Grade 9-12 STEM Challenge

# Operation Marble Drop

Inspired by Gabi, an Electrical Engineer in the Indiana Uplands.

Published by Regional Opportunity Initiatives

GRADE 9-12 STEM CHALLENGE

# Operation Marble Drop

Inspired by Gabi, an Electrical Engineer in the Indiana Uplands.

Students will create a zipline and delivery device to drop a marble on a target area.


## CAREER CONNECTION AND LESSON OVERVIEW

Engineers who work for the Navy, like Gabi, are given unique challenges to solve every day. All engineers use the engineering design process as a blueprint for solving problems and devising solutions. Like real engineers, students will be given criteria (what the design must do) and constraints (resources and limitations) in order to meet an objective.

In this challenge, students will have to design a system that accurately delivers a payload, similar to the types of guidance systems Gabi designs for the Navy (but much less high tech!) They create a paper cup system that will hold a marble, slide down a smooth line, and drop the marble onto a target. The designed system will need to hold the marble while it is traveling and release it when required.

## LESSON TIMELINE

**DAY 1**
- Show the inspiration video, "Gabi - Electrical Engineer" (10 minutes)
- Introduce the Engineering Design Process (10 Minutes)
- Introduce the challenge (5 Minutes)
- Brainstorm, Design, and Build (20 minutes)

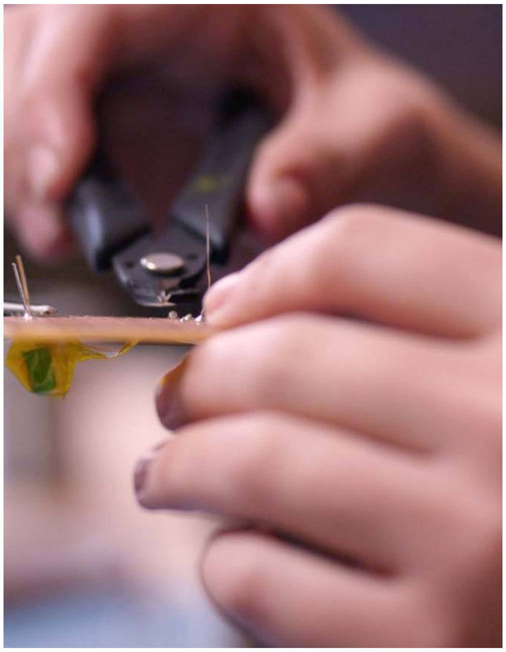
**DAY 2**
- Finish zipline designs (time varies, provide at least a class period for students to build and test)
- Test and refine designs (time varies)

**DAY 3**
- Final design performance evaluation (if not completed on day 2)

## Recommended Supplies

General supplies per group (3-4 Students):
- 9 feet (3m) of smooth line (e.g. fishing line or kite string)
- Index Card
- Marble
- Masking Tape
- Paper Clip
- 1 Medium Sized Paper Cup
- Scissors
- Target (drawn on paper)
- Yard Stick

Zipline range or course (usually strung between two chairs.)



# IN THIS CHALLENGE, STUDENTS WILL:

- Use the engineering design process to create a marble-delivery device.
- Make connections between their designs and the real world systems created by engineers.

# Standards

**Science & Engineering Process Standards**
SEPS.1 Posing Questions (for science) and defining problems (for engineering)
SEPS.2 Developing and using models and tools
SEPS.4 Analyzing and interpreting data
SEPS.6 Constructing explanations (for science) and designing solutions (for engineering)
SEPS.8 Obtaining, evaluating, and communicating information

**Preparing for College and Careers**
PCC-2.1 Determine roles, functions, education, and training requirements of various career options within one or more career clusters and pathways
PCC-2.2 Analyze career trends, options and opportunities for employment and entrepreneurial endeavors for selected career clusters and pathways
PCC-2.3 Evaluate selected careers and pathways for education requirements, working conditions, benefits, and opportunities for growth and change
PCC-2.4 Use appropriate technology and resources to research and organize information about careers

**Integrated Chemistry and Physics**
ICP-4.2 Identify forms of energy present in a system (kinetic, gravitational, elastic, etc.)
ICP-4.3 Understand and explain that the total energy in a closed system is conserved.
ICP-4.4 Qualitatively and quantitatively analyze various scenarios to describe how energy may be transferred into or out of a system by doing work through an external force or adding or removing heat.

