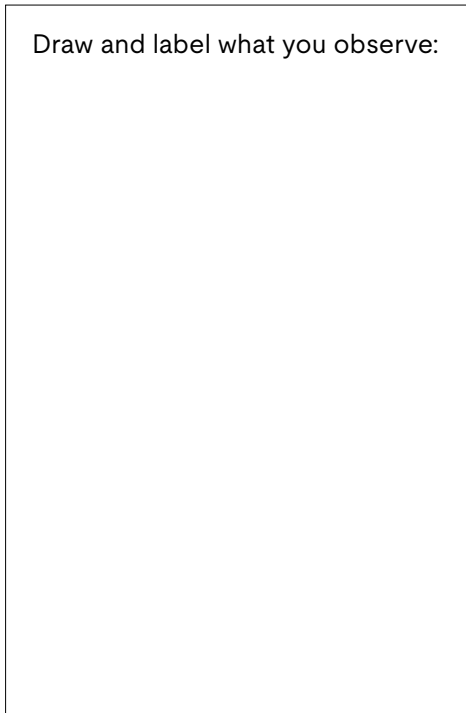
What kinds of energy transfer or transformation does a battery perform? How do they occur?

Describe a lithium-ion battery's role within a circuit.

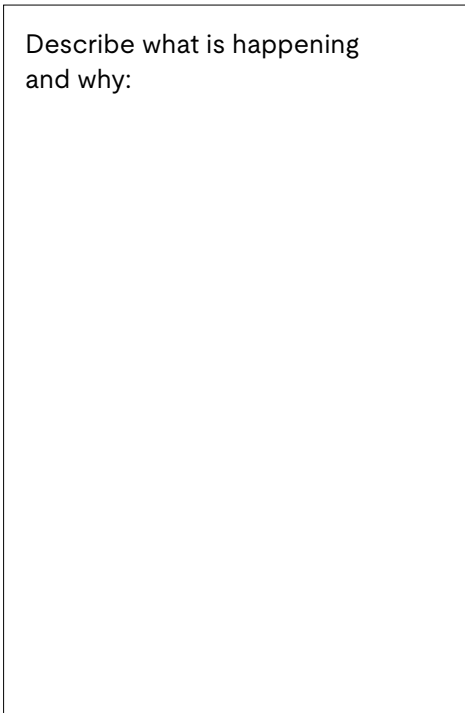
What is a short circuit?

Watch the video of the bologna test (or perform the bologna test yourself).

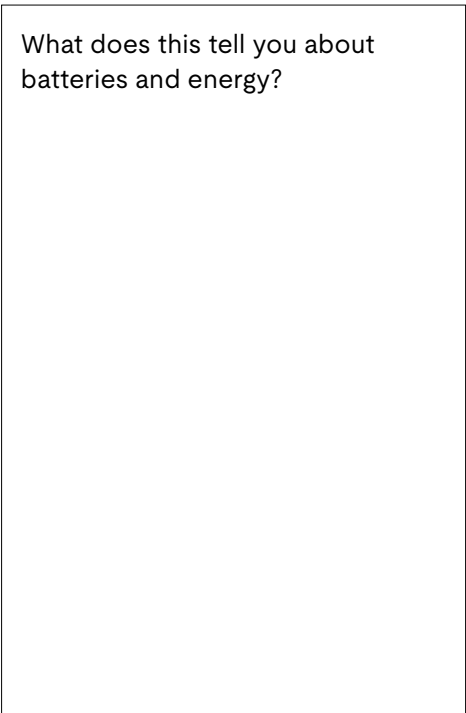
Draw and label what you observe:



Describe what is happening and why:



What does this tell you about batteries and energy?



Gather this information

Describe how ions in a lithium-ion battery move during charge and discharge.

Define the function of a lithium-ion battery's separator. Explain in your own words why it is important.

What are the benefits of using lithium-ion batteries?

Analyze the two battery types:

What are some similarities?

What are some differences?

What is the relationship between a lithium-ion cell and battery?

What changes about a lithium atom to make it a lithium ion?

