UL XPLORLABS

PORTABLE ELECTRICAL POWER

STUDENT

TENSILE TEST AND DURABILITY

CASE STUDY OF SCIENCE AND ENGINEERING

SCIENTISTS ASK WHY. ENGINEERS ASK HOW.

YOUR NAME

QUESTIONS TO XPLORE

WHAT IS THE MOST DURABLE MATERIAL TO USE FOR AN ENCLOSURE?

Maybe you have heard about lithium-ion batteries. They are used as a power source in portable electrical and electronic products like smart phones, electric vehicles, hoverboards, and yes, even robotic lawn mowers. While the rate of failures of these batteries is small, several well-publicized incidents related to lithium-ion batteries (including fires and explosions) have raised concerns about their overall safety.

Just like you are learning to follow procedures in scientific tests, there are specific test standards that safety scientists follow that help determine specific risks associated with the use of lithium-ion batteries. It is this type of safety science-based testing, following safety standards, that help identify if the way a product is made and/or how it is used can cause harm. Safety engineers follow set procedures to find out what could present a risk to the people who buy and use the product.

Lithium-ion battery technologies are evolving. Improvements to the batteries mean that they have the ability to store more energy in a smaller package, have a longer life cycle, and improved reliability.

Yet, there are tradeoff's when producing more power! One thing that has not changed is that batteries produce heat. When designing a product that uses lithium-ion batteries, consideration has to be given to the amount of heat the batteries produce and where that heat goes. Products like hoverboards need an enormous amount of power, so batteries are bundled together to form a battery pack (there can be up to 20 in one hoverboard!). Can you imagine how much heat a bundled battery pack can produce? A lot! Product design, and safety testing, must account for the heat and ensure that the heat is dealt with in safe, acceptable ways.

Enclosures help to protect the internal components (parts of the product), like a battery pack, and also keep people from the hazards inside the product. And, the enclosures must be designed so that they do not trap too much heat from the batteries! Too much heat can create a situation where a person could burn themselves when they touch the product, or ride it, like a hoverboard! Too much heat can also lead to **thermal runaway**.

For this investigation, your challenge is to select a material that meets certain safety criteria for performance in durability (**tensile strength**) and heat (**thermal performance**). These tests help ensure that the enclosure will protect the lithium-ion battery pack in a hoverboard from the outside world, as well as protect the user from the battery pack's heat.

THE CHALLENGE

Each team must select and test materials to determine the best performance in durability (tensile strength) and design and construct an enclosure. The enclosure design and material must protect the battery pack from the outside world. The team must also consider a possible consequence of the enclosure — it may trap the heat released from the battery pack and, consequently, put the user in danger of being burned.

CRITERIA

Ultimately, you want to select a material with the best performance in durability (tensile strength) and design an enclosure that will protect the battery pack from the outside world, hold the weight of a person, and can withstand abusive situations (i.e., tossed in a backpack, dropped on accident). Another critical element to think about is if the material will protect the user from the battery pack's heat or will it conduct the heat through the enclosure.

Part A: Material must pass tensile strength test by supporting more than 1 pound of weight for 2 minutes
Part B: Material must be able to be formed into the shape of an enclosure that is roughly 8" x 3" x 3"

PART A: XPLORATION

In this investigation, you will test the tensile strength/durability of different materials in order to find the best material to build your hoverboard enclosure. In Part B, you will design a hoverboard enclosure out of the material you prove to be the strongest and then test the enclosure to make sure it holds up.

MATERIALS (ONE SET PER GROUP)

- ○ **1 set of clamps (or other way to pull material taut)**
- ○ **2 thick hard-bound books**
- ○ **4 pieces of 5"x7" sized material**
- ○ **1 can of soup weighing 16-18 oz.***
- ○ **Standard metric ruler**
- ○ **XplorLabs pages or data sheet**

NOTES

*The soup is meant to represent the shape and weight distribution of a person relative to the size of your hoverboard enclosure that you will design in the next test.