**Physics I**
PI.3.1 Understand Newton's first law of motion and describe the motion of an object in the absence of a net external force according to Newton's first law
PI.4.2 Identify the forms of energy present in a scenario and recognize that the potential energy associated with a system of objects and is not stored in the object itself
PI.4.3 Conceptually define "work" as the process of transferring of energy into or out of a system when an object is moved under the application of an external force and operationally define "work" as the area under a force vs. change in position curve

**Grade 9-10 Employability Skills**
9-10.M.2 Able to view feedback as data' that helps the learning process
9-10.M.3 Demonstrate an awareness of strengths and weaknesses while accepting constructive criticism from others to improve results
9-10.WE.2 Complete tasks or activities with minimal prompting and guidance
9-10.LS.1 Write documents for a variety of purposes and audiences using varied media formats
9-10.LS.7 Predict outcomes to problems based on data and evidence
9-10.LS.10 Able to approach problems with reasoning and logic to hypothesize results
9-10.LS.11 Able to combine concepts in different ways to create new ideas and innovative solutions
9-10.SE.3 Able to listen to others' ideas and respect different ways of being and doing

# Planning and Implementation

OPERATION MARBLE DROP

## Essential Vocabulary

- NEWTON'S FIRST LAW OF MOTION: An object at rest stays at rest and an object in motion stays in motion until acted upon by an outside force.
- VELOCITY: The speed at which an object movies.
- FORCE: A push or pull on an object that transfers energy to the object.
- ACCELERATION: The change in an object's velocity per unit of time.
- FRICTION: The resistance one object encounters when moving over another.
- TRAJECTORY: The path followed by a projectile flying or an object moving under the action of given forces.
- POTENTIAL ENERGY: The stored mechanical energy resulting from its position, i.e. the energy a marble has at the top of a hill before it starts rolling down.
- KINETIC ENERGY: The energy of an object in motion.

## In this challenge, students will:

- Use the engineering design process to:
  - Modify a cup to carry a Navy payload (a marble) down a zipline.
  - Attach a string to tip the cup and release their payload (again, played by the marble.)
  - Test their device by sliding the cup down a zipline, releasing the payload, and trying to hit the target landing zone.
- Brainstorm, design, test, evaluate, and redesign their delivery vehicles before reporting their best designs out to their teachers and peers.

## Before Class:

- Read the activity outline sheet and leader notes to become familiar with the activity.
- Gather necessary materials. Be sure that you have enough materials and space for students to work in groups of 3-4. Each zipline requires approximately 4 m of space. Construct example zip lines if necessary.

