

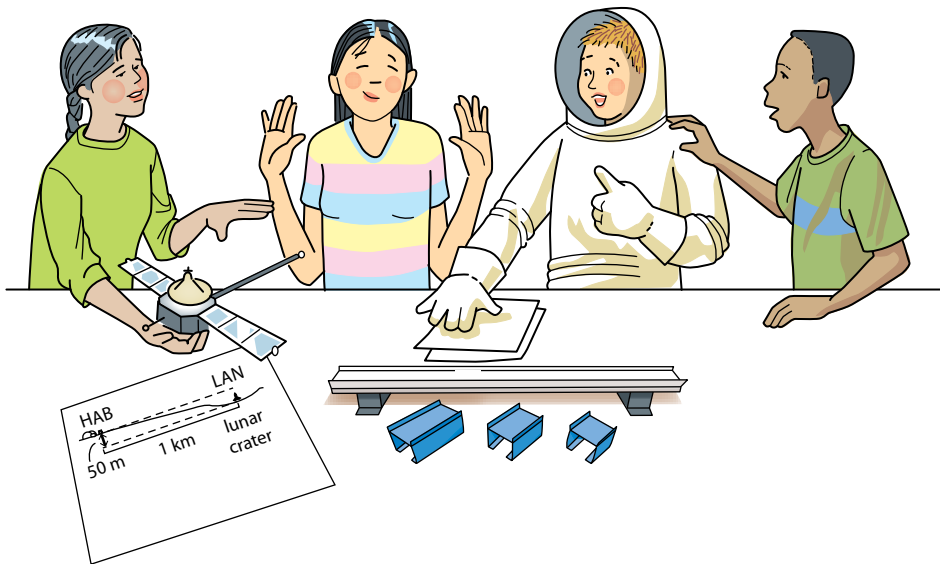
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Magnetic Transporter

DESIGN

THE ASTRONAUTS ON the Moon are still thinking about ways to move supplies and people back and forth between the LAN and the HAB, which are 1 km apart. The engineers start brainstorming how they might use magnetic fields in the transport system. They decide to design a magnetic cart to model their transport system.

In this activity, you will design a prototype of the transport system. A **prototype** is an early sample of a product that provides information about how the device or system works. Your prototype will use forces from magnetic and gravitational fields. Models of all kinds are important for testing solutions. Thus, your prototype will help show the engineers a possible transport system.



GUIDING QUESTION

How can magnetic fields be used to design a transporter prototype?

MATERIALS

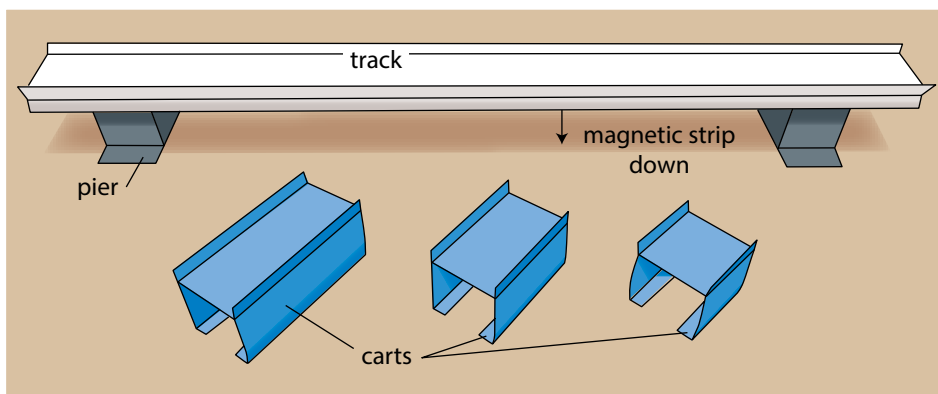
For each group of four students

- 1 track with magnetic strip
- 2 track piers
- 3 carts (1 short, 1 medium, and 1 long)
- 4 small ceramic disk magnets
- 4 large ceramic disk magnets
- 1 magnetic wand
- 2 nickels
- 4 4-g metal strips
- 2 20-g metal pieces

PROCEDURE

Part A: Magnetic Cart Testing

1. With your group, examine the equipment. Brainstorm ways to make the cart move down the track.



Transporter equipment

2. Choose any round magnet, and place it on top of the longest cart. Take another magnet of the same type, and place it on the underside of the cart so that it is attracted to the first magnet.
3. Place this cart over the track to see if the magnets attract or repel the cart from the track. If the magnets are attracted to the track, remove the cart from the track and flip over both magnets. Place the cart back over the track so that it sits above the track.

Note: Do not leave magnets on the track because they can damage the magnetic strip on the bottom of the track.

4. Test the motion of the cart by using the magnetic wand to force the hover cart along the track without touching the cart with the wand. Pay close attention to how well-balanced the cart is and how high it sits above the track.
5. Use your observations to improve the magnetic cart. Your design may use any combination of cart and magnets available. The cart should move along the track in a balanced and smooth manner. Record the prototype design in your science notebook.
6. With your group, identify the important variables you adjusted while constructing your prototype. A **variable** is a changing factor. In an experiment, the variable is what is studied, such as the effect of changing hill height on a roller coaster's maximum speed. List the variables in your science notebook.

