6 *Magnetic Transporter*

DESIGN

2–3 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students apply what they have learned about the phenomena of gravity and magnetism to design a magnetic transporter. They define a design problem that can be solved through the development of an object that meets multiple criteria and constraints. They use an iterative testing procedure to optimize the transporter to carry as much weight as possible.

This activity provides a formal assessment opportunity for Performance Expectation MS-ETS1-1.

NGSS CORRELATIONS

Performance Expectations

MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Working toward MS-PS3-2: Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

Working toward MS-PS2-4: Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

Working toward MS-ETS1-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Working toward MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Working toward MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Disciplinary Core Ideas

MS-PS3.A Definition of Energy: A system of objects may also contain stored (potential) energy, depending on their relative positions.

MS-PS2.B Types of Interactions: Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass (e.g., Earth and the sun).

MS-ETS1.A Defining and Delimiting Engineering Problems: The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

MS-ETS1.B Developing Possible Solutions:

A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.

There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.

Models of all kinds are important for testing solutions.

MS-ETS1.C Optimizing the Design Solution:

Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of the characteristics may be incorporated into the new design.

The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Science and Engineering Practices

Developing and Using Models:

Develop a model to describe unobservable mechanisms.

Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.

Analyzing and Interpreting Data: Analyze and interpret data to determine similarities and differences in findings.

Asking Questions and Defining Problems: Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

Engaging in Argument from Evidence: Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Constructing Explanations and Designing Solutions: Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system.

Crosscutting Concepts

Systems and System Models: Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy and matter flows within systems.

Connections to Nature of Science: Influence of Science, Engineering, and Technology on Society and the Natural World:

All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of people and the natural environment.

The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

Common Core State Standards—ELA/Literacy

SL8.5: Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.

RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

INVESTIGATIVE PHENOMENA AND SENSEMAKING

Gravity, magnetism, electricity, and electromagnetism are used in designed systems.

Students combine their growing knowledge of fields, forces, and the potential energy in gravitational and magnetic fields with their experience in using the engineering design process. As they engage in a design challenge, students bridge any gaps in their knowledge between these physical phenomena and its use in technology and design.

WHAT STUDENTS DO

Students apply what they know about the properties of magnetic and gravitational fields to design a magnetic transporter cart. They follow the engineering design process to design a cart that will, given certain criteria and constraints, maximize the amount of mass it can carry.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*
  - 1 Visual Aid 6.1, "Oral Presentations" (optional)
  - 1 Visual Aid 1.2, "Developing Communication Skills" (optional)
  - 1 Visual Aid 1.3, "Group Interactions Classroom Rubric" (optional)
  - 1 Scoring Guide: ENGINEERING DESIGN SOLUTIONS (ENG)
  - 1 Scoring Guide: DEVELOPING AND USING MODELS (MOD)
  - 1 Scoring Guide: COMMUNICATING CONCEPTS AND IDEAS (COM)
  - 1 small ceramic disk magnet
  - 1 small neodymium disk magnet

- *For each group of four students*
  - 1 track with magnetic strips
  - 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
  - 4 4 g metal strips
  - 2 20 g metal pieces
  - 4 small neodymium disk magnets (optional)
  - tape (optional)
  - * 2 nickels

- *For each student*
  - 1 Student Sheet 1.2, "Evaluating Group Interactions" (optional)
  - 1 Scoring Guide: ENGINEERING DESIGN SOLUTIONS (ENG) (optional)
  - 1 Scoring Guide: DEVELOPING AND USING MODELS (MOD) (optional)
  - 1 Scoring Guide: COMMUNICATING CONCEPTS AND IDEAS (COM) (optional)

* *not included in kit*

The ENGINEERING DESIGN SOLUTIONS (ENG), DEVELOPING AND USING MODELS (MOD), and COMMUNICATING CONCEPTS AND IDEAS (COM) Scoring Guides can be found in the Assessment tab in the back of this Teacher Edition. Students can find "Oral Presentations" in Appendix E: Literacy Strategies in the Student Book.

If the magnetic strips are not already placed in the underside of the tracks, place them before beginning the activity. Make sure that the poles all face in the same direction and that they are stored with the fields aligned.

The neodymium magnets are listed as optional materials for this activity because they are fragile. They can chip or break if they abruptly snap back together. They can also pinch your skin in the process. Separating them is best done by sliding them, one at a time, off the top of the stack. If students will not use them during the activity, consider using them for demonstration purposes.

