Moon Landing Challenge

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Target Grade: 9th-12th Grade Physics

Time Required: 5-6 days, 40 minute lessons

Standards

Next Generation Science Standards (NGSS):

- HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Lesson Objectives

Students will:

- Engage in the engineering process of building a landing system out of found materials to land an object on a target.
- Analyze the trajectory of the object to describe its motion utilizing the principles of 2-dimensional motion.
- Communicate their design, methods, and results in a written report and presentation using the scientific process.

Central Focus

This lesson plan has students engage with 2-dimensional motion either in the classroom or from the comfort of their homes. Students, using the scientific process, will create and test a moon landing prototype using materials found in their home. They will then analyze their system, accounting for factors such as acceleration, mass, and initial and final velocity. To conclude the lesson, students will write a formal report on their collected data and design.

Key terms: physics, online, hybrid, digital classroom, NASA, space, range, altitude, velocity, kinematic formulas

Background Information

Students will further their understanding of the principles of 2-dimensional motion of horizontally launched projectiles, including horizontal velocity, vertical velocity, acceleration due to gravity, range, altitude, and other complimentary concepts. In addition, this lesson brings focus to the re-emergence of crewed missions led by the United States, NASA, and SpaceX. The main objective of this lesson is to allow students to participate in an engaging activity that helps them to step away from electronics to participate in project-based learning that utilizes the engineering process.

Project Example: https://youtu.be/d_xSgtDkmk8

Prior to this lesson, students should be aware of most aspects of 2-dimensional motion, including:

- Separation of x and y dimensions, including what factors affect each dimension
  - For example, gravity affects the vertical dimension (y), acting as an accelerating force on the object. The string acts both vertically (y) and horizontally (x) and can be broken down into components.
- Range, altitude, initial and final velocities in each dimension, acceleration due to gravity
- Manipulation of kinematics formulas to determine missing/required components. For reference:

Kinematic Equations

- $a = \frac{v_f^2 - v_i^2}{2\Delta d}$ *__NO__ "t"
- $d = v_i t + \frac{1}{2} a t^2$ *__NO__ "V_f"
- $V_f = V_i + at$ *__NO__ "d"
- $V_f^2 = V_i^2 + 2ad$ *__NO__ "t"

https://image1.slideserve.com/2157638/kinematic-equations-l.jpg

Some considerations to ensure students have all the required materials:

- This lesson requires students to build a contraption in a group. This activity is ideal for in-person classrooms but can be done virtually, either with students building their own contraptions or working together online to design and refine the contraption as one group member builds it.
- If this lesson is done virtually, students should choose and present materials in advance to ensure equity. Materials are planned to be commonly found in households.
- For any materials that students do not have and/or are unable to obtain, materials should be made available by the teacher/school/school district. Again, these are commonly-found items, so the availability of these items should not be an issue.
- The lesson plan is created with the understanding that internet access may be a challenge for students. For digital classrooms, the portions of the activity that are internet-based can be easily adjusted as take-home materials provided by the teacher/school/school-district.

Key lesson knowledge:

- Newton's First Law: As it travels down the zip line, the object builds up a forward speed. Once launched, it will keep going at that speed until a force acts on it, such as hitting the ground.
- Acceleration: Due to Earth's gravitational pull, the object's speed increases as it falls.

- Vectors: The object's motion has both a horizontal and a vertical component, and these motions can be represented in a vector diagram.
- Trajectory: When an object that's already moving horizontally is dropped (like an object dropped from a cup moving down a zip line), it travels in a curved path, called a trajectory.
- Potential and kinetic energy: The object's stored (potential) energy changes to motion (kinetic) energy as it falls. In this case, the amount of potential energy depends on the initial height and mass of the object.
- Measurement: You measure to make the zip line. You also measure the height from which the object is dropped and how far it lands from the target.

