Unit Title: Gravity Racers
Date Developed/Last Revised: 05.08.13
Unit Author(s): L. Higashi, L. Lum, R. Saito, K. Umeda

Grade Level: 1
Time Frame: 20 class periods
Note: Teachers may select lessons to fit their instructional time frame.
Primary Content Area: Science, Engineering

UNIT DESCRIPTION:
Students will investigate physical science concepts through engagement in the scientific inquiry process. They will learn what forces are, and how forces such as gravity affect an object's motion. Through the Engineering Design Process (EDP), students will then apply these concepts to engineer a technological device such as a car, and be able to explain why these devices are created.

Students will apply their knowledge of this science to The Engineering Design Process (EDP). This process will engage students in developing prototypes of their ideas to solve problems, and to create and redesign products and systems. They will also practice the GLOs and the STEM Competencies as they apply the cooperative skills needed to work in engineering design teams and optimize their product. In this unit, students will work in teams and apply their scientific knowledge of forces and motion towards engineering cars of their own design. Mathematics and technology are integrated and rigorously applied throughout each of these processes.

Big Ideas (Student Insights that Will Be Developed Over the Course of the Unit):
- A force is a push or a pull.
- Forces affect the motion of objects.
- People create technological devices.
- Scientific inquiry investigations enable us to answer questions about the world around us.
- The Engineering Design Process enables us to solve problems and design solutions.

Essential Questions (Questions that Will Prompt Students to Connect to the Big Ideas):
- How do we conduct scientific inquiry investigations?
- How do forces affect an object’s motion?
- Why do people create technological devices?
- What is the Engineering Design Process?
- How does the Engineering Design Process help us?
<table>
<thead>
<tr>
<th>Benchmark/Standard/Group</th>
<th>Example Benchmarks/Standards/Learning Goals</th>
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</table>
| **Science**              | • SC.1.1.1: Collect, record, and organize data using simple tools, equipment, and techniques safely (L1)  
  • SC.1.1.2: Explain the results of an investigation to an audience using simple data organizers (L2)  
  • SC.1.7.1: Describe how the motion of an object can be changed by force (push or pull) (L2)  
  
  *Note:* The “L” codes at the end of each benchmark refer to the assigned level of the Marzano’s Taxonomic Level of Understanding. For example, “L3” refers to Taxonomic Level 3: Analysis. |
| **Technology**           | • SC.1.2.1: Explain why people create technological devices (L2) |
| **Engineering**          | • CTE Standard 1: TECHNOLOGICAL DESIGN: Design, modify, and apply technology to effectively and efficiently solve problems |
| **Mathematics**          | **Supporting CCSS Mathematical Standards**  
  • CCSS.Math.Content.1.NBT.A.1: Count to 120, starting at any number less than 120. In this range, read and write numerals and represent a number of objects with a written numeral.  
  • CCSS.Math.Content.1.MD.C.4: Organize, represent, and interpret data with up to three categories; ask and answer questions about the total number of data points, how many in each category, and how many more or less are in one category than in another.  

**Supporting CCSS Mathematical Practices**  
• CCSS.Math.Practice.MP1: Make sense of problems and persevere in solving them.  
• CCSS.Math.Practice.MP2: Reason abstractly and quantitatively.  
• CCSS.Math.Practice.MP3: Construct viable arguments and critique the reasoning of others.  
• CCSS.Math.Practice.MP5: Use appropriate tools strategically.  
• CCSS.Math.Practice.MP6: Attend to precision. |
<table>
<thead>
<tr>
<th>English Language Arts and Literacy</th>
<th><strong>Supporting CCSS Language Arts Standards</strong></th>
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<tr>
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<td>• CCSS.ELA-Literacy.RI.1.10: With prompting and support, read informational texts appropriately complex for grade 1.</td>
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<td>STEM Competencies</td>
<td>• Indicator 2.2: Collaborates with, helps and encourages others in group situations (in science and engineering teams)</td>
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<td>• Indicator 2.5: Demonstrates responsible and ethical behavior in decision making (while making choices for the team’s implementation plans)</td>
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<td>• Indicator 6.4: Uses the appropriate technologies for communication, collaboration, research, creativity, and problem solving (data collecting tools/internet/apps/etc.)</td>
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<tr>
<td>Lesson Title/Description</td>
<td>Learning Goals (What Students Will Know and Be Able to Do)</td>
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| **1** Marble Madness Inquiry • Engagement Activity | *Students will know:*  
• A force is a push or a pull.  
• Gravity is a force that pulls on objects.  

*Students will be able to:*  
• Identify a force as a push or pull.  
• Collect, record, and organize data.  
• Participate in collaborative discussions with diverse partners. | Formative:  
• Discussions (conversations) of concepts  
• Observations conducted as participants conduct their investigations  
• Product: Data recording sheets | 1 class period |
| **2** Marble Madness Inquiry • Exploration Activity | *Students will know:*  
• A force is a push or a pull.  
• Gravity is a force that pulls on objects.  
• Forces affect the motion of objects.  
• Mass and friction affect an object’s motion.  
• That people create technological devices to make life easier.  

*Students will be able to:*  
• Identify a force as a push or pull.  
• Investigate how the amount and type of force affects an object’s motion.  
• Collect, record, and organize data.  
• Describe how the amount and type of force (push or pull) affects an object’s motion.  
• Explain why people create technological devices (e.g., a car).  
• Participate in collaborative discussions with diverse partners.  
• Ask questions to clarify concepts being investigated. | Formative:  
• Discussions (conversations) of concepts  
• Observations conducted as participants conduct their investigations  
• Product: Data recording sheets | 1 class period |
| 3 | Marble Madness Inquiry  
  - Researching of Background Information | Students will know:  
  - A force is a push or a pull.  
  - Gravity is a force that pulls on objects.  
  - Forces affect the motion of objects.  
  - That people create technological devices to make life easier.  

Students will be able to:  
- Read/gather information from provided sources with guidance and support.  
- Participate in collaborative discussions with diverse partners.  
- Ask questions about topics under discussion.  

| Formative:  
- Discussions (conversations) of concepts  
- Observations conducted as participants conduct their investigations  
- Product: Data recording sheets | 1 class period |
|---|---|---|---|
| 4-5 | Marble Madness Inquiry  
  - Guided Class Investigation | Students will know:  
  - A force is a push or a pull.  
  - Gravity is a force that pulls on objects.  
  - Forces affect the motion of objects.  
  - Mass and friction affect an object’s motion.  
  - That people create technological devices to make life easier.  