Under some circumstances, the forces on the track are significant enough that the track can become unstable. Consider providing tape to students to secure the piers onto the table.

TEACHING SUMMARY

GET STARTED

1. Students discuss how magnetic fields could be useful in engineering design.
    a. Brainstorm different household objects that use magnets in their designs.
    b. Discuss how the properties of magnetic fields could be useful.
    c. Discuss the strength of magnetic materials.
2. Introduce the transporter design challenge.
    a. Have students read the introduction.
    b. Support students' design process using the engineering design process.

DO THE ACTIVITY

3. Students build and test their first prototypes.
    a. Support group interactions during the procedure.
    b. Have students follow Part A of the Procedure to build a basic hover cart.
    c. Draw force diagrams of the cart.
    d. Compare force arrows and field lines.

4. Students use the engineering design process to complete the hover cart challenge in Part B.
   a. Review the design challenge.
   b. Introduce the testing procedure.
   c. Review the variables in the design.
   d. Students engage in a scaffolded version of the engineering design process.
   e. (ENG ASSESSMENT) Introduce and use the ENGINEERING DESIGN SOLUTIONS (ENG) Scoring Guide.
   f. (LITERACY) Students prepare an oral presentation on their engineering design process.

BUILD UNDERSTANDING

5. Have students complete the Analysis items.
   a. Review or introduce balanced forces.
   b. (MOD ASSESSMENT) Assess students' ability to model energy in the transporter.
   c. Student co-construct scientific ideas about potential energy.
   d. (COM ASSESSMENT) Assess students' ability to define a design problem.

TEACHING STEPS

GET STARTED

1. Students discuss how magnetic fields could be useful in engineering design.
   a. Brainstorm different household objects that use magnets in their designs.

      Remind students that engineers often use concepts from science to inform their product design. Ask students to work with their groups to come up with some different products in their homes that use magnetic fields. While many products use magnets in some form or another, it may be difficult for students to think of many examples because magnets are often integrated into a multifunctional device. Some common household objects that make use of magnets are refrigerator magnets, clasps on objects like purses, speakers, headphones, ceiling fans, Etch-a-Sketch, smartphones, tablets, and computers.

   b. Discuss how the properties of magnetic fields could be useful.

      Have students think back to the "Mapping Magnetic Fields" activity where they mapped the field lines of different magnet configurations.

Ask them, "Under what circumstances do magnets attract and repel?" Students should know that two magnets will repel each other if the two like poles are facing each other, and they will attract if the two opposite poles are facing each other. Discuss how this property could be relevant to designing the magnetic transporter in this activity if magnets were placed on both the track and the transporter. In this case, forces from both the magnets and the force of gravity need to be taken into account.

c. Discuss the strength of magnetic materials.

Ask students, "Do all materials have the same magnetic strength?" Students should respond, "No, some magnets are stronger than others." Show them the small ceramic and neodymium magnets, and ask them to come up with a quick experiment that would provide evidence for their response. For example, put each magnet into a pile of paper clips, and compare which magnet picks up more clips. This should demonstrate that permanent magnets will vary in their magnetic strength. When thinking about why, students should consider that because both magnets are approximately the same size and shape, other variables must come into play to make their strengths different. Two possible variables that determine the strengths of the magnets are the composition of the materials and how they were magnetized. This idea will become relevant when students engage in the practice of *constructing explanations and designing solutions* as they design, construct, and test a transporter system in this activity.

2. Introduce the transporter design challenge.

a. Have students read the introduction.

The introduction will help students understand how they will use the engineering design process to build a transport system. Review the term *prototype* with students, as they will build prototypes in this activity and then optimize them to better meet the criteria within the constraints of the engineering design challenge. Introduce the materials that students will have access to, and remind them not to touch the disk magnets to the track. Remind students that they will be developing a model of a transport system and that models of all kinds are important for testing solutions.

b. Support students' design process using the SEPUP engineering design process.