Part B: Magnetic Cart Challenge

7. Review the following criteria and constraints for designing a magnetic cart that will transport mass from one end of the track to the other end. Add to or clarify any of the criteria and constraints until the whole class agrees on them.

Design Criteria

The magnetic cart must:

- Travel the entire length of the track
- Travel over a stack of two nickels without knocking a nickel off the stack
- Carry as much mass as possible without dropping it

Design Constraints

The solution is limited by the following:

- You can use only magnetic fields to make the cart move.
- You can use only the materials provided.

8. With your team, use the engineering design process to design a cart that meets these criteria and constraints.

Brainstorm Solutions

With your group, imagine two different prototypes for the carts. Record your ideas in your science notebook.

Design

Create design diagrams for the two different carts that you think will satisfy the criteria. Record your design diagrams in your science notebook.

Build

Build the two prototypes. Label these Prototype 1 and Prototype 2.

Test

Systematically test your two designs. Create a data table to record the test results for both prototypes in your science notebook.

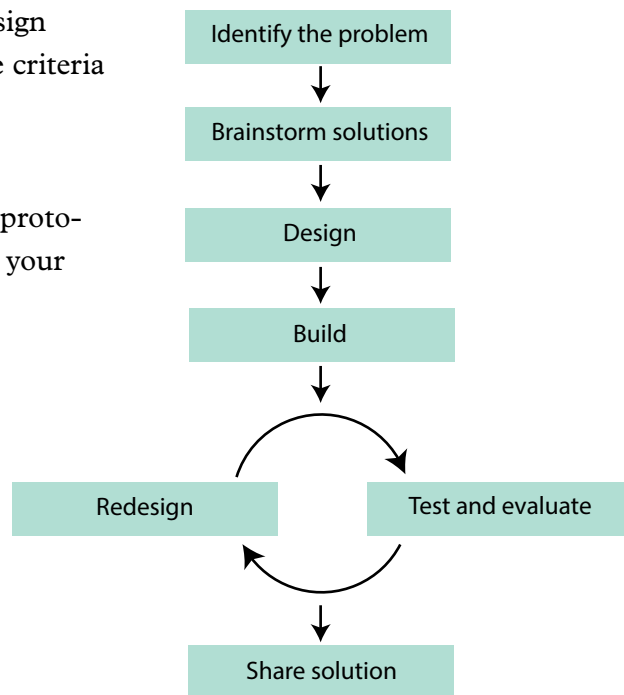
Evaluate

With your group, analyze the similarities and differences in the test results. Use the data to evaluate your design. Identify which characteristics met the jointly defined criteria and constraints, and which characteristics could be improved.

Redesign

Design Prototype 3 by combining the most successful characteristics of Prototypes 1 and 2. Test and evaluate Prototype 3.

Optimize the cart further by continuing to redesign, build, test, and evaluate. For each “Evaluate” step, record how you are using your test results to improve the design. Continue until your design carries the most mass possible for the full length of the track.



Share Solution

Prepare a report summarizing your design process and your optimized design to share with the class. Include a sketch or image of your design, a description of the design, the data collected, and an explanation of any design trade-offs you made.

Follow your teacher's guidelines for presenting and listening to the reports.

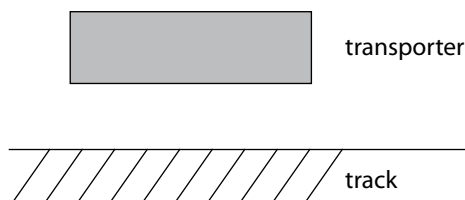
EXTENSION

Calculate the mass per dollar ratio of your design, using the following pricing. Then optimize your design to find the lowest mass per dollar ratio of the cart.

OBJECT	PRICE
Small cart	\$8
Medium cart	\$12
Large cart	\$16
Small magnet	\$3
Large magnet	\$5

ANALYSIS

1. Draw a diagram, like the one below, of the magnetic transporter hovering over the track.



- a. On the transporter, draw one arrow to show the force of magnetism. Draw another arrow to show the force of gravity. Label your diagram.
- b. Draw a second diagram of the magnetic transporter hovering over the track. In this diagram, show what happens when mass is removed from the magnetic cart. Describe what would happen to the magnetic cart's hover height, and explain why it changed.
- c. Imagine that the magnetic force was suddenly removed. When the cart hits the track, what evidence would there be that energy was transferred?

2. Is it possible to design a transporter that is able to hover only from the force of gravity? Explain why or why not.
3. When the magnetic cart is hovering above the track but not moving, the cart has two kinds of potential energy because of its position.
 - a. What are the two kinds of potential energy in the system?
 - b. If you add more magnets to the cart and the track so the cart hovers higher, what happens to the gravitational potential energy?
 - c. If, instead, you put more mass on the cart so it hovers closer to the track, what happens to the magnetic potential energy?
4. **Revisit the issue:** Imagine a problem you would need to solve if you were trying to build a transporter on the Moon.
 - a. Describe the problem.
 - b. What are some criteria and constraints that would have to be considered?
 - c. Why would it be important for the criteria and constraints to be precise?
 - d. What information or scientific ideas are relevant to the problem?
 - e. What needs will be met by solving the problem?
 - f. What are the impacts of a solution on Earth's resources?
 - g. What is one solution or tool that you would like to invent to solve this problem?