Students will be able to:  
- Identify a force as a push or pull.  
- Investigate how the amount and type of force affects an object’s motion.  
- Collect, record, and organize data.  
- Explain the results of their investigation using simple data organizers.  
- Participate in collaborative discussions with diverse partners.  
- Describe how the amount and type of force (push or pull) affects an object’s motion.  

| Formative:  
- Discussions (conversations) of concepts  
- Observations conducted as participants conduct their investigations  
- Products: Data recording sheets, class charts, Science notebook, (optional)  
- Explanation of the results of their investigation to an audience | 2 class periods |
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| 6 | Revisiting Technology | • Explain why people create technological devices (i.e., a car).  
• Participate in collaborative discussions with diverse partners. | • Discussions (conversations) of concepts | |
| 7 | Assessments | Students will be able to:  
• Describe how the amount and type of force (push or pull) affects an object’s motion.  
• Explain why people create technological devices (i.e., a car). | Formative:  
• Discussions (conversations) of what was learned from the investigations | Summative:  
• Constructed response to the following prompts:  
  1. Describe and give an example of how a force affects an object’s motion.  
  2. Identify a technological device and explain why it was created. | 1 class period |
| 8-9 | Building a Gravity Racer | Students will be able to:  
• Work in groups to engage in discovery learning.  
• Collect, record, and analyze data.  
• Learn about the effects factors such as size, weight, and friction have on motion. | Formative:  
• Teacher Observations and Conversations  
• Data Recording Sheet | 1-2 class periods |
| 10 | Discovery Learning Stations | Students will be able to:  
• Understand what engineers do and why we engineer things.  
• Identify the problem of the performance task and what they are creating.  
• Ask and record questions they have about constructing a gravity racer. | Formative:  
• Teacher Observations and Conversations  
• EDP Journal | 1 class period |
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|11 | EDP Step 2: Imagine     | • Individually brainstorm ideas for constructing a gravity racer.  
• Draw and/or write their ideas in their EDP Journal.  
• Share their ideas with their engineering team and be able to defend their reasons for their specific prototype. | • Teacher Observations and Conversations  
• EDP Journal | 1 class period |
|12 | EDP Step 3: Plan        | Students will be able to:  
• Work with their engineering team to decide on or create one design for their gravity racer.  
• Record their team’s prototype with precision in their EDP Journal. | • Teacher Observations and Conversations  
• EDP Journal | 1 class period |
|13-14 | EDP Step 4: Create | Students will be able to:  
• Work with their engineering teams to follow their plan and build their prototype.  
• Agree upon and record any modifications that needed to be made to make their prototype work.  
• Share their prototype gravity racer with the whole class. | • Teacher Observations and Conversations  
• EDP Journal | 2 class periods |
|15 | EDP Step 5: Experiment  | Students will be able to:  
• Work with their engineering teams to test their gravity racer.  
• Log the data into their journals. | • Teacher Observations and Conversations  
• EDP Journal | 1 class period |
|16-18 | EDP Step 6: Improve | Students will be able to:  
• Work with their engineering teams to review the results of their data.  
• Repeat the Engineering Design Process to improve their gravity racer.  
• Conduct a data analysis comparing the first set of results with the second set of data.  
• Explain their conclusions made based on the data analysis. | • Teacher Observations and Conversations  
• EDP Journal | 4 class periods |
|19 | Assessments             | Students will be able to:  
• Demonstrate their understanding of the Engineering Design Process. | • EDP Assessment Sheet  
• EDP Reflections | 1 class period |
| 20 | Building a Gravity Racer  
- Wrapping it Up | **Students will be able to:**  
- Review concepts learned in this unit through the creation of a concept (thinking) map. | **Formative:**  
- Teacher Observations and Conversations | 1 class period |
PLANNING (Steps 1, 2, & 3)

1. Standards/Benchmarks and Process Skills Assessed in this Lesson:

   Science
   - SC.1.1.1: Collect, record, and organize data using simple tools, equipment, and techniques safely (L1)
   - SC.1.1.2: Explain the results of an investigation to an audience using simple data organizers (L2)
   - SC.1.2.1: Explain why people create technological devices (L2)
   - SC.1.7.1: Describe how the motion of an object can be changed by force (push or pull) (L2)

   Engineering
   - CTE Standard 1: TECHNOLOGICAL DESIGN: Design, modify, and apply technology to effectively and efficiently solve problems

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   - CCSS.Math.Practice.MP1: Make sense of problems and persevere in solving them.
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b. Build on others’ talk in conversations by responding to the comments of others through multiple exchanges.

c. Ask questions to clear up any confusion about the topics and texts under discussion.

• CCSS.ELA-Literacy.SL.1.4: Describe people, places, things, and events with relevant details, expressing ideas and feelings clearly.

2A. Criteria- What Students Should Know and Be Able to Do:

Students will know:
- A force is a push or a pull.
- Gravity is a force that pulls on objects.
- Forces affect the motion of objects.
- Mass and friction affect an object’s motion.
- That people create technological devices to make life easier.

Students will be able to:
- Identify a force as a push or pull.
- Investigate how the amount and type of force affects an object’s motion.
- Collect, record, and organize data.
- Explain the results of their investigation using simple data organizers.
- Describe how the amount and type of force (push or pull) affects an object’s motion.
- Explain why people create technological devices (i.e., a car).

2B. Assessment Tools/Evidence:

Formative:
- Discussions (conversations) of concepts
- Observations conducted as participants conduct their investigations
- Products: Data recording sheets, Science notebook, EDP Journal (see attached rubric)
- Explanation of the results of their investigation to an audience

Summative:
- Constructed response to the following prompts:
  1. Describe and give an example of how a force affects an object’s motion.
  2. Identify a technological device and explain why it was created.

3. Learning Experiences (Lesson Plan)

Handouts/Other Resources:
- Marble Madness Data Recording Sheet (one per student)
- Student Inquiry Data Recording Sheet
- Elementary Inquiry Rubric
Teacher Background Information:
Forces and Motion
- ScienceSaurus, Red Edition: pages 280-289
- ScienceSaurus, Blue Edition: pages 268-279
- Robertson, William C. Stop Faking It!, Forces and Motion. National Science Teachers Association, 2002

Science Vocabulary
In this unit, students will be introduced to rigorous science vocabulary, some of which would be assessable (i.e., forces, motion, gravity, technology) and some which should not but are necessary to move instruction forward (i.e., attributes, friction, resistance). A Handbook for Classroom Instruction That Works (2001) recommends the following guidelines for teaching vocabulary:
- Present students with a brief explanation or description of the words.
- Provide non-linguistic representations (pictures) of the terms.
- Ask students to generate their own explanations and create their own non-linguistic representations of the word.
- Provide multiple exposures to the words in multiple ways.

To this end, a science word wall is suggested as it provides an ongoing, organized display of key words and provides visual reference for students throughout a unit of study or a term. This wall should be extended to include engineering concepts as the unit progresses.