Review the diagram, shown in the Student Book procedure, which was first introduced in the "The Apollo Missions" activity. In this activity, you will look for students' engagement related to the steps "Test,"

Engineering Design Process in the Classroom

Students are engaged in:

- defining a successful solution or design
- clarifying what is not the problem
- developing criteria and constraints

NGSS SEP: Asking Questions and Defining Problems

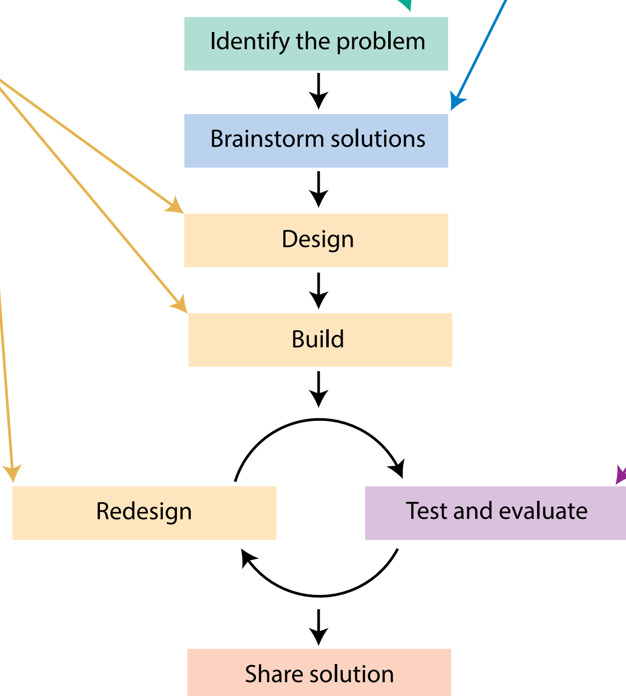
SEPUP support: COM Scoring Guide (ASSESSMENT)

Students are engaged in:

- generating potential solutions, initially without evaluating those ideas
- researching scientific information that supports various solutions
- narrowing down a list of possible solutions to those that are most likely to meet the criteria and constraints

NGSS SEP: Obtaining, Evaluating, and Communicating Information

SEPUP support: Facilitating Group Work (SENSEMAKING)



Students are engaged in:

- designing prototypes for testing
- considering the material properties involved
- using test results to inform a redesign
- combining the best aspects of multiple designs to optimize performance

NGSS SEPs: Developing and Using Models, Constructing Design Solutions

SEPUP support: MOD and ENG Scoring Guides (ASSESSMENT), Facilitating Group Work (SENSEMAKING)

Students are engaged in:

- recording data from testing
- analyzing test results for strong performance
- using data to indicate redesign improvements

NGSS SEPs: Developing and Using Models, Using Mathematics and Computational Thinking, Analyzing and Interpreting Data, Planning and Carrying Out Investigations

SEPUP support: ENG and AID Scoring Guides (ASSESSMENT), Facilitating Group Work (SENSEMAKING)

Students are engaged in:

- presenting their design ideas
- explaining the evolution of the design
- comparing designs across teams
- using evidence to argue for particular design attributes
- weighing the trade-offs of designs

NGSS SEPs: Engaging in Argument from Evidence; Constructing Explanations; Obtaining, Evaluating, and Communicating Information

SEPUP support: ARG, EXP, and COM Scoring Guides (ASSESSMENT), Oral Presentations (LITERACY)

"Evaluate," "Redesign," and "Share solution." Engage students in the first step, "Identify the problem," through a class discussion before students complete the rest of the engineering design cycle.

The diagram on the previous page, "Engineering Design Process in the Classroom," provides some direction for guiding students through an engineering-focused activity. This diagram helps identify what to can expect from students during different steps in the SEPUP engineering design process.

DO THE ACTIVITY

3. Students build and test their first prototypes.

   a. Support group interactions during the procedure.

      Considering using Student Sheet 1.2, "Evaluating Group Interactions," and Visual Aid 1.2, "Developing Communication Skills," to support students in working as a group. "Developing Communication Skills" can also be found in Appendix E of the Student Book. For more support on group interactions in the classroom and to evaluate how groups interact during the activity, use Visual Aid 1.3, "Group Interactions Classroom Rubric."

   b. Have students follow Part A of the Procedure to build a basic hover cart.

      Have students work in their groups to complete Part A, which familiarizes students with the materials and variables they will modify in Part B. In Step 3, students are instructed to make sure that the magnet orientation is correct. Assist as needed to ensure that the magnets on the hover cart repel the magnets in the track. It is important that the magnets on the hover cart do not come into contact with the track if they are attracting.

   c. Draw force diagrams of the cart.