Taken from: https://www.nasa.gov/sites/default/files/atoms/files/edu_on-target.pdf

This lesson is an adaptation using the following references:

Artemis. (n.d.). Retrieved October 06, 2020, from https://www.nasa.gov/specials/artemis/

Mahoney, E. (2020, April 30). More About the Human Landing System Program. Retrieved October 06, 2020, from https://www.nasa.gov/content/more-about-the-human-landing-system-program
Mars, K. (2016, August 17). Gateway. Retrieved October 06, 2020, from https://www.nasa.gov/gateway

May, S. (2020, April 27). On Target. Retrieved October 1, 2020, from https://www.nasa.gov/stem-ed-resources/on-target.html

National Aeronautics and Space Administration. (2020). Artemis Plan: NASA's Lunar Exploration Program Overview. https://www.nasa.gov/sites/default/files/atoms/files/artemis_plan-20200921.pdf

Materials

- Internet-enabled electronic device
- Telephone
- Notebook/paper
- Smooth string/fishing line (at least 3 meters)
- Tape
- Paper clips
- Scissors
- Any other found items that may be useful in design
- Moon Landing PowerPoint
- Moon Landing Challenge sheet
- Moon Land Report Requirements and Rubric
- Camera (phone cameras will work)
- Calculator
- Paper cup
- Small round object (marble, bouncy ball, etc.)
- Ruler
- Index cards
- Moon Landing Evaluation Form
- Online Classroom platform (Zoom, Goggle Classroom, Teams, etc.)
- 2-dimensional motion map
- Moon Landing Engineering Notebook
- At least two chairs/fence posts/items to tie string to

Instruction

Day 1 Introduction (40 minutes)

The lesson follows along with the presentation.

10 minutes (slide 2)

- Have students fill out/create a concept map about what they know about 2-dimensional motion (Figure 1).
- Have students take a photo of their map to share with the class.
    - Allow students who do not have printer access to draw the map by hand.
    - Students working with the printed version can extend it by hand to adapt it to their thinking.

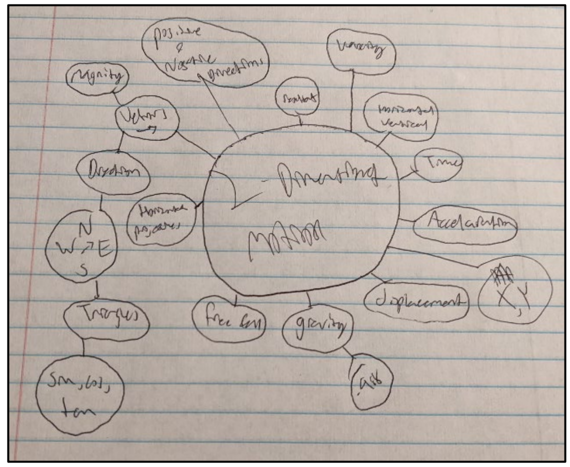


Figure 1: Example of Student's work

5 minutes (Slide 3)

- Next, show a picture of the moon and ask, “What do you know about the moon?”
    - Allow students to discuss in small break out groups or discussion board.
    - Some advancing questions: What affects motion in space? What forces are different in space/near the moon than on Earth?

10 minutes (Slide 4)

- Show the students the following video about Artemis.
    - https://youtu.be/_T8cn2J13-4
- If time allows, share to following links for the students to read:
    - https://www.nasa.gov/what-is-artemis
    - https://www.nasa.gov/gateway
- After students have had time to watch and possibly review each link, lead a short class discussion of the following question in either small groups, a discussion board, or Padlet:
    - What is the main goal for the Artemis mission with respect to going to the surface of the moon? Specifically discuss the Lunar Gateway and the Human Landing System (HLS).