Procedure:
THE SCIENTIFIC INQUIRY PROCESS
Summary
Students will:
- Engage in observations and classification of marbles. Make observations of what happens when marbles are dropped to the ground.
- Explore how a force such as gravity affects a marble’s motion as it rolls down a ramp.
- Explain how variables such ramp height (potential energy), marble type (friction) and marble size (mass) can affect a marble’s motion. Research background information to gain deeper understanding of these concepts.
- Elaborate and extend student’s understanding and skills through an inquiry investigation.
- Evaluate student’s understanding through observations, conversations, and products created by the students.
Lesson 1: Engagement Activity

**Materials:**
- Sets of marbles of various types and sizes (one set per team of students)
- Plate or tray to sort the marbles in (one per team of students)
- Marble Madness Data Recording Sheet (one per student)

**Procedure:**
- Ask students to make and record observations of the marbles onto their data recording sheet.
- Ask students to explore one way they could sort their marbles. Have student teams share the different ways they did their sort. Explain that sorting by color, size or texture is sorting by “attributes”.
- Review the Data Recording Sheet with the students. Guide students to explore other ways they could sort their marbles, record their observations, and identify as many attributes as they can. Challenge them to sorting their marbles into 2, 3 and 4 groups.
- Discuss their findings as a class.
- Discuss and record wonderings and possible questions they have based on their wonderings.
- Next, hold up a marble and demonstrate while asking:
  - What will happen if I drop this marble?
  - Drop two marbles at the same time?
  - Drop a pitted marble and a smooth marble at the same time?
- Ask: Why do marbles fall to the ground when you drop them?
- Introduce the word “gravity” and explain that gravity is a force. Explain that a force is a push or a pull, and that gravity is a force that pulls objects towards the Earth.

Lesson 2: Exploration Activity

**Materials:**
- Sets of marbles of various types and sizes (one set per team of students)
- 2 rulers each per student team
- 1 tape measure for student team
- 1 book per student team
- Marble Madness Data Recording Sheet (one per student)

*Note: Rulers need to be of the type that has the groove running down the middle of it. The books need to all be the same and will be used to elevate one of the rulers to create a ramp. Pipe insulators that are cut in half lengthwise also work well as ramps.*
Procedure:

- Pass out all of the materials and demonstrate how to set them up as shown below. The tape measure will extend beyond the end of the ruler to enable the students can measure how far the marble travels.

- Review what was learned in the previous lesson.
- Introduce that today we will be doing more exploration with marbles by using ramps. Introduce that a ramp is a form of technology. Explain that a technology is: “Any tool or machine designed to help people in some way”. (ScienceSaurus, pg. 486)
  Note: As you work with your students, you should deliberately make connections with the different technologies used in their investigations (i.e., ruler, pencil, scissors, etc.) and why we use them.
- Demonstrate by releasing a small marble to roll down a ramp, then what to record on their data sheet.
- Say: There are many ways to explore these marbles using these ramps. Let see how many ways you can explore.
  - Possible guiding question to encourage more discoveries: What could be explored to make the marbles travel faster and farther?
- Suggestion: If an iPad is available, use it to record video of the various marbles traveling down the ramp and have students view it together to provide a foundation for the discussion.
- Discuss their findings as a class. Some of the variables that students may have explored include:
  - marble size
  - marble type
  - ramp height
- Questions that may guide the discussion include:
  - Did the size of the marble make a difference in how far the marble traveled?
  - What about the marble’s type or surface?
  - Did anyone change the height of the ramp? What happened to the marble when you did that?
  - What is causing the marble to roll down the ramp? (Gravity)
- Introduce the terms mass, friction and potential energy and briefly define them. ScienceSaurus provides the following definitions:
  - Mass: The amount of matter in an object or substance. (p. 467)
  - Friction: A force between two surfaces rubbing against each other; friction works
against motion. (p. 457)
  o Potential Energy: Energy that is stored in an object. (p. 476)

- Have students discuss and record their observations and wonderings they now have based on everything they have learned up to this point. The discussion should encourage the students to ask questions that will clarify their understanding of the concepts being presented in this investigation.

Lesson 3: Researching of Background Information

Procedure:
Have students build a deeper understanding of forces, gravity, friction, and potential energy through selective engagement with the following suggested resources:

**Discovery Education:**
- On DE home page, >click on “Science Elementary” >click on ‘Forces and Motion>Force>About Force> May the Force Be With You (eBook)
- On DE home page, >click on “Science Elementary” >click on ‘Forces and Motion>Force>Intro to Force and Motion>Playground Motion (eBook)
- On your DE homepage, type in “changing the speed of motion”. Click on Search. Click on **Exploration** “changing the speed of motion”; Click on ‘Launch in Popup’; follow instructions.
- On your DE homepage, type in “pulling your weight”. Click on Search. Click on **Virtual Lab** “pulling your weight”; click on Launch in Popup and follow instructions.
- On your DE homepage, type in “making things move”. Click on Search. Click on **Fun-damental** “making things move”; click on Launch in Popup; Have fun !
- On your DE homepage, type in “making things move”. Click on Search. Click on **video segment** “making things move”; click on Play

**The BBC:**
- Forces and Movement:
  [http://www.bbc.co.uk/schools/scienceclips/ages/6_7/forces_movement.shtml](http://www.bbc.co.uk/schools/scienceclips/ages/6_7/forces_movement.shtml)
- Pushes and Pulls:
  [http://www.bbc.co.uk/schools/scienceclips/ages/5_6/pushes_pulls.shtml](http://www.bbc.co.uk/schools/scienceclips/ages/5_6/pushes_pulls.shtml)
- Friction:
- About Forces:
  [http://www.zephyrus.co.uk/forces1.html](http://www.zephyrus.co.uk/forces1.html)
- ReviseWise Science--Activity-Physical Processes: Forces, Gravity, Friction
  [http://www.bbc.co.uk/schools/ks2bitesize/science/physical_processes/forces_action/read1.shtml](http://www.bbc.co.uk/schools/ks2bitesize/science/physical_processes/forces_action/read1.shtml)

ScienceSaurus, Red Edition: pages 280-289
Encourage student questioning to clarify topics under discussion.
Lessons 4-5: Guided Class Investigation

Materials:
- Sets of marbles of various types and sizes (one set per team of students)
- 2 rulers each per student team
- 1 tape measure for student team
- 1 book per student team
- Student Inquiry Data Recording Sheet
- Chart paper
- Pens

Procedure:
- Review student wonderings and identify one wondering they would like to explore as a class.
- Guide the students to develop their wondering into a research question and a hypothesis, and consider charting them for easy reference.
- Discuss how the procedure would be conducted and chart this as well. Introduce that as part of the procedure, students will need to run their experiment three times. This is called “replicable trials”.
- Pass out the materials to the students.
- Guide students to set up the ramps and review the Data Recording Sheet.
- Demonstrate how to conduct their experiment, with emphasis on accuracy of implementation (i.e., starting the marble at the top of the ramp in the same place for each trial, how to read the tape measure, how to measure when the marble strays from the tape measure, how to record the data on their data sheet, etc.).
- Have students implement their procedure, collect and record their data.
- Analyze the data as a class and determine whether their hypothesis was supported or not supported by the data.
- Discuss conclusions and record them on their chart.