      Students who have studied forces and motion may be familiar with force diagrams. If so, you can ask them to create force diagrams of the cart in this activity. Otherwise, take a moment to explain how force diagrams work by drawing a force diagram of the cart in this activity. The following components should be part of the force diagram:

      - The arrow starts at the center of the object and points away from the object.
      - The arrow shows the direction of the force with an arrowhead.
      - The arrow should be labeled with its magnitude.

      An example of a force diagram is included in the Sample Responses to Analysis.

d. Compare force arrows and field lines.

The "Gravitational Force" activity focused on force and the "Mapping Magnetic Fields" activity focused on field lines, both of which are indicated by lines with arrows in diagrams. Clarify how field lines and force arrows are similar in that they both model something, but they are different in that they model different phenomena. Field lines show the field in the three-dimensional space around the object to which the field is associated. From field lines, you can determine where a field is strongest, based on where the lines are densest or closest together, but the length of a field line does not indicate the magnitude or strength of a field. Field lines do show the direction that a force would be applied to an object at any particular location in that field. On the other hand, a force arrow is always straight, and its length is related to its magnitude. It simply shows how strong the force on an object is and in what direction it comes from.

4. Students use the engineering design process to complete the hover cart challenge in Part B.

a. Review the design challenge.

As a class, review the design criteria and constraints listed in the Student Book. Decide if anything needs to be clarified or added to the list. Remind students that they will be designing a system model of the transport system for the Moon base. This is an opportunity to call out the crosscutting concept of *systems and system models*.

This activity comprises a sequence of learning around the fourth driving question: How can engineers solve problems using magnetism and gravity? This driving question is identified in the Phenomena, Driving Questions, and SEPUP Storyline overview. Pose the question, and have students share their initial ideas. You'll revisit the question at the end of this activity.

b. Introduce the testing procedure.

Explain to students that a successful hover cart is one that will be able to meet all the criteria within the constraints. Show students the hover tester (the two nickels stacked on the track), and demonstrate how the cart must pass over the nickels to be considered successful. Remind students that they will have an opportunity to optimize their designs for better performance. Have students work with their groups to complete Part B of the Procedure.

c. Review the variables in the design.

Introduce the term *variable*, if students are not familiar with it, and discuss the variables that relate to the cart design: cart size, magnet size, number of magnets, and placement. Encourage students to be systematic about changing the variables in their designs.

d. Students engage in a scaffolded version of the engineering design process.

Procedure Step 8 in this activity walks students through an engineering design process. This process includes a systematic process for evaluating solutions based on how well they meet the criteria and constraints of the problem. To do this, students analyze and interpret data related to their prototypes, identify the similarities and differences between their designs, and evaluate how well their designs performed. This is important because it allows students to identify the characteristics of the design that performed the best when tested. Students can then use those characteristics in their next prototypes. They combine the successful parts of the different solutions to create a new solution that performs better than their initial prototypes. They continue testing and modifying their designs, based on their evaluations of the test results, in order to improve their solutions. To optimize their solutions, students iteratively test, evaluate, and modify their prototypes, which leads to refined solutions.

e. (ENG ASSESSMENT) Introduce and use the ENGINEERING DESIGN SOLUTIONS (ENG) Scoring Guide.

Teacher Resources

SEPUP Scoring Guides

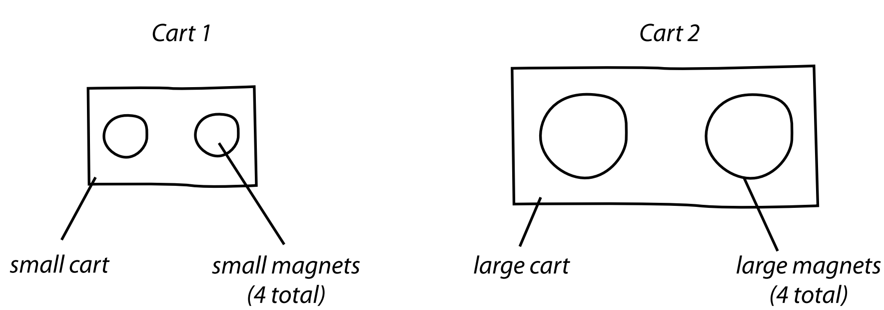
Procedure Step 8 is the first use of the ENGINEERING DESIGN SOLUTIONS (ENG) Scoring Guide in this unit. Project or distribute the Scoring Guide, and point out how it has the same levels as other Scoring Guides but different descriptions for each level. Review the levels as needed.