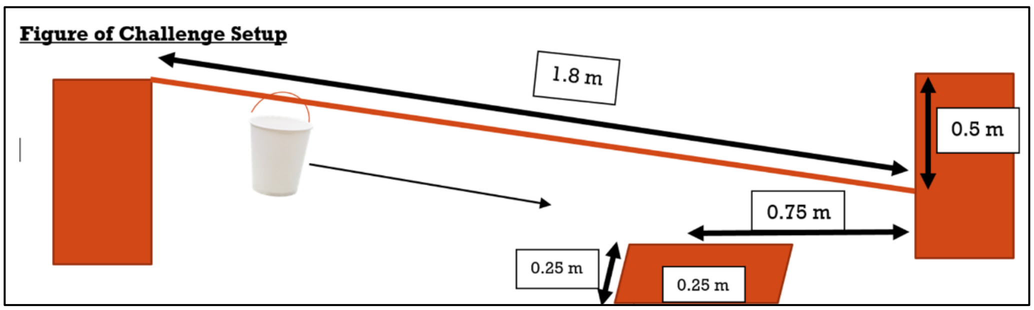
10 minutes (Slide 5-6)

- Next, have students answer the following questions while reflecting back on their concept maps:
    - How does the delivery system of the Lunar Gateway relate to what we have been talking about with 2D motion?
    - What variables are at play during a lunar landing?

- Teachers can choose to do discussions via groups, a discussion board, or Padlet according to the class format.

5 minutes (Slide 7)

- To end the class, provide students the following challenge:
    - Thinking about The Gateway with its delivery mechanism and your understanding of 2-dimensional motion, design a system using commonly-found materials to land an object on a target.
- Show the following YouTube video to give students an idea of what the challenge will look like:
    - https://www.youtube.com/watch?v=d_xSgtDkmk8
- Show the following diagram to give students an idea of what their design might look like.



Days 2-4:

- Begin the class by going over the details of the project.
    - Students should have access to Moon Landing Engineering Notebook, Moon Landing Challenge sheet, and Moon Land Report Requirements and Rubric.
    - Review each form (Slides 8-18) with the class.
- Students can participate in collaboration with each other throughout this challenge, as deemed appropriate. The following are ways they could collaborate together:
    - For an in-person class, students can work together in small groups.
    - For virtual classrooms, students can work with a partner/group remotely, with one (or two) building the apparatus and the others participating via video chat.
    - Have students participate in class discussions about the progress of their project.
    - Create a "gallery" presentation at the end, where each student/group presents their projects and results.
- Inform students that they will create an individual report to turn in at the end of the project. Ask students to keep an engineering notebook that will be part of the report where they will do the following:
    - Create drawings of their designs and redesigns
    - Provide a detailed account of their design process, including reasoning for any design changes

- Describe results of their experiment(s)

- Have students begin constructing and testing their design. Groups should video their system in action to include in their presentation and/or report.

Days 5-6

- Once finished, ask students to analyze the motion of their object and include this analysis in their report. They will use measurement tools and kinematic equations to calculate the following:
  - Height of drop
  - Range from release to ground
  - Time of drop
  - Horizontal velocity of object
  - Vertical velocity of object as it hits the ground
  - Diagram of the trajectory of the object as it leaves the cup and lands on the target, with velocities and distances labeled
- Next, have students write answers to the following questions for their report:
  - What was the most important piece of the design to allow the object to hit the target?
  - What were your redesigns, and why did they occur?
  - How did the object move after it left the release system?
  - Discuss the motion of the object as it leaves the cup and lands on the target. What is causing it to move? (Ask students to use academic language, ex. potential vs kinetic energy, force, acceleration, etc.)
  - What was the most difficult part of this challenge, and how did you overcome the obstacles?
  - What did you like most about this challenge?
- Have students submit the formal report about their project and provide the rubric for guidance. This report will include their engineering notebook, their answers to the discussion questions, and all their calculations.
- If time allows, have students create presentations of their findings as a group and present them to the class. If there is a time constraint, students can post their presentations gallery-style on an online platform.
- If some groups or individuals finish early, have them reflect upon the project and how it can connect to future space missions. For more directed reflection, ask students to complete quick research about another space mission that happened in the past, is currently happening, or is planning to happen where an object lands on a foreign surface. The students will answer the following:
  - What were the landing mechanism(s) for this mission?
  - How did the landing mechanism contribute to the success/failure of the mission?
  - Determine the trajectory of the object as it lands on the surface. How does it compare to the trajectory of your object?