Lesson 6: Revisiting Technology

Procedure:
- Ask students to recall what a technology is. If necessary, reinforce that a technology is: “Any tool or machine designed to help people in some way.” (ScienceSaurus, pg. 486)
- Tell students that they are now going on a “Technology Scavenger Hunt.” Explain that when you give the signal, their job is to get up and search the room for a “technology”. Further explain that the students should then bring their technology with them to the discussion area. Have students take turns sharing their technology with the class and tell why it is an example of “technology”.
- Introduce that in the next phase of their learning, they will build a car. Conclude by asking if the car is a form of technology and why.
**Lesson 7: Assessments**

**Procedure:**
- Discuss what students have learned from this investigation. Consider recording the student’s responses on a chart or graphic organizer.
- Address any wonderings they might still have.
- Have students complete the short constructed response assessment.

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<th>TEACHING &amp; ASSESSMENT (Steps 4, 5, 6, &amp; 7)</th>
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<td>Completed by teacher after instruction has taken place</td>
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| 4. Teaching and Collecting of Evidence of Student Learning: |
| Teacher Notes: |

| 5. Analysis of Student Products/Performances - Formative: |
| Teacher Notes: |

| 6. Evaluation of Student Products/Performances – Summative (Not necessary for every lesson): |
| Teacher Notes: |

| 7. Teacher Reflection: Replanning, Reteaching, Next Steps: |
| Teacher Notes: |
PLANNING (Steps 1, 2, & 3)

1. Standards/Benchmarks and Process Skills Assessed in this Lesson:

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   Note: The “L” codes at the end of each benchmark refer to the assigned level of the Marzano’s Taxonomic Level of Understanding. For example, “L3” refers to Taxonomic Level 3: Analysis.

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   - CTE Standard 1: TECHNOLOGICAL DESIGN: Design, modify, and apply technology to effectively and efficiently solve problems

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<td>• Understand that the Engineering Design Process is a systematic process used to design and redesign solutions to problems.</td>
</tr>
<tr>
<td>• Design products and solutions using the Engineering Design Process.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2B. Assessment Tools/Evidence:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Formative:</strong></td>
</tr>
<tr>
<td>• Discussions (conversations) of concepts</td>
</tr>
<tr>
<td>• Observations conducted as students build their gravity racers</td>
</tr>
<tr>
<td>• Products: Recorded results of each step of the Engineering Design Process</td>
</tr>
<tr>
<td>• Explanation of the results of their investigation to an audience, including connections to the concepts focused on in their targeted benchmarks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Summative:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Student written assessment product:</td>
</tr>
<tr>
<td>• Engineering Design Process Assessment</td>
</tr>
<tr>
<td>• Engineering Design Process Reflections</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. Learning Experiences (Lesson Plan)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Materials:</strong></td>
</tr>
<tr>
<td>• Measuring tape</td>
</tr>
<tr>
<td>• Pencil and mechanical pencil</td>
</tr>
<tr>
<td>• Sub-standard examples of gravity cars</td>
</tr>
<tr>
<td>• Large ramps from corrugated cardboard boxes</td>
</tr>
<tr>
<td>• Materials for gravity racers (milk cartons, tape, scissors, wheels made using bottle drink caps for wheels and barbeque skewers inserted in straws to create an axle, coins or other small objects to add weights, etc.)</td>
</tr>
<tr>
<td>• See Station Cards document for materials needed for the Discovery Learning Stations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Handouts/Other Resources:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Station Cards</td>
</tr>
<tr>
<td>• Gravity Racer Learning Stations Data Recording Sheet</td>
</tr>
<tr>
<td>• Gravity Car Engineering Design Process Journal</td>
</tr>
<tr>
<td>• EDP Rubric</td>
</tr>
<tr>
<td>• Student Observation Recording Sheet</td>
</tr>
</tbody>
</table>
Teacher Background Information:
We have just learned about forces and motion. In this unit, students will be engineering a model of car. As a prerequisite to building this car, it would be beneficial for students to know a little about aerodynamics, friction, and mass, and their affects on acceleration.

- Acceleration is the rate of change of an object’s speed or direction.
- Friction causes moving objects to slow down.
- Aerodynamics is the way air moves around things.
- An aerodynamic design reduces the amount of air friction acting on a car.

Consider reading the following articles:
- http://www.grc.nasa.gov/WWW/k-12/airplane/bga.html

Procedure:
THE ENGINEERING DESIGN PROCESS

Lesson 8-9: Discovery Learning Stations
- Establish the following Learning Stations for students to observe and explore the different concepts identified above. A Station Cards document that includes instructions for setting up the stations and a Data Recording Sheet accompany this unit.

<table>
<thead>
<tr>
<th>Station 1</th>
<th>Station 2</th>
<th>Station 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friction</td>
<td>Aerodynamics</td>
<td>Weight</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Station 4</th>
<th>Station 5</th>
<th>Station 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramp Height</td>
<td>Wheel Alignment</td>
<td>Size of Wheels</td>
</tr>
</tbody>
</table>

- Have students visit the stations in teams of 2-3.
- Consider the ability levels of your students in determining how many stations they can explore at one time. 2-3 stations per instructional period may be more realistic for this age level.
- Have student teams share their data at the end of each day’s explorations.
- Explain that we will now be using what we have just learned to build a car. Ask: What are some of the things we will need to remember as we build it?

Lesson 10: Engagement Activity
Getting Ready for the Big Event: Materials and Preparation
- Duplicate the Student Observation Recording Sheet to record evidence of their learning.
- Duplicate the Gravity Car EDP journal.
- Create large ramps from corrugated cardboard boxes and set them up.
• Attach measuring tape to the floor (starting at the base of the ramp) for students to quantify the distance the car travels.
• Pass out Gravity Car EDP Journals to each student.
• Note that the class will go through each step of the process together. Stop after each step to discuss what the students did and the criteria needed. Teacher may refer to the “Engineering Design Process Rubric” to help guide discussions. Do the amount of steps you feel your students can handle in the time allotted. It may take 1 day or many days to go through and understand these steps. Don’t worry… it’s the process that’s important.
• Just as they would in the real world, assign students to work in teams.
• Explain that although the students are part of a team, each student is responsible for completing each part of their own engineering design process journal. The team is there to help brainstorm, share ideas, and create 1 product, but each student must participate and contribute their individual ideas to help the group.
• Show students a pencil. Ask students...
  o What is an engineer? (A person who solves problems by creating technological tools/products by applying their scientific knowledge)
  o How is this pencil an example of engineering?
• Show students a mechanical pencil. Ask students...
  o How did an engineer come up with this new design?
  o What process did the engineer go through to redesign this pencil?
• Guide the discussion to show that their natural way of thinking of how to do things is similar to the Engineering Design Process that they will be experiencing.