PROCEDURE STEP 8 SAMPLE LEVEL 4 RESPONSE

Brainstorm Solutions

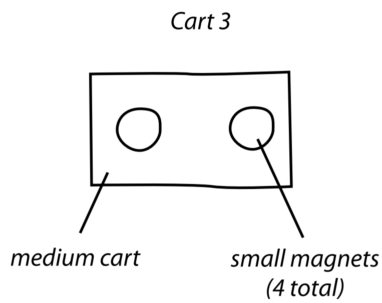
For our two prototypes, we brainstormed designing a small cart and a long cart. For the small cart, we think we will use the shortest hover cart and four of the small disk magnets. For the large cart, we will use four of the large disk magnets. We think that the longer hover cart will need stronger magnets because it is bigger, but we also think that it might work better at carrying the mass because there is more room on top of it.

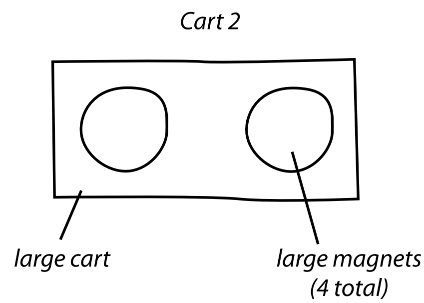
Design and Build



Test and Evaluate

Cart 1 kept tipping when it was filled with mass, and it was difficult getting the mass on the top of Cart 1. Cart 2 was well-balanced but seemed to be too heavy with the large magnets, and it started out with more mass. Both carts hovered well before any mass was added. The data is in the table below.



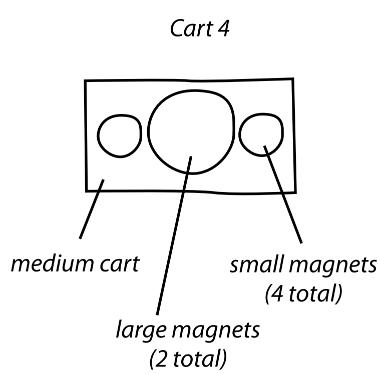


For Cart 3, we would like to try using the medium-sized cart. We think it will be more stable than Cart 1 and less massive than Cart 2. In terms of magnets, we think we'll use only four, like Cart 1, but make them the small ones.

Test and Evaluate

Cart 3 was able to carry the most mass out of all the designs we tried. It seemed pretty stable, so we think we just want to add more magnets to make it hover better. We will try optimizing it by adding two of the large disk magnets in the middle of the cart. The data is in the table below.

Redesign



Cart 4 worked the best for us because it moved the largest mass. It seemed really well balanced the whole time, which helped make sure that no mass slid off. If we were to continue designing, we would want to find stronger magnets because we don't think there's enough room to add any more magnets. The data is in the table below.

Prototype	Mass Carried (g)
1 (small cart)	24
2 (large cart)	44
3 (medium cart)	48
4 (medium cart), optimized	64

f. (LITERACY) Students prepare an oral presentation on their engineering design process.

Oral Presentations

Let students know that at the end of Procedure Step 8, each group will give an oral presentation about how they used the engineering design process. Consider showing Visual Aid 6.1, "Oral Presentations," which can also be found in Appendix E in the Student Book, to help students organize what they will say. Encourage students to make attractive presentations, but stress that the evidence and ideas presented on the poster are most crucial to a good presentation.

BUILD UNDERSTANDING

5. Have students complete the Analysis items.

a. Review or introduce balanced forces.

Explain to students that any object that is speeding up or changing direction requires an unbalanced force acting on the object. Similarly, an object that is not speeding up or changing direction requires that all forces acting on it are balanced. Knowing this, students should be able to conclude that when the hover cart is hovering, all forces acting on it are balanced. Analysis item 1 gets at this idea explicitly by asking students to draw a force diagram that shows the force of gravity on the hover cart being equal and opposite to the force of the magnets acting on the cart.

b. (MOD ASSESSMENT) Assess students' ability to model energy in the transporter.