Describe the transformations of energy that result in thermal energy in lithium-ion battery-powered devices?

In your own words, summarize: *How does a lithium-ion battery work?*

Return to your initial model of thermal runaway (pg. 2)

Add and/or label:

- The lithium-ion battery in the device, including essential components Begin with a simple image, picture, or even outline. It does not need to be a perfect, life-like reproduction
- The energy source, conductor, and load in the device's circuit
- The transformations of energy that are occurring
- Be sure you've identified any thermal energy that results from transformations of energy

Tips for improving your model:

- Consider adding arrows to show direction
- You can make concepts that are invisible, visible using labels and symbols"

Why are battery-powered devices designed to prevent physical damage?

Note: Tests should only be performed on lithium-ion batteries and the devices powered by them in a controlled laboratory setting by professionals and with proper safeguards in place. You should never attempt to perform abuse tests on lithium-ion batteries and their devices yourself. If this kind of testing appeals to you, consider pursuing a career as a safety engineer.

I CAN carry out an investigation as I further identify criteria and constraints of the design problem to address the interactions of matter and energy associated with energy transfer in overcharging lithium-ion powered devices.

Besides the examples given in the module, what are some real-world conditions similar to the tests?

What do you observe in the test video?

Why did this test result in thermal runaway?

Besides the examples given in the module, what are some real-world conditions similar to the tests?

Crush Test

Blunted Nail Test

Drop Test. Online, drop the hoverboard from at least one short, medium, and tall height. Record your observations below:

Height

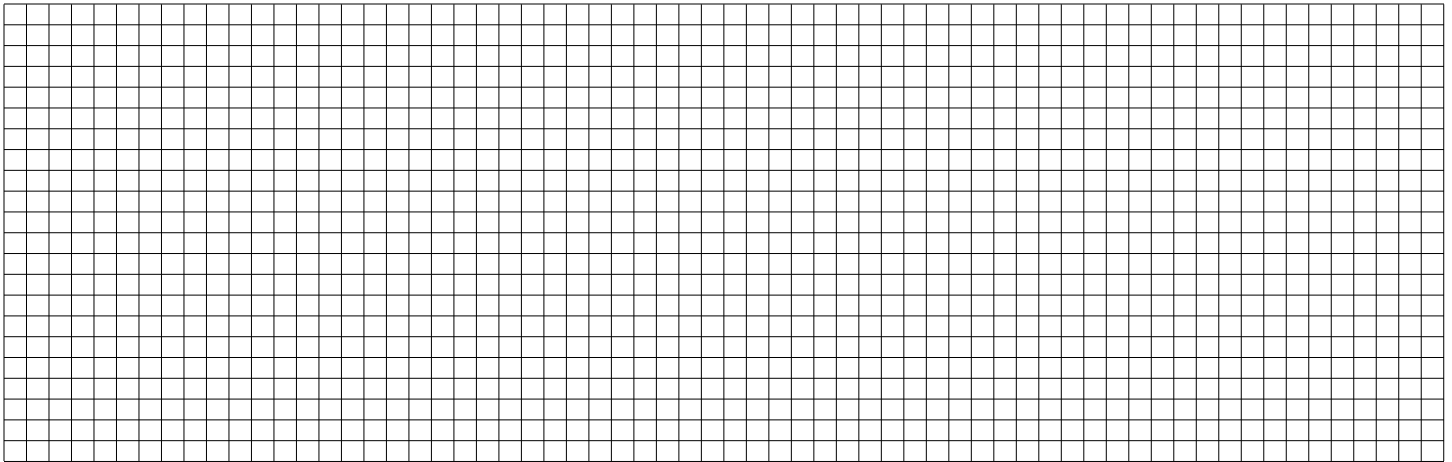
Evidence of physical damage

Run results (include battery temperature and qualitative data)

Is the hoverboard "safe"? Why or why not?

What are your conclusions from the investigation?