Performance Task
Read performance task to students...
Gasoline is so expensive! Your parents complain about the price of gas all the time and don’t want to drive you to all the places that you want to go! Oh! No! How will you get to your soccer games? That’s a problem. How can people use less gas? Gravity could do the work! Instead of using gas, cars could roll to their destinations. The more a car rolls, the less gas it uses. Your task is to design a car that will travel down a slope in a straight line for the longest distance possible powered only by gravity. Have fun creating your Gravity Car!
### Steps of the Process

#### EDP Step 1: Ask
- Show sub-standard examples of Gravity Car (that you created).
- Have students identify:
  - the problem of the performance task
  - what they are creating
  - the criteria and constraints for making this Gravity Car
- Show students the materials that are available for them to use. Consider keeping all of the materials on a “materials table” for easy access.
- Have students:
  - write further questions they may have about constructing this Gravity Car
  - share questions with the class for teacher to answer
- Stop and go over the criteria for the “Ask” section of the process. Take notes on the Student Observation Recording Sheet to record evidence of their learning.

#### Lesson 11: EDP Step 2: Imagine
- Instruct students to independently brainstorm ideas for building a Gravity Car and draw or write out ideas in their journal.
- Encourage students to discuss their ideas with the rest of the engineering team. Students should defend their reasons for using specific ideas from their prototype. (Ex. Need an aerodynamic hood for the car to cut through the air)
- Tell students that each engineering team may then decide on ONE person’s design to use or create ONE new hybrid idea incorporating all the differing ideas.
- Stop and go over the criteria for the “Imagine” section of the process. Take notes on the Student Observation Recording Sheet to record evidence of their learning.

#### Lesson 12: EDP Step 3: Plan
- Designate one person to sketch a diagram of the team’s “Gravity Car” prototype onto a piece of paper. This sketch should include labels for each of the parts and possible measurements. The sketcher must be sure to incorporate all the agreed upon ideas into the design. Students then list all possible materials that will be needed to create the prototype.
- Inform students that when all team members are satisfied with the prototype design, each member should copy this diagram of the Gravity Car onto their journals.
- Instruct team members to check with each other to see if all drawings and labels are completed and everyone has the same plan to follow.
- Stop and go over the criteria for the “Plan” section of the process. Take notes on the Student Observation Recording Sheet to record evidence of their learning.

#### Lessons 13-14: EDP Step 4: Create
- Instruct students to follow their team plan as closely as possible when building their prototype. If they are modifying their original prototype to make their prototype work, guide students to be sure each person writes down and adds that information to their journal diagram plans as well.
• Ask teams to share your prototype Gravity Car to the large group, stating what modifications were made to the plan and why.
• Stop and go over the criteria for the “Create” section of the process. Take notes on the Student Observation Recording Sheet to record evidence of their learning.

Lesson 15: EDP Step 5: Experiment  Test it out!
• Bring your gravity car to the starting line on the ramp.
• Place car behind the starting line.
• Let go of car when teacher says, “Go!”
• Measure the distance that the car rolled.
• No modifications should be made to the cars during this testing time if the cars already roll down the ramp. The only modifications that can be made are to the cars that are not able to roll down the ramp. At this phase, modifications made are for making the product work.
• Log data onto student journals. Circle the trial with the longest distance.
• Have teams share out their data and the reasons for their results to the class. Chart the distances of each car for all students to see. (Students will be learning from each other and using other people’s ideas, as well as their own, as they are improving upon their prototype)
• Stop and go over the criteria for the “Experiment” section of the process. Take notes on the Student Observation Recording Sheets to record evidence of their learning.

Lessons 16-18: EDP Step 6: Improve
• Have each team review the results of their data.
• Repeat the EDP to optimize the product. Students would continue to record the following in their journal...
• Ask: What worked? What didn’t work? Why?
• Imagine: Which variables will they change to help the car roll a greater distance? What’s the rationale for the changes?
• Plan: The diagram of the team’s 2nd prototype, with parts and measurements labeled.
• Create: Building of the second prototype following the team’s design.
• Experiment: Their data results from testing their 2nd prototype.
• Write 3 facts comparing the data tables for prototypes 1 and 2.
• Analyze the data and explain the results that you find.

Reminder: You may go through this EDP cycle many times to get an optimized product that is wanted. It all depends on the amount of time you have available.

Summary and Conclusions:
• Have each team share their product, how they changed and improved their Gravity Car with a rationale of why, as well as their data. They may also share what they learned about the forces of push and pull, and gravity.
Lesson 19: Assessments
- Have the students review/explain EDP process and what was involved at each step.
- Have students complete:
  - The EDP Assessment
  - EDP Reflections

Lesson 20: Wrapping It Up
- If a Science and Engineering Word Wall was established, consider using the vocabulary to create a concept (thinking map). Be sure to emphasize the following Big Ideas as the map is created:
  - A force is a push or a pull.
  - Forces affect the motion of objects.
  - People create technological devices.
  - Scientific inquiry investigations enable us to answer questions about the world around us.
  - The Engineering Design Process enables us to solve problems and design solutions.

<table>
<thead>
<tr>
<th>TEACHING &amp; ASSESSMENT (Steps 4, 5, 6, &amp;7)</th>
<th>Completed by teacher after instruction has taken place</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4. Teaching and Collecting of Evidence of Student Learning:</strong></td>
<td></td>
</tr>
<tr>
<td>Teacher Notes:</td>
<td></td>
</tr>
<tr>
<td><strong>5. Analysis of Student Products/Performances - Formative:</strong></td>
<td></td>
</tr>
<tr>
<td>Teacher Notes:</td>
<td></td>
</tr>
<tr>
<td><strong>6. Evaluation of Student Products/Performances – Summative (Not necessary for every lesson):</strong></td>
<td></td>
</tr>
<tr>
<td>Teacher Notes:</td>
<td></td>
</tr>
<tr>
<td><strong>7. Teacher Reflection: Replanning, Reteaching, Next Steps:</strong></td>
<td></td>
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<tr>
<td>Teacher Notes:</td>
<td></td>
</tr>
</tbody>
</table>
# Marble Madness Data Recording Sheet

<table>
<thead>
<tr>
<th>Record marble observations:</th>
<th>Determine marble attributes:</th>
<th>Identify attributes that would allow for sorting into:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2 Groups</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Groups</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 Groups</td>
</tr>
</tbody>
</table>

Record your wonderings:

Record possible questions based on your wonderings:
## Exploring with Ramps

<table>
<thead>
<tr>
<th>What We Explored (Tested)</th>
<th>Data</th>
<th>Observations and Wonderings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>
Student Inquiry Data Recording Sheet

Our Hypothesis:

_________________________________________________________________________________________________
_________________________________________________________________________________________________
_________________________________________________________________________________________________

Data Table

<table>
<thead>
<tr>
<th>Variable Tested</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Note: What is entered on the left column depends on the variable being tested, whether its small vs. large marble, smooth vs. pitted marble, ramp height, etc.