Use the MOD Scoring Guide to assess students' responses to Analysis item 1, which is also an opportunity for a formative assessment of Performance Expectation MS-PS3-2: Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. Students will have a summative assessment on this performance expectation in the "Electric Field Transporter" activity. A sample Level 4 response is provided in the Sample Responses to Analysis.

c. Student co-construct scientific concepts about potential energy.

Analysis item 3 provides an opportunity for students to discuss the potential energy of the cart while hovering at different heights and with different masses. Students should be familiar with the fact that gravitational potential energy is determined by the mass and height of an object in a gravitational field. They may be less familiar with the fact that magnetic potential energy is determined by the fields of interacting magnets, meaning that the strength of the magnets, the relative orientation of the magnets, and the distance between the magnets each contribute to the energy stored in the system. With this information, students should be able to discuss and make sense of the fact that adding mass to the cart increases its potential energy, due to the magnetic field.

d. (COM ASSESSMENT) Assess students' ability to define a design problem.

Teacher Resources

Learning Pathways

You can use the COM Scoring Guide to assess students' work on Analysis item 4, which is also an opportunity to assess Performance Expectation MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. A sample Level 4 response is provided in the Sample Responses to Analysis.

Revisit the driving question for this learning sequence—How can engineers solve problems using magnetism and gravity?—and have students add to or revise their ideas as needed.

EXTENSION

Students have an opportunity to make a cost-efficient design by calculating the mass per dollar ratio of their design and then optimizing it to find the lowest mass per dollar ratio of the cart. If you had them use the neodymium magnets, price each magnet at $8.

SAMPLE STUDENT RESPONSE

My group tried three different carts. The first cart we tried was the short cart with four small magnets. The second one we tried was the medium cart with four small and two large magnets. The last cart we tried was the large cart with four large and two small magnets.

Cart design	Cart cost	Mass moved (g)	Mass per dollar (g/$)
Small cart with 4 small magnets	*$20*	*32*	*1.60*
Medium cart with 4 small magnets and 2 large magnets	*$34*	*64*	*1.88*
Large cart with 4 large magnets and 2 small magnets	*$42*	*72*	*1.71*

Looking at our data, we think that our second cart was the best because it had the highest mass per dollar, which means that for every dollar spent, it could move more mass than the other carts we designed. The result was surprising because our first cart was the cheapest, and our last cart carried the most mass, but our middle cart had the best ratio of mass to cost.

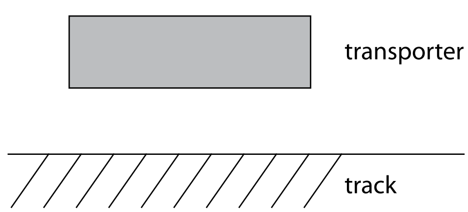
STRATEGIES FOR TEACHING DIVERSE LEARNERS

Below are suggestions for differentiating instruction and assessment in this activity for diverse learners in your classroom:

- Students with learning disabilities: In Part A, use a diagram similar to the one provided in Analysis item 1 to illustrate the direction of the magnetic and gravitational forces.
- Academically gifted students: In Procedure Step 6, ask students to identify the controlled variables in addition to the variables they change in their design.

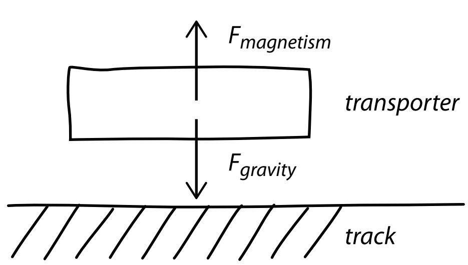
SAMPLE RESPONSES TO ANALYSIS

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

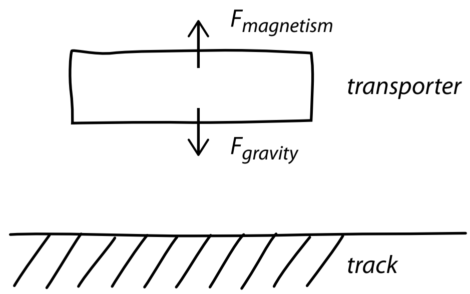


SAMPLE LEVEL 4 RESPONSE

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.