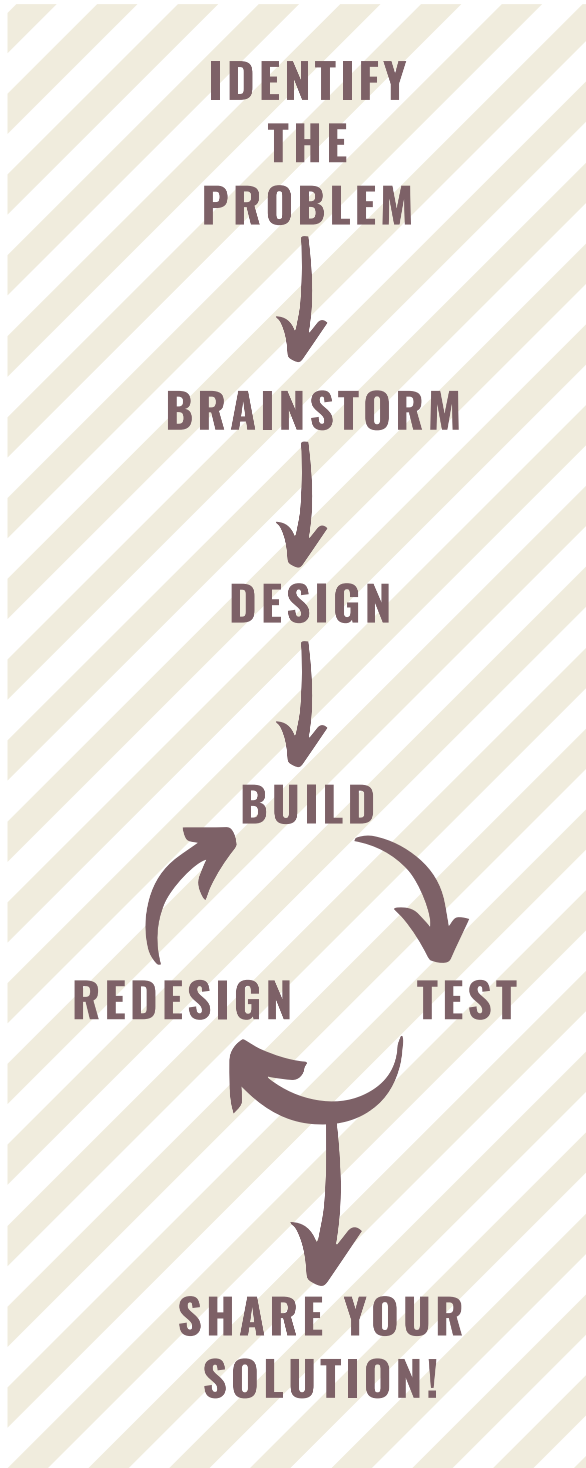
## Guiding Questions

1. How will you modify the cup so that it can both carry the marble and be able to drop it onto the target?
2. How will your device release the marble at the right time?
3. When will the device need to release the marble in order to accurately hit the target?
4. Where in this system do you see potential energy? Kinetic energy?
5. What are the forces affecting your system?

## Introduction

Show students Gabi's career shadow video. Talk about what engineers do and outline the engineering design process. There are many versions of the EDP that include more or fewer steps but each should include some variation of:

- Identify the problem
- Brainstorm
- Design
- Build
- Test & evaluate
- Redesign (if necessary)
- Communicate the sSlution




Show the students a model zipline. Hang the cup on the zipline, using a hook made of a paper clip. Show students how the cup travels down the zipline. Alternatively: show only the zipline and provide the supplies. Let students decide how to attach their cups to the line. The level of guidance depends on the grade level of students.

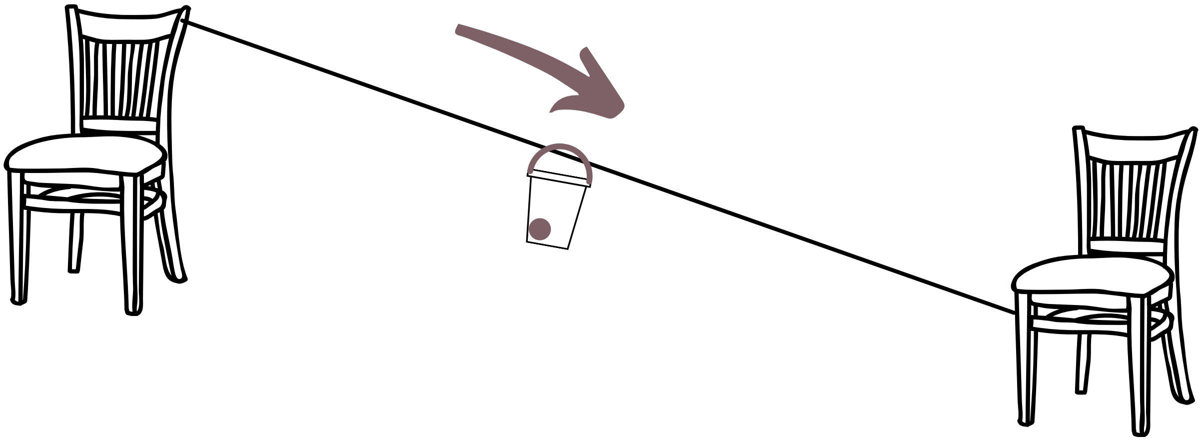
> *"Today you'll turn a paper cup into a device that can slide down a line and drop a Navy payload (played here by a marble) onto a target. Just as the safety of military personnel depends on the systems Gabi designs for the Navy, your successful device will depend on being able to hit the target accurately. Your first design may not work perfectly the first time and that's okay! The engineering design process is about not only creating designs but revising them until you find an optimal solution."*