Data Analysis: ____________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Summary and Conclusions: ____________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
# Elementary Inquiry Rubric

<table>
<thead>
<tr>
<th>Component</th>
<th>4-More than Adequate Progress (Exceeding the Standards)</th>
<th>3-Adequate Progress (Meeting the Standards)</th>
<th>2-Limited Progress (Approaching the Standards)</th>
<th>1-No Progress (Well Below the Standards)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Question</td>
<td>Question to be answered during the investigation is clearly identified, stated in proper form, &amp; focuses on relevant benchmark(s). It is a meaningful question that drives investigation to help students understand deeply the appropriate benchmark(s). Question is based on initial explorations &amp; observations.</td>
<td>Question to be answered during the investigation is identified &amp; stated in proper form. Question is based on initial explorations &amp; observations.</td>
<td>Question to be answered during the investigation is partially identified &amp; stated in somewhat unclear manner.</td>
<td>Question to be answered during the investigation is irrelevant.</td>
</tr>
<tr>
<td>Background Information</td>
<td>Many relevant &amp; significant background sources used &amp; documented correctly. Information written in student’s own words &amp; shows detail &amp; specific connections to the investigation.</td>
<td>Several relevant &amp; significant background sources used &amp; documented correctly. Information written in student’s own words.</td>
<td>Few background sources were used &amp; documented somewhat incorrectly. Some information is written in student’s own words.</td>
<td>Little or no background sources used. Information is directly copied from source(s).</td>
</tr>
<tr>
<td>Hypothesis</td>
<td>Hypothesis is clearly stated &amp; testable using the form “If ___, then ___ because ______.” It is based on observations &amp; prior research.</td>
<td>Hypothesis stated in a testable form “If ___, then ___ because ___. Hypothesis based on general knowledge &amp; observations.</td>
<td>Hypothesis is unclear &amp; poorly stated. Hypothesis is loosely connected to observations or general knowledge.</td>
<td>Hypothesis is missing.</td>
</tr>
<tr>
<td>Experimental Design (Materials)</td>
<td>All materials used in the investigation are reasonable and obtainable. They are correctly listed &amp; accurately described.</td>
<td>Most materials used in the investigation are reasonable &amp; obtainable. Most materials are listed &amp; described.</td>
<td>Some of the materials used in the investigation are reasonable &amp; obtainable. Some of the materials are listed.</td>
<td>One or more important materials may not be obtainable. Materials are listed inaccurately.</td>
</tr>
<tr>
<td>Experimental Design (Method)</td>
<td>Experimental design is well constructed to test the hypothesis. A control is included where appropriate. The investigation is controlled to test one variable. The procedure is clear &amp; easy to follow. Anyone should be able to follow the design so that the investigation can be repeated, if needed. The design includes meaningful data sheets.</td>
<td>Experimental design is adequate to test the stated hypothesis but might need some clarifications. The procedures are generally complete &amp; in sequence; however, minor modifications are needed. Attempts to control variables are made but need modifications.</td>
<td>Experimental design is relevant to the hypothesis, but is not a complete investigation. The procedures are incomplete &amp; major modifications are needed. Little attempt to control variables.</td>
<td>Experimental design is not relevant to the hypothesis. The procedures are incomplete &amp; there is no control of variables.</td>
</tr>
<tr>
<td>Component</td>
<td>4-More than Adequate Progress (Exceeding the Standards)</td>
<td>3-Adequate Progress (Meeting the Standards)</td>
<td>2-Limited Progress (Approaching the Standards)</td>
<td>1-No Progress (Well Below the Standards)</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------------------------------------------</td>
<td>---------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td><strong>Data</strong></td>
<td>Data are well organized &amp; neatly presented. Graphs &amp; tables are labeled, summarized &amp; titled correctly. Graphs &amp; tables accurately &amp; meaningfully present the data.</td>
<td>Data are organized &amp; presented in an appropriate manner. Minor errors are present. Graphs &amp; tables are labeled, summarized &amp; titled.</td>
<td>Data are poorly organized &amp; the presentation is inappropriate. Major errors are present. Graphs or tables are not labeled, titled, or summarized correctly or may be missing.</td>
<td>Data are not organized or &amp; the presentation is inappropriate or data are not shown. Graphs &amp;/or tables are poorly done or missing.</td>
</tr>
<tr>
<td><strong>Data Analysis</strong></td>
<td>Highlights of the data are well summarized, capturing the significant details to provide the evidence needed to answer the research question. Important relationships, patterns, &amp; changes observed throughout the investigation are included in the summary to make deep &amp; meaningful connections of understandings.</td>
<td>Most of the obvious highlights are summarized with clarity &amp; some detail. Some comparisons &amp; relationships are made to show connections of understanding.</td>
<td>Some obvious highlights are summarized but may include misconceptions. Connections are not always logical. Some patterns &amp; relationships are not based on the data collected.</td>
<td>Highlights of the data collected may not be included. There is no connection between the summarized data &amp; the actual data collected.</td>
</tr>
<tr>
<td><strong>Discussion / Conclusion</strong></td>
<td>Conclusion includes a reasoned decision about the hypothesis &amp; is fully supported by data. Conclusion also includes possible sources of error, what was learned in the investigation &amp; implications/next steps of investigation.</td>
<td>Conclusion includes a decision about the hypothesis &amp; is supported by data. Conclusion also includes what was learned in the investigation.</td>
<td>Conclusion includes a decision about the hypothesis but is not supported by data.</td>
<td>Conclusion is not related to the hypothesis &amp; data support is lacking or missing or no conclusion was included in the investigation.</td>
</tr>
</tbody>
</table>
## GRAVITY CAR STATION CARDS AND INSTRUCTIONS

<table>
<thead>
<tr>
<th>STATION</th>
<th>MATERIALS NEEDED</th>
<th>INSTRUCTIONS</th>
<th>PICTURES</th>
</tr>
</thead>
</table>
| **1 Friction** | • 1 set of wheels that are smooth  
• 1 set of wheels that have tape on them to increase friction,  
• 1 ramp (Note: The ramp should be of sufficient width so that two cars can be tested at the same time.) | Roll each set of wheels down the ramp.  
Which one rolled farther? | ![Station 1: Friction](image1.png) |
| **2 Aerodynamics** | • 1 “rectangular bus”  
• 1 aerodynamic car (both created from a half-gallon milk carton so they have approximately the same mass)  
• 1 fan | Roll each vehicle into the wind.  
Which vehicle is able to travel farther? | ![Station 2: Aerodynamics](image2.png) |
| **3 Weight** | • 2 vehicles of the same construction, with one vehicle filled with rocks or sand to give it weight  
• 1 ramp | Roll each vehicle down the ramp.  
Which rolls farther? | ![Station 3: Weight](image3.png) |
<table>
<thead>
<tr>
<th></th>
<th>4</th>
<th>Ramp Height</th>
</tr>
</thead>
</table>
|   | • 2 sets of wheels  
   | • 2 ramps  
   | • 1 basket (as in the picture) or anything to prop up the ramp to make it steeper |
|   | Roll the axle down each ramp.  
   | Which ramp makes the wheels roll faster and farther? |