The cart would hover higher. This is because the force of gravity pulling the transporter down would be less when some of the mass was removed. The force of magnetism repelling the transporter from the track would push the hover cart farther up until the new attractive force of gravity equaled the repelling force of magnetism.

c. Imagine that the magnetic force was suddenly removed. When the cart hits the track, what evidence would there be that energy was transferred?

The evidence that energy was transferred would be in the sound and/or vibration it made when it hit. If it was heavy enough, it could even dent or damage the track. This shows that the energy of motion when the cart hits was transferred into other energy types.

2. Is it possible to design a transporter that is able to hover only from the force of gravity? Explain why or why not.

No, it is not possible. This is because gravity is always attractive and not repulsive. For the cart to hover over the track, it needs a repulsive force away from the ground.

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?

Gravitational potential energy and magnetic potential energy

b. If you add more magnets to the cart and the track so the cart hovers higher, what happens to the gravitational potential energy?

The gravitational potential energy would increase because the cart would hover higher off the track, and gravitational potential energy gets larger when the distance is increased.

c. If, instead, you put more mass on the cart so it hovers closer to the track, what happens to the magnetic potential energy?

The magnetic potential energy will change because the magnets will now be closer together. Since they are repelling, the magnetic potential energy will have increased.

4. (COM ASSESSMENT, MS-ETS1-1) **Revisit the issue:** Imagine a problem you would need to solve if you were trying to build a transporter on the Moon.

   Students' responses will likely vary. A sample response is shown below.

   SAMPLE LEVEL 4 RESPONSE

   a. Describe the problem.

      I think a big problem that would face people on the Moon is not having enough liquid water for the astronauts during the transporter construction.

   b. What are some criteria and constraints that would have to be considered?

      One criterion is that the astronauts on the Moon need enough water to survive. The water would also have to be clean enough for consumption without making anyone sick. A major constraint is that they would have to bring all the water that they need with them from Earth.

   c. Why would it be important for the criteria and constraints to be precise?

      Having more-precise constraints, like knowing the exact amount of water needed, would help the solution be more successful. If the criteria and constraints are not focused, the solutions might not work as well as hoped. In this case, astronauts could die if the criteria of amount of water was not specified.

   d. What information or scientific ideas are relevant to the problem?

      I think you can make water if you have the right chemicals, so that would be an important scientific idea for helping solve the problem. The other important idea would be getting water out of other liquids and recycling it.

   e. What needs will be met by solving the problem?

      If this problem is solved, people would be more likely to survive on the Moon. If not, people could never stay on the Moon for very long.

   f. What are the impacts of a solution on Earth's resources?

      This could have environmental impacts on Earth as it would require water or other chemicals to leave Earth and go to the Moon. Right now, many processes on Earth require the cycling of water, so if water were taken away from Earth, that might affect those processes. There could also be a lot of fighting over who should get the water and whether it should stay on Earth or go to the Moon base.

   g. What is one solution or tool that you would like to invent to solve this problem?

      A tool that I would like to invent is a device that can turn urine into clean drinking water. This device would help make sure that no water is wasted on the Moon.

REVISIT THE GUIDING QUESTION

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

Magnetic fields can be used to make a cart hover over a track even in the presence of gravity. By making two magnets repel, there can be space between magnets where they are still affecting each other without touching. In this case, the gravitational force on the transporter is balanced by the magnetic force. Depending on the number, strength, and position of magnets, the cart will be able to hold a different amount of mass and successfully transport it down the track.

ACTIVITY RESOURCES

KEY VOCABULARY

constraint

criteria, criterion

engineering design process

optimize

prototype

variable

VISUAL AID 6.1

ORAL PRESENTATIONS

- Your presentation time is short. Focus your presentation on the most important ideas you need to communicate.
- Communicate clearly by planning your words in advance. When speaking, talk slowly and loudly, and look at your audience.
- Group members should ask for and give each other support if they need help expressing a key word or concept.
- Include graphs and maps when possible. Make sure the type or handwriting and the images are large enough for everyone in the audience to see them.
- While you have your own opinions on a topic, it is important that you present unbiased and complete information. Your audience can then make their own conclusions.
- All the members of a group must participate.
- Since any group member may be asked to answer questions from the class, all group members should fully understand the presentation.
- In a group presentation, you could all play the role of different experts when presenting your information. The class would represent the community members who might be making a decision on the issue.