Select two variables from your table above. Graph the relationship between them below



In your own words, summarize: *Why are battery-powered devices designed to prevent physical damage?*

Return to your initial model of thermal runaway (pg. 2)

Add and/or label:

- The effects of physical damage on the lithium-ion battery in your device
- The effects of physical damage on the exterior of your device
- Some potential hazards facing your device that could cause physical damage (and potential solutions)

Tips for improving your model:

- Add additional information to the side of your model if necessary
- Consider using color to indicate types or categories of information

How does overcharge connect to thermal runaway?

Note: Tests should only be performed on lithium-ion batteries and the devices powered by them in a controlled laboratory setting by professionals and with proper safeguards in place. You should never attempt to perform abuse tests on lithium-ion batteries and their devices yourself. If this kind of testing appeals to you, consider pursuing a career as a safety engineer.

I CAN carry out an investigation as I further identify criteria and constraints of the design problem to address the interactions of matter and energy associated with energy transfer in overcharging lithium-ion powered devices.

Watch the abusive overcharge test video.

What do you observe in the test video?

What do you observe in the test video?

Why did this test result in thermal runaway?

Besides the examples given in the module, what are some real-world conditions similar to the tests?

What is voltage?

What is the impact of excessive voltage on a battery?

Define the function of a lithium-ion battery's battery management system (BMS). Explain in your own words why it is important.

Charger test data collection

Choice 1

Choice 2

What data does the label for your **charger** choice include?

What data does the input label for the **hoverboard** include?

Predict: What do you anticipate will happen when using this charger? Why do you think this will happen?

Observe: What occurred? Include quantitative and qualitative data.

What are your conclusions from the investigation?

What factors are important to consider when selecting a charger for your own lithium-ion battery-powered devices?

In your own words, summarize: How does overcharge relate to thermal runaway?

Return to your initial model of thermal runaway (pg. 2)

Add and/or label:

- The way that the battery inside the device receives energy
- Text, numbers, labels, and/or symbols that indicate a charger is appropriate for the device

Tips for improving your model:

- Labels can emphasize relevant information

How does thermal runaway spread?

Note: Tests should only be performed on lithium-ion batteries and the devices powered by them in a controlled laboratory setting by professionals and with proper safeguards in place. You should never attempt to perform abuse tests on lithium-ion batteries and their devices yourself. If this kind of testing appeals to you, consider pursuing a career as a safety engineer.

I CAN carry out an investigation as I further identify criteria and constraints of the design problem to address the interactions of matter and energy associated with energy transfer in overcharging lithium-ion powered devices.

Watch the Fire Exposure and Projectile test video:

What do you observe in the test video?

Why did this test result in thermal runaway?

Besides the examples given in the module, what are some real-world conditions similar to the tests?

How could one cell in thermal runaway physically damage another?

Why does heat present a risk of thermal runaway for lithium-ion batteries?

How can the heat generated by one cell in a battery impact other cells or the device as a whole?

Why is it important for a lithium-ion battery to lose heat at a safe rate?

What kinds of design features or materials would decrease the risk of thermal runaway spreading from cell to cell or battery to battery?

Summarize: How does thermal runaway spread?

Why is it important for a lithium-ion battery to lose heat at a safe rate?

What kinds of design features or materials would decrease the risk of thermal runaway spreading from cell to cell or battery to battery?

Summarize: How does thermal runaway spread?

Return to your initial model of thermal runaway (pg. 2)

Add and/or label:

- The materials in the device and how their physical or chemical properties impact the likelihood of thermal runaway
- The design features of the device that impact the temperature of the battery

Tips for improving your model:

- Highlight important features using labels and arrows
- It is common practice to finalize a model by creating a cleaned-up copy synthesizing overall understanding. You have space to do so below

Solve the scenario:

Identify sources of risk in the scene and explain why each one is hazardous.

Make a claim: What do you think was the most probable cause of the thermal runaway?

Support your claim with evidence: Describe what you see in the room that supports your claim. Consider the causes of thermal runaway that you learned during the Science of Thermal Runaway pathway.

Provide reasoning: Use scientific knowledge you learned during the Science of Thermal Runaway pathway to explain how the evidence supports your claim.