<table>
<thead>
<tr>
<th></th>
<th>5</th>
<th>Wheel Alignment</th>
</tr>
</thead>
</table>
|   | • 1 car with the wheels parallel to each other  
   | • 1 car with the wheels off alignment  
   | • 1 ramp |
|   | Roll the vehicles down the ramp.  
   | Which word best describes how the car is rolling? |

<table>
<thead>
<tr>
<th></th>
<th>6</th>
<th>Size of Wheels</th>
</tr>
</thead>
</table>
|   | • 1 set with large wheels attached  
   | • 1 set with small wheels attached  
   | • 1 set with a small and a large wheel attached (optional).  
   | • 1 ramp |
|   | Roll each set of wheels down the ramp.  
<p>| Which set of wheels rolled down the ramp faster? |</p>
<table>
<thead>
<tr>
<th>Station 1: Friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roll each set of wheels down the ramp. Which one rolled farther?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Station 2: Aerodynamics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roll each vehicle into the wind. Which vehicle is able to travel farther?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Station 3: Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roll each vehicle down the ramp. Which rolls farther?</td>
</tr>
<tr>
<td>Station 4: Ramp Height</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>Roll the axle down each ramp. Which ramp makes the wheels roll faster and farther?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Station 5: Wheel Alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roll the vehicles down the ramp. Which word best describes how the car is rolling?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Station 6: Size of Wheels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roll each set of wheels down the ramp. Which set of wheels rolled down the ramp faster?</td>
</tr>
</tbody>
</table>
Gravity Racer Learning Stations Data Recording Sheet

**Station 1: Friction**

Roll each set of wheels down the ramp. Which rolls farther?

☐ Wheels with friction ☐ Wheels without friction

Observations:
______________________________________________________________________________
______________________________________________________________________________

Why do you think this happened?
______________________________________________________________________________
______________________________________________________________________________

**Station 2: Aerodynamics (How the force created by the motion of air affects the motion of an object)**

Roll each vehicle into the wind. Which vehicle is able to travel farther?

☐ Rectangular bus ☐ Aerodynamic car

Observations:
______________________________________________________________________________
______________________________________________________________________________

Why do you think this happened?
______________________________________________________________________________
______________________________________________________________________________

**Station 3: Weight**

Roll each vehicle down the ramp. Which rolls farther?

☐ Heavy vehicle ☐ Light vehicle

Observations:
______________________________________________________________________________
______________________________________________________________________________

Why do you think this happened?
______________________________________________________________________________
______________________________________________________________________________
**Station 4: Ramp Height**

Roll the axle down each ramp. Which ramp makes the wheels roll faster?

- [ ] High ramp
- [ ] Low ramp

Roll the axle down each ramp. Which ramp makes the wheels roll farther?

- [ ] High ramp
- [ ] Low ramp

Observations:
______________________________________________________________________________
______________________________________________________________________________

Why do you think this happened?
______________________________________________________________________________
______________________________________________________________________________

**Station 5: Wheel Alignment**

Roll the vehicle down the ramp. What word best describes how the car is rolling?

Car 1: (wheels parallel)

- [ ] Straight
- [ ] Curved
- [ ] Circular
- [ ] Zigzag

Car 2: (wheels not parallel)

- [ ] Straight
- [ ] Curved
- [ ] Circular
- [ ] Zigzag

Observations:
______________________________________________________________________________
______________________________________________________________________________

Why do you think this happened?
______________________________________________________________________________
______________________________________________________________________________
Station 6: Size of Wheels

Roll each set of wheels down the ramp. Which set of wheels rolled faster?

☐ Large wheels  ☐ Small wheels  ☐ Large and small wheels

Observations:

______________________________________________________________________________
______________________________________________________________________________

Why do you think this happened?

______________________________________________________________________________
______________________________________________________________________________
Gravity Car Engineering Design Process Journal

**Performance Task:** Gasoline is so expensive! Your parents complain about the price of gas all the time and don’t want to drive you to all the places that you want to go! Oh, no! How will you get to your soccer games? That’s a problem. How can people use less gas? Gravity could do the work! Instead of using gas, cars could roll to their destinations. The more a car rolls, the less gas it uses. Your task is to design a car that will travel down a slope in a straight line for the longest distance possible powered only by gravity. Have fun creating your Gravity Car!

**Criteria and Constraints:**
- Your Gravity Car will be placed on a ramp behind the starting line and released. Pushing the car is not allowed.
- Every part of the car must be constructed by you using the materials that are available, except for the wheels and axle, which will be provided.
- The distance your car travels will be measured from the bottom of the ramp to the back end of your car.

What is the problem? _____________________________________________________________

What are you being asked to design? _______________________________________________

**STEP 1: ASK:** Ask questions that pertain to completing the performance task.

1. ________________________________________________________________________________
   ________________________________________________________________________________
2. ________________________________________________________________________________
   ________________________________________________________________________________
3. ________________________________________________________________________________
   ________________________________________________________________________________
4. ________________________________________________________________________________
STEP 2: IMAGINE: Use your background knowledge of forces and gravity to design a prototype of a Gravity Car. These are some ideas you should consider when creating your Gravity Car: weight distribution, mass, air resistance, aerodynamics, and friction.

Draw your possible designs and label the parts. Be ready to share and discuss your design and explain the reasons for your design choices. Your design team will be choosing one to develop.
STEP 3: PLAN: Draw the diagram of your team’s prototype. Label each part. Also state the type of material used for each part and the possible measurements.

Side View:

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Top View:
**STEP 4: CREATE:** Build your prototype following your team’s design. Keep to the plan.
What modifications did you need to make in order to be sure that your design would hold together and work? Be sure to record them on your plan.