Differentiation

- Students with difficulties in mathematics:
  - For this lesson, it is assumed that the students have already been working with the physics and the mathematics required. However, here are some strategies to implement if needed:
    - Reiterate the order of operations and modeling of how to complete problems.
    - Provide equation sheets for the calculations in the final report.
    - Ask guiding questions to help them understand order of operations.
      - What is happening to the variable?
      - How can you "undo" what is happening to the variable?
    - Provide equation slotting. As an example, see below:
      - final velocity = initial velocity + (acceleration * time)
      - final velocity (?) = 0 + (-9.8*3)
      - final velocity (?) = 0 + _______
      - final velocity (?) = ________
- Students with other academic challenges:
  - For the concept map, have some bubbles already filled out or provide a list of terms the students can use.
  - Frequently check on progress via individual conferences.
  - Provide a template of the Engineering Notebook and final report to fill out.
  - Require draft versions of their Engineering Notebook and/or final report on days as determined by you.
  - Give a sample of a landing mechanism and/or provide options for the release mechanism.
  - Create a model report and provide as an example for students to reference.
  - Provide a slotted version of the Engineering Notebook to allow students to fill in as they complete items.
  - Provide a step-by-step instruction guide of how to build a landing system that they can follow and report on.
  - If students are unable to build the system, the teacher completes a landing system and records a video with measurements for students to use as theirs in the report. Students would not complete the Engineering Notebook portion of their report.
  - During the presentation, group students with differing skill levels together so that all students are supported.
  - Allow students to use different platforms to create their presentation (poster, PowerPoint, etc.).
  - If needed, students could record themselves answering the discussion questions orally to supplement their written answers for the final report.

- English Language Learners:
  - Provide a vocabulary list at the beginning of the unit. The vocabulary list can be fully filled out in English and their L1 if they need additional support, or it can be a required assignment that is requested to see their mastery of the terms in English. Example terms to include:
    - Velocity
    - Vertical
    - Horizontal
    - Acceleration
    - Target
    - Range
    - Altitude
    - Etc.
  - Have students participate in a read-aloud of the Artemis article(s) provided, highlighting specific passages. Depending on their level, the teacher can have them practice the pronunciation or have the students read specific passages out loud. This can be completed via video conference or phone.
  - Require students to prepare a script to read out loud during their presentation.
  - If students are concerned about their speaking ability in a public setting, schedule a video conference with just the student to present or have them complete the presentation via FlipGrid for the teacher to view only.
- Students who need more of a challenge:
  - Have the students release different objects and compare.
  - Have the students add an initial velocity to the landing system by pushing the cup as opposed to letting it slide down due to gravity. Discuss the difference in performance.
  - Determine the vertical velocity of the object at different points throughout its trajectory instead of just at the end.
  - Ask students questions during their presentations that require them to say more than "yes/no."
  - Ask students advancing questions, such as, "What materials could you use to make this design better?" and "Which component of 2-D motion do you think is most important in this system and why?"
- Variations in learning styles:
  - Visual learners can participate in the project by creating the models and diagrams of the lander and its performance.
  - Kinesthetic learners can participate in the project by building the lander and testing it.
  - Audio-visual learners can participate in the project by working on the oral presentation of their group's results and findings.
  - Verbal learners can participate in the project by creating a written report and by orally presenting their findings.

- Logical learners can participate in the project by analyzing the lander's performance and calculating its trajectory.
- Social learners can participate in the project by managing the group activities and assisting their group in completing the various parts of the project.
- Solitary learners can participate in the project by working on the report as an individual.

