Introduction to the problem: 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 introduction to the problem video and record your observations.

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

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

For this project, your job is to consider safer ways to make lithium-powered devices. your job is to consider how engineers would more safely design a lithium-ion battery enclosure for an e-mobility device (for example, an electric scooter, electric bicycle, or hoverboard). Your enclosure should prevent the problem known as thermal runaway, which you saw in the video.

In your own words, describe what you know right now about the problem of thermal runaway:

Connect the Introduction to Your Engineering Design Challenge

After watching the introduction video, choose an electrical device for which you'll design a safer battery enclosure, or space around a battery. What electrical device will your design protect? It could be a device that you own, one that you want, or one that you've only heard about.

If you are stuck, ask your teacher for a ***"real-world device card"***

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.

After modeling, fill in this draft problem statement:

We as _____ **will design a safer space for a** _____ **Li-ion battery**
team name/role *device*

Driving Question 1: How does a lithium-ion battery work?

In this online investigation, you gather and analyze data to learn key scientific information about causes of thermal runaway and its potential effects. This is information that engineers use when designing and testing devices.

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 throughout the driving question:

List uses of lithium-ion batteries

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

Develop a model of a lithium-ion battery during discharge. (Label all components of the system.)

Develop a model of a lithium-ion battery during recharge. (Label all components of the system.)

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

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

What are some advantages of using lithium-ion batteries?

What do you think are disadvantages or potential concerns for lithium-ion use?

Connect Driving Question 1 to your engineering design challenge: DEFINE THE ENERGY TRANSFERS AND TRANSFORMATIONS

In this online investigation, you gather and analyze data to learn key scientific information about causes of thermal runaway and its potential effects. This is information that engineers use when designing and testing devices.

How does your device use energy? Is any energy lost to the environment?

Copy your initial drawing of the device and battery to the space below (or continue on the back or the poster paper), add markings, arrows, labels, or symbols to show the types of energy that are involved in your device charging and uncharging.

Add your thinking about energy changes to your draft problem statement:

We as _____ **will design a safer space for a** _____ **Li-ion battery.**
team name/role *device*

to minimize _____ **while charging and uncharging**
unwanted energy changes

Driving question 2: 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.*

Watch the abusive overcharge test video.

What is voltage?

What is the impact of excessive voltage on a battery?

Identify the hazard that can lead to a dangerous battery event.

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?

Explain your thinking about the following questions from evidence gathered throughout the driving question:
Describe the impact that voltage and current have on lithium-ion batteries.

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

What is the relationship between overcharge and thermal runaway?

Connect Driving Question 2 to the engineering design challenge: OVERCHARGE

Think about why overcharge occurs and why it can lead to thermal runaway. How can your design prevent this? Use a new color to update your design model to incorporate at least one potential solution to the problem of thermal runaway based on what you know now about overcharge.

Add your thinking about energy changes to your draft problem statement:

We as _____ **will design a safer space for a** _____ **Li-ion battery.**
team name/role *device*

to minimize _____ **while charging and uncharging**
unwanted energy changes

with the appropriate charger to avoid _____ **.**
risk from mismatched chargers

Driving Question 3: Why are battery-powered devices designed to prevent 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.*

	Crush Test	Blunted Nail Test
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?		

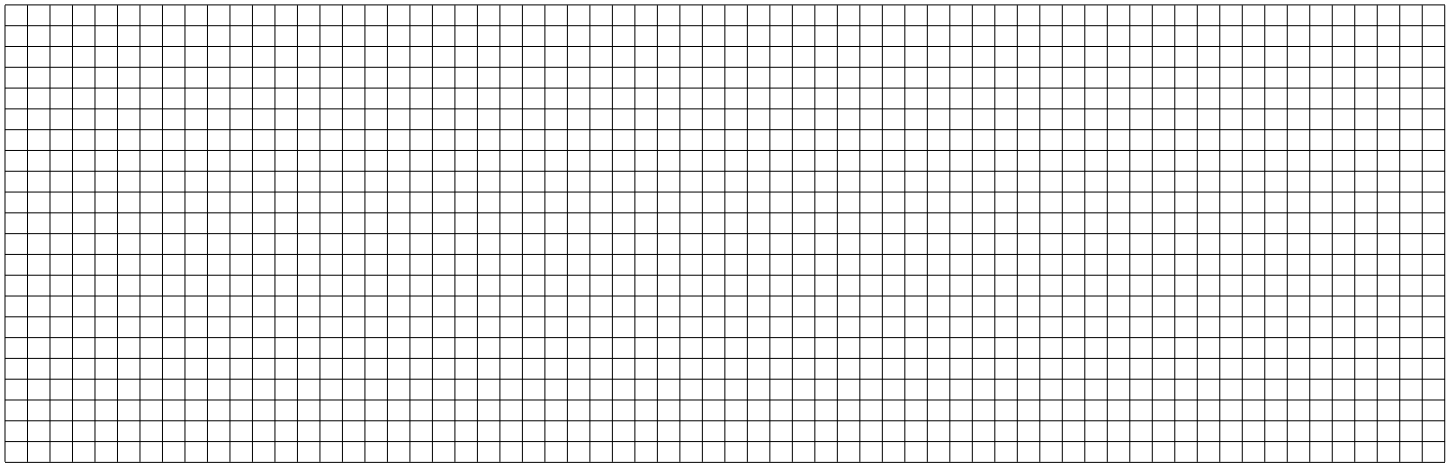
Drop Test

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?

Graph your data below.



Connect Driving Question 3 to the engineering design challenge: ADDRESS DAMAGE IN YOUR DESIGN

How might your device be damaged and lead to thermal runaway? Update your design model to incorporate at least one potential solution to the problem of thermal runaway. This solution needs to be based on what you know now about how a damaged battery can lead to thermal runaway.

Add your thinking about energy changes to your draft problem statement:

We as _____ will include _____ in our designed _____ .

This will minimize risks associated with product damage because _____ .

We as _____ will design a safer space for a _____ Li-ion battery. To minimize _____
team name/role *device* *unwanted energy changes*

while charging and uncharging with the appropriate charger to avoid _____ . Protecting the
risk from mismatched chargers

battery from external damage caused by _____ which could lead to thermal runaway.
possible damage to your device

Driving Question 4: 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.*

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?

Compounding the risks of thermal runaway video:

What do you observe in the test video showing the cube of cells?

Why did this test result in thermal runaway of all the cells in the cube?

Based on your observation, why is it important that the battery's casing not be flammable?

What are the tradeoffs between physical strength of a battery enclosure and thermal insulation as it relates to the entire battery's system?

Connect Driving Question 3 to the engineering design challenge: ADDRESS DAMAGE IN YOUR DESIGN

How might your device be damaged and lead to thermal runaway? Update your design model to incorporate at least one potential solution to the problem of thermal runaway. This solution needs to be based on what you know now about how a damaged battery can lead to thermal runaway.

Add your thinking about energy changes to your draft problem statement:

We as _____ **will design a safer space for a** _____ **Li-ion battery. To minimize** _____
team name/role *device* *unwanted energy changes*

while charging and uncharging with the appropriate charger to avoid _____ **. Protecting the**
risk from mismatched chargers

battery from external damage caused by _____ **which could lead to thermal runaway**
possible damage to your device

and preventing the spread of thermal runaway by avoiding _____ **.**
excessive internal or external temperatures, explosions, or projectiles

Scenario-based assessment:

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

Which source of risk do you think was the source of the thermal runaway? **Support your claim with evidence and reasoning.**