WRITE THE NAME OF THE FOUR MATERIALS TO BE TESTED BY YOUR GROUP

1. ______________________________

2. ______________________________

3. ______________________________

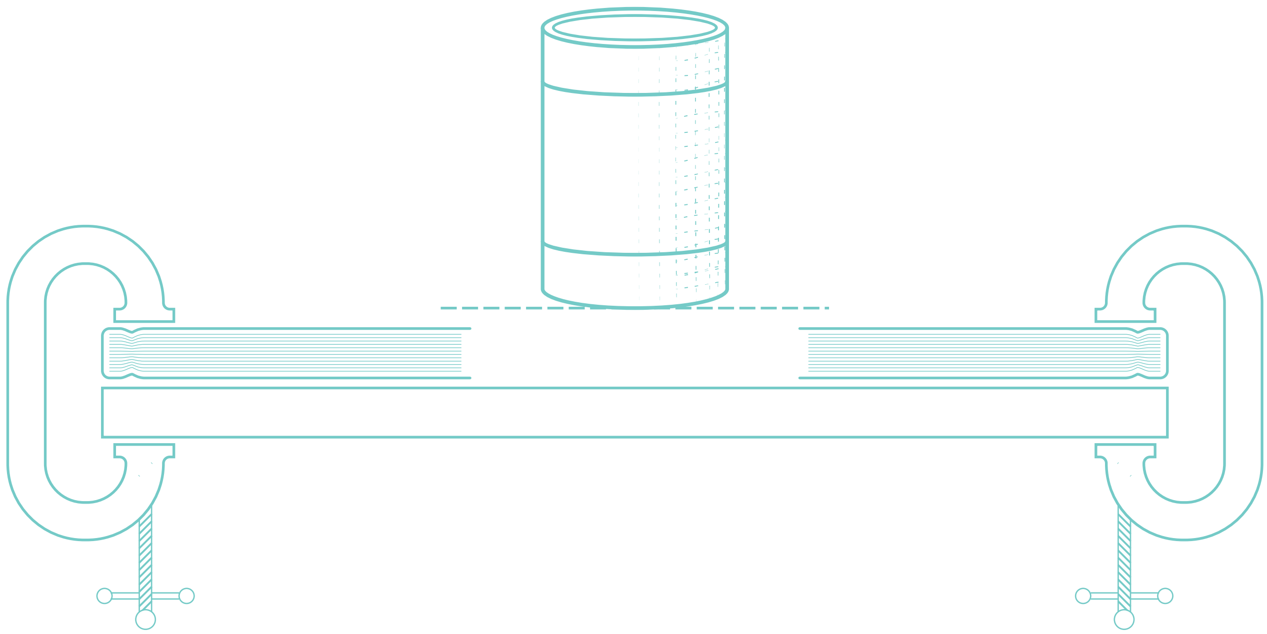
4. ______________________________

Engineers do a series of tests, make models and prototypes, test those prototypes, redesign, and so on, until they find a successful design that meets their criteria. It is not often, if ever, that an engineer gets the perfect design on the first try. Engineering is about gathering information, making a plan, testing, and redesigning. Remember that as you test the durability of the materials. Can you make it better by making modifications?

PROCEDURE

- ◯ **Choose or assign roles for group work.**
- ◯ **Each group collects all of the materials for the group.**
- ◯ **Place clamps and books 6.5" apart on table.**
- ◯ **Place first piece of material and suspend between the two books. Secure the material to the books and table using the clamps. Test to make sure the material is not over-stretched. Also make sure that the material does not overlap the books by more than .25" (this will influence the results).**
- ◯ **Place the soup can on the material evenly between the books/clamps.**
- ◯ **Begin the stopwatch and time for 2 minutes.**
- ◯ **At end of 2 minutes, use the ruler to measure any "sag" or dip in the material toward the table's surface (see illustration 1).**
- ◯ **Document any damage or wear on the material.**
- ◯ **Record findings in data table.**
- ◯ **Repeat with all four materials.**
- ◯ **If a material failed the tensile strength test, is it possible to modify the material in a way that it would pass the test (doubling/tripling layers, folding, or possibly combining different materials, etc.)? If so, modify (redesign) the material and test it again.**

ILLUSTRATION 1



ROLES

THE STUFF SUPERVISOR

Gathers and cleans up materials

THE EXPERIMENT EXEC

Runs the experiment

THE DIRECTOR OF DOCUMENTS

Reads the procedure to the group and helps the group members with data collection

THE PRINCIPAL PRESENTER

Shares the group's work with the rest of the class

DRAW THE SETUP OF THE TENSILE STRENGTH TEST HERE

TENSILE STRENGTH TEST DATA

TENSILE STRENGTH PERFORMANCE DATA TABLE: EXAMPLE

Material name	Description of material after tensile strength test	Sag or Dip Measurement	2-min tensile strength (pass/fail/redesign and retest)
1. Copy paper	small tears around clamps	2 mm	redesign and retest