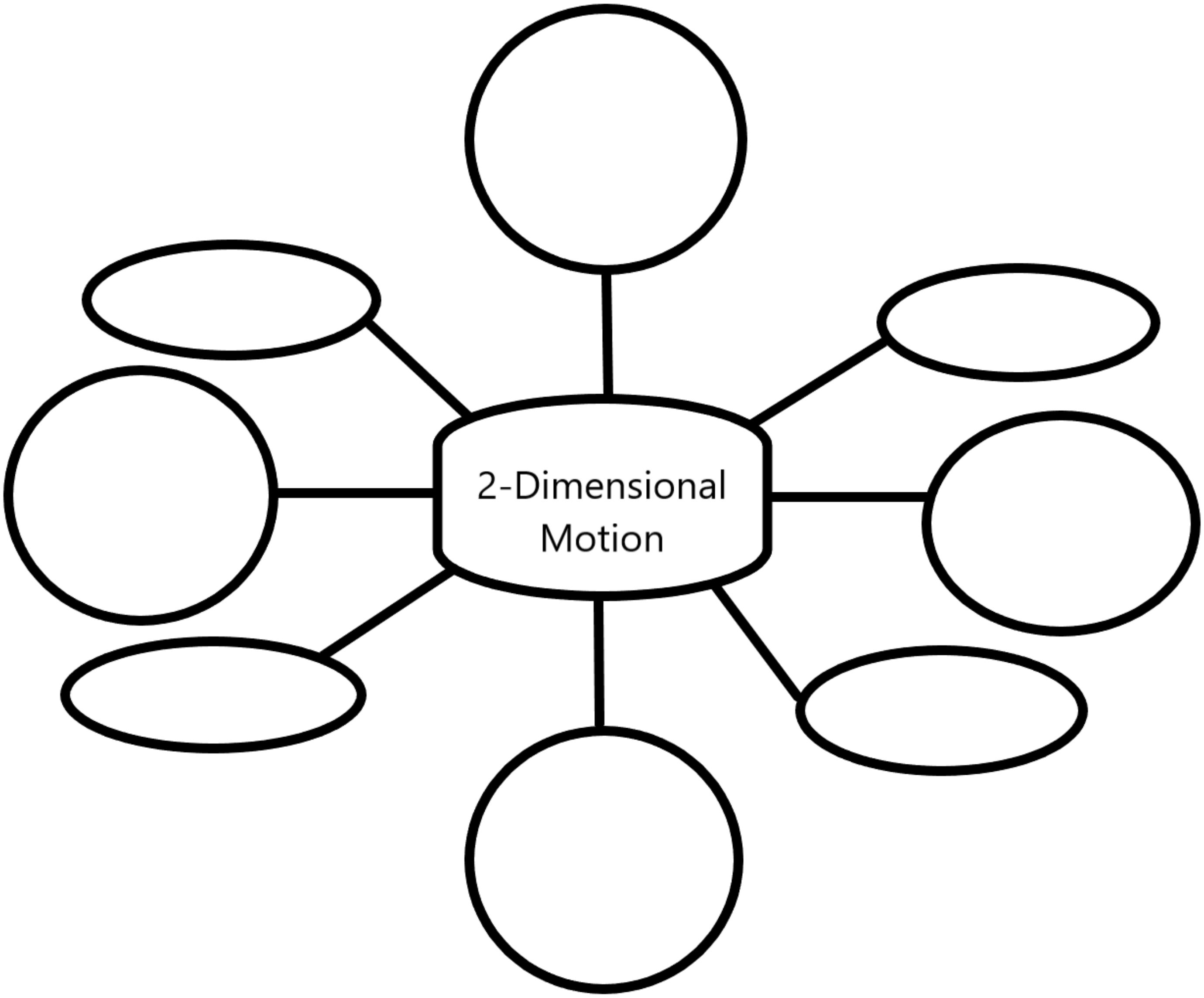
Assessment

Formative assessment

- Each discussion can be used as a form of formative assessment to quickly check students' understanding of the content.
- The initial concept map will allow the teacher to assess prior knowledge the students may have.
- During the project building, the teacher can periodically check up on students to assess their progress throughout the lesson.
- The group presentations will allow the teacher to assess what students learned during the group work.

Summative assessment

- The final report will allow the teacher to assess each individual student's mastery of the lesson content. Score the report using the attached rubric.