**STEP 5: EXPERIMENT:**

<table>
<thead>
<tr>
<th>Data Table 1: Distance Rolled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inches</td>
</tr>
<tr>
<td>Trial 1</td>
</tr>
<tr>
<td>Trial 2</td>
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<tr>
<td>Trial 3</td>
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</tbody>
</table>

**STEP 6: IMPROVE:**

**ASK:** Looking at your data, answer the following questions:

- What worked? Why? ________________________________

- What didn’t work? Why? ________________________________

<table>
<thead>
<tr>
<th>Things to Consider</th>
<th>Did it work?</th>
<th>Why or why not?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape of body (aerodynamics)</td>
<td>Yes</td>
<td>Why or why not?</td>
</tr>
<tr>
<td>Wheels (friction)</td>
<td>Yes</td>
<td>Why or why not?</td>
</tr>
<tr>
<td>Wheels (position)</td>
<td>Yes</td>
<td>Why or why not?</td>
</tr>
<tr>
<td>Weight of car Distribution of weight on car</td>
<td>Yes</td>
<td>Why or why not?</td>
</tr>
</tbody>
</table>
IMAGINE: Which variable(s) of the Gravity Racer will you change to help it roll a longer distance? What is your rationale for changing each variable?

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PLAN: Draw a diagram of your team’s 2nd prototype. Remember to label your parts, state the type of material used for the part, and possible measurements.

Side View:
CREATE: Build your 2nd prototype following your team’s design. Keep to the plan. Use the materials listed as well as the measurements that your group decided upon.

EXPERIMENT:

Data Table 2: Distance Rolled

<table>
<thead>
<tr>
<th></th>
<th>Prototype 1</th>
<th>Prototype 2</th>
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</thead>
<tbody>
<tr>
<td><strong>Trial 1</strong></td>
<td></td>
<td></td>
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<tr>
<td><strong>Trial 2</strong></td>
<td></td>
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<tr>
<td><strong>Trial 3</strong></td>
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</tbody>
</table>

Write at least three facts comparing data tables 1 and 2.

Fact 1

Fact 2

Fact 3
**Data Analysis:** Compare the data from prototype 1 and prototype 2.

1. Which prototype was more effective? (circle)  
   - Prototype 1  
   - Prototype 2

Use your background knowledge of weight distribution, air resistance, mass, aerodynamics, friction, and your data to explain your answer.

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**IMPROVE:** If you had more time and materials, what would you do to optimize your Gravity Car even more? Explain your thinking.

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# Engineering Design Process Rubric

<table>
<thead>
<tr>
<th>ASK</th>
<th>Advanced (ME)</th>
<th>Proficient (M)</th>
<th>Partially Proficient (DP)</th>
<th>Novice (WB)</th>
</tr>
</thead>
</table>
|     | - Clarifies the problem clearly  
|     | - Forms the conditions and limitations on their own  
|     | - Obtains information from prior knowledge and other sources with citation by self  
| IMAGINE | - Brainstorms a variety of innovative ideas  
|     | - Innovative ideas are relevant to the problem  
| PLAN | - Chooses the best possible idea that is testable  
|     | - Draws a useable and accurate prototype design with more than 2 views to scale  
|     | - Lists all materials needed that are affordable, obtainable, and safe  
| CREATE | - Able to follow their design plan accurately  
|     | - Able to improve original design to optimize performance  
| EXPERIMENT | - Collects and records detailed data accurately and completely  
|     | - Analyzes data by comparing patterns and relationships accurately with logic  
| IMPROVE | - Reviews data to make logical decisions to optimize product  
|     | - Repeats process until an optimized product is reached with greatly improved data  
|     | - Clarifies the problem  
|     | - States all the conditions and limitations  
|     | - Obtains information from prior knowledge by self  
|     | - Clarifies the problem  
|     | - States all the conditions and limitations  
|     | - Obtains information from prior knowledge by self  
|     | - Needs more clarification of the problem  
|     | - States most conditions and limitations  
|     | - Obtains information from prior knowledge (drawn out by teacher)  
|     | - Brainstorms a complete idea  
|     | - Idea is relevant to the problem  
|     | - Brainstorms an incomplete idea  
|     | - Idea is somewhat relevant to the problem  
|     | - Chooses one idea that is testable  
|     | - Draws a useable prototype design with multiple views to scale  
|     | - Lists all materials needed  
|     | - Able to follow their design plan, with some inaccuracies  
|     | - Able to add to the original design to make the design work  
|     | - Collects and records data accurately and completely  
|     | - Analyzes data by showing patterns or relationships accurately  
|     | - Reviews data to make decisions to redesign product  
|     | - Repeats process to optimize a product. Data may/may not show improvement  
|     | - Reviews data to make decisions to redesign product  
|     | - Repeats process to optimize a product  
|     | - Reviews data to make decisions to redesign product with assistance  
|     | - Repeats process to maintain a product  
|     | - Reviews data to make decisions to redesign product with some assistance  
|     | - Data collection inaccurate and incomplete  
|     | - States obvious patterns or relationships with assistance  
|     | - Reviews data to make decisions to redesign product (assistance needed)  
|     | - Does not repeat process to improve product or repeats process with much assistance  
|     | - Problem is unclear  
|     | - States few (or no) conditions and limitations  
|     | - Information given by teacher  
|     | - Unable to brainstorm ideas, teacher assistance needed  
|     | - Brainstormed ideas have little relevance to the problem  
|     | - Chooses an idea that is not testable  
|     | - Draws an unusable prototype design with one or more views  
|     | - Incomplete or inaccurate lists of materials (assistance needed)  
|     | - Data collection inaccurate and incomplete  
|     | - States obvious patterns or relationships with assistance  
|     | - Reviews data to make decisions to redesign product (assistance needed)  
|     | - Does not repeat process to improve product or repeats process with much assistance  
|     | - Unable to follow their design plan  
|     | - Sticks to original design although it may not work  

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**Note:** The rubric is designed to assess how well students apply the engineering design process to solve a problem. Advanced students are those who clearly and independently identify and state the problem, obtain information from prior knowledge and other sources, and think innovatively. Proficient students can independently state all the necessary conditions and limitations, and obtain information from prior knowledge. Partially proficient students need more clarification of the problem, and may state most of the necessary conditions and limitations and obtain information from prior knowledge. Novices may not be able to clearly identify and state the problem, and may need more clarification and assistance to think innovatively.
<table>
<thead>
<tr>
<th>Activity:</th>
<th>Date:</th>
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<tbody>
<tr>
<td>Student’s Name</td>
<td>Observation</td>
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Name: ________________________________                    Date: ____________

**Engineering Design Process Reflections**

What did you learn about the Engineering Design Process?

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Which part was easy for you? Why?

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Which part was harder for you? Why?

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Engineering Design Process Assessment

Directions: Draw or write what you did at each step of the process.

<table>
<thead>
<tr>
<th>Ask - I asked questions to help me understand what I need to know and do.</th>
<th>Imagine - I thought of different ideas of how to make my product.</th>
<th>Plan - I chose one of my ideas and drew a picture of it.</th>
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<tr>
<th>Create - I followed my plan as I made my product.</th>
<th>Experiment - I tested my product and collected and recorded my data on tables and graphs.</th>
<th>Improve - I thought about what worked and didn’t work and how I could improve my product.</th>
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Engineering Design Process Assessment

Now draw and/or write to tell us how the Engineering Design Process helps us.