A zipline is a great demonstration of how different types of energy, gravity, velocity, and acceleration interact. Newton’s First Law of Motion states that objects at rest remain at rest and objects in motion will continue in a straight line unless acted upon by another force. The carrier device’s velocity increases (accelerates) as it is pulled down the line by gravity. Some of this kinetic energy will be transferred to the marble when it is released. As they plan and build, encourage students to think about how this energy, friction, and the pull of gravity interact to affect how the marble travels through the air.

### Brainstorm and Design

Share the challenge as well as the criteria and constraints. Encourage students to think about:

- How will you modify the cup so it can carry a marble down a zipline and also drop it onto the target? Will the marble ride in the cup? Outside of the cup? How will it drop the marble?
- How will you release the marble from the cup remotely?
- When do you need to launch the marble so that it will hit the target? Will the marble drop straight down? Why or why not?
- Where in this system is the potential energy at its maximum? At what point does this become kinetic energy?

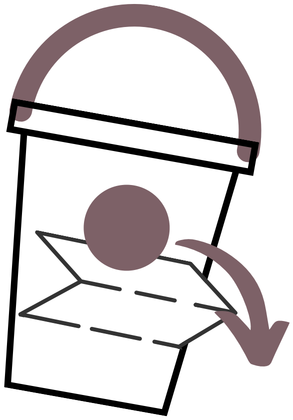


### Build, Test, Evaluate, and Revise

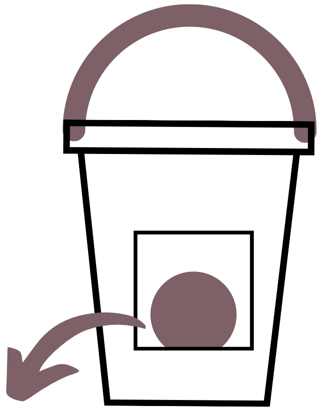
Students should be fairly self-directed but be prepared to help students troubleshoot their designs. The amount of time provided to design, build, test, evaluate, and revise is flexible and can be adjusted based on the needs of the classroom. Generally, each group will:

- Set up their zipline. Tie approximately 6 to 10 feet (1.8 – 3.0 m) of line between two objects. Chairs work well as do tables. Make sure that the line is taut, and that one end is approximately 20 inches (50 cm) below the other so that the line is at an incline.
- Determine how to modify the cup to carry the marble down the line.
- Add a remote release to the marble carrier. Students will decide how to tip the cup, open the door, etc. at the appropriate time to hit the target.
- Clip the cup to the zipline. The cup should be hooked onto the line so that it slides smoothly.
- Testing! The target should be placed near the end of the zipline. Students will likely need to test several times before hitting the target reliably.

Potential issues and challenges...



- *The cup goes slowly down the zipline.*
  Check that the cup slides freely and that the angle of the line is steep enough to allow the cup to gain momentum.
- *The remote release line is too short.*
  Students should estimate where the "drop zone" on the zipline should be and make the remote release line at least that long.
- *The marble doesn't eject cleanly.*
  This may require enlarging the opening or loosening whatever is holding the marble to the outside of the cup.
- *The marble accidentally falls out of the cup or off the platform.*
  Adjust the tilt or add tape or paper to hold the marble back.
- *The marble misses the target.*
  Check that the release point is correct (not too early and not too late.) Ensure that the marble isn't bouncing off of something as it drops or the cup is spinning.



## Discuss and Report

Each student group should share out their initial designs as well as any revisions or modification. Ask them to describe their approach in writing through a simple lab report (see template.)