TENSILE STRENGTH PERFORMANCE DATA TABLE

Material name	Description of material after tensile strength test	Sag or Dip Measurement	2-min tensile strength (pass/fail/redesign and retest)
1			
2			
3			
4			

TENSILE STRENGTH TEST DATA

Material(s) with best tensile strength performance:

Material(s) requiring redesign and retest. Description of changes to material(s):

Based on the class data, what are the materials with the highest tensile strength performance?

1.

2.

3.

Based on your findings, and the class data, which ONE of your tested materials will you select to create your hoverboard enclosure?

XPLANATION

What materials failed the tensile strength test? What materials required modification or redesigning to pass the test? What materials were too weak to pass the test even with modification or redesigning?

XPLANATION

What does the tensile strength test tell us? Why is the tensile strength of a material important for designing an enclosure? What about an enclosure that is intended to support the weight of a person?

XPLANATION

What other tests can we do to get better understandings of our materials for the enclosure?

PART B: XPLORATION

In this investigation, you will build your hoverboard enclosure from the best performing material from Part A's tensile strength test.

KEEP IN MIND, YOUR ENCLOSURE NEEDS TO MEET THE FOLLOWING CRITERIA

- **Dimensions are 8"x 3" x3"**
- **Protect the battery pack (inside the enclosure)**
- **Hold up a can of soup weighing 16-18 oz. for more than 2 minutes**

After you design and build your enclosure, you'll place the "battery pack" inside the hoverboard enclosure. Remember your enclosure will have to protect the battery pack from the outside world, hold the weight of a person, and withstand abusive situations (i.e., tossed in a backpack, dropped on accident). In preparation for Investigation 3, you will need to start thinking about the internal heat of a battery pack and the possibility of the enclosure acting as a conductor for that heat. So don't forget to think about the heat!

MATERIALS CHECKLIST - PART B

- ◯ **Selected material that passed tensile strength test (now, you can use larger or smaller sizes)**
- ◯ **Tape (different types – painters, Scotch, masking, duct)**
- ◯ **Paper clips**
- ◯ **Toothpicks**
- ◯ **Random scraps/sections of materials used in Part A, other materials teacher or students would like to use**
- ◯ **One can of soup weighing 16-18 oz**
- ◯ **A ruler**
- ◯ **Extinguished or inactive handwarmers – bundle of 4 (if available) to use for placing battery pack in enclosure (if inactive, the handwarmers must remain in packaging)**
- ◯ **XplorLabs pages or data sheet**

PROCEDURE

- Choose or assign roles for group work.
- Each group collects all of the materials for the group.
- Use an inactive battery pack to measure for size and shape.
- Using the material and any of the items from this list, design and build a 3D enclosure for your battery pack that measures 8"x 3"x 3".
- Does the 3D enclosure hold one 16-18 oz. soup can for 2 minutes?
- If the enclosure holds the required weight for 2 minutes without damage or sag, it has passed the tensile strength test.
- If the enclosure cannot hold the required weight without stretching, ripping, tearing, falling, or other damage, it has failed the tensile strength test.
- If an enclosure fails, redesign the enclosure and test it again. Be sure to record all changes to your design and materials!

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ENCLOSURE DESIGN

Record the materials used for your design here. Draw your design and include labels for the parts of the enclosure. Need to redesign? No problem! Record all of your modifications.

XPLANATION

What design element helped strengthen your enclosure? Was it the material used, other materials added, or the way the material was modified? Did the shape help strengthen the overall design?

XPLANATION

When you added the battery pack how did you secure it to the enclosure? Why did you choose this method of securing it?

XPLANATION

Is it possible the heat from the batteries could be conducted through the enclosure? If so, why?

XPLANATION

Do you think the enclosure will trap the heat? If so, how will that affect your design?

XPLANATION

What are the design trade-offs you may have to make to protect the user from being burned from too much heat being transmitted through the enclosure?

XPLANATION

In a hoverboard, could other heat sources like the motors and electrical circuits, affect the amount of heat being generated? In this investigation, we focused on the battery pack, but if you think about it, there are other parts that generate heat; what changes would need to be made to your group's enclosure design?