Invite students to think about the STEM connections in this activity:

- What parts of your design were most important in getting the marble to hit the target?
- What changes did you make to your design after your initial tests? Why?
- How did your marble move after it was released from the cup? Students should be able to describe that it moved both downward and forward in a curved trajectory. Connect this to vectors. The marble's path has both a horizontal (from the cup's movement) and vertical (from gravity) components.
- Newton's First Law states that an object in motion continues in straight line motion until acted upon by a force. How did your marble's behavior demonstrate this?
- How is your system similar to the tracking and guidance systems soldiers use? How is it different?

## Career Exploration and Extension

Prompt students to think about and research what a career as an electrical engineer might entail.

- What does an electrical engineer do all day? What does Gabi do?
- What kind of training would a student need to become an electrical engineer? What about an engineer in general? What other types of engineers are there?
- Are jobs like Gabi's in high demand? Will more people be hired to be engineers in the future?
- What kind of education is needed to be an engineer? Where could a student be trained locally for a career in engineering? What types of classes are important?

Name: ____________

# Operation Marble Drop

## Student Lab Report Guide

You will be writing up a brief report on your marble drop project. Please be sure to include the following sections. Please compile your report either on a separate sheet of paper or on a computer and use complete sentences.

**Title**: This should be a brief, concise, yet descriptive title.

Example: *"A Design for a Marble Delivery Device"* or *"Operation Marble Drop: Success!"*

**Introduction**: State the problem you are trying to solve. Include the criteria your design must meet and the constraints on your design.

- What was your challenge?
- What did it have to do?
- What were your constraints?

**Materials**: Include a list of all materials you used in your design.

**Procedure**: Write a paragraph (don't forget the complete sentences!) explaining what you did. In addition to a written explanation of your process you may want to include:

- Any preliminary designs or drawings your team made.
- Any revisions or changes that you made to your design.

Name: ________________

# Operation Marble Drop

Student Lab Report Guide (continued)

**Data:** Here you want to include any data you collected. For this project, you'll want to include a table of how many times you tested each design and how close your marble landed each time (in centimeters.)

**Example:**

| *Design version* | *Distance from Target (cm)* |
|---|---|
| *1* | *Test 1:*<br>*Test 2:*<br>*Test 3:*<br>*Test 4* |
| *2* | *Test 1:*<br>*Test 2:*<br>*Test 3:*<br>*Test 4* |
| *3* | *Test 1:*<br>*Test 2:*<br>*Test 3:*<br>*Test 4* |

**Conclusions**: Discuss your team's designs and talk about which one was the best solution to the problem. You should also explain:

- Which parts were important for moving it to or reaching the target?
- What changes did you make to your design after your initial tests? Why?
- What role did energy play in your design? Force?

# ACKNOWLEDGEMENTS

Activities developed and written for Regional Opportunity Initiatives by

**Adrienne Evans Fernandez**
Education Specialist

**Emily Menkedick**
Education Specialist

ROI would like to thank the following members of our Educator Advisory Group for their gracious support and review of this curriculum:

**Amy Gordon**
Elementary STEM Coordinator
Brown County Schools

**Kelly Grimes**
7th Grade Science Teacher
Richland-Bean Blossom
Community School Corporation

**Alexis Harmon**
Academy of Science &
Entrepreneurship Principal
Monroe County
Community School Corporation

**Alison Kern**
6th Grade Science Teacher
Mitchell Community Schools

**Joann Novak**
Business & Computer Science Teacher
Monroe County
Community School Corporation

**Jean Schick**
High School Science Dept Chair (Ret)
Monroe County
Community School Corporation

**Katy Sparks**
STEM & Computer Science Coach
Monroe County
Community School Corporation

**Tara Weisheit**
4th Grade Teacher
Washington Community Schools

# IMAGE AND CONTENT CREDITS

## Images

Stock photography courtesy of Canva.com
Still video images from "Gabi - Electrical Engineer," available at https://regionalopportunityinc.org/gabi/

## Content

Lesson adapted from "On Target," (2021, April 15). Retrieved from https://www.jpl.nasa.gov/edu/pdfs/ontarget.pdf.

# Operation Marble Drop

Inspired by Gabi, an Electrical Engineer in the Indiana Uplands.

Published by Regional Opportunity Initiatives