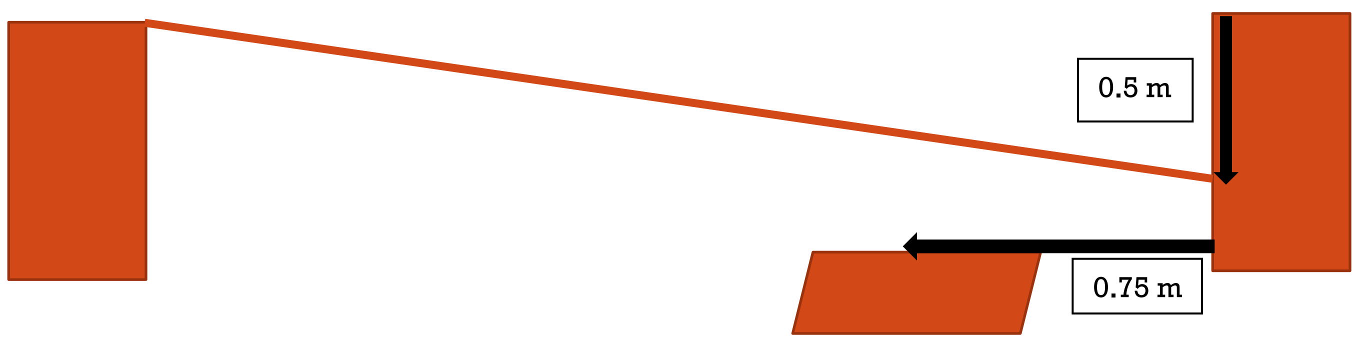


- Terms to include:
    - Trajectory
    - Gravity
    - Acceleration
    - Vertical velocity
    - Horizontal velocity
    - Etc.

On Target

<u>Challenge</u>: Modify a paper cup to release a marble onto a target as it travels down a zip line.

- Consider the following:
  - How will you modify the cup to carry a marble and drop it onto its target?
  - How will you remotely release the marble?
  - When do you need to launch the marble to hit the target?
- Requirements:
  - Complete an engineering notebook to track your progress (see "Engineering Notebook" for requirements).
  - Zip line is 1.8 meters in length, stretched taut.
  - One end of the zip line is 0.5 meters higher than the other.
  - Target is 0.25 meters by 0.25 meters, with the center of the target located 0.75 meters from the lowest end of the zip line.



- Materials Needed:
  - Camera
  - Calculator
  - Notebook/paper
  - Paper cup
  - Smooth string/fishing line (at least 3 meters)
  - Small round object (marble, bouncy ball, paper, etc.)
  - Tape
  - Ruler
  - Paper clips
  - Index cards
  - Scissors
  - At least two chairs/fence posts/items to tie string to
  - Any other found items that may be useful in design
- Process:
  - Brainstorm/Design your delivery system
  - Build your delivery system
  - Test your delivery system
  - Evaluate its performance
  - Redesign the system as needed to obtain the desired result
  - Complete a report discussing your design, process, results, and big takeaways

Engineering Notebook

As an engineer in this project, you will want to keep track of all the iterations of your design as you progress. You will be discussing your design process in the final report.

Your notebook should contain:

- Design of delivery system, including any and all changes made to the prototype
    - Include specifics on the measurements of each object used, amount of items, release system timing, etc.
- Results from each experiment of prototypes
    - Record measurements of where on zip line it was released, where it landed relative to its release, and the distance from the target upon landing.

Use the template below to help guide your completion of the notebook.

Date	Prototype Number	Information on Design	Drawing/Diagram of Design

Date	Prototype Number	Result	Changes needed

7) Discussion & Calculation
- Discussion Questions
    - What was the most important piece of the design to allow the object to hit the target?
    - What were your redesigns, and why did they occur?
    - How did the object move after it left the release system?
    - Discuss the motion of the object as it leaves the cup and lands on the target.
    - What was the most difficult part of this challenge, and how did you overcome the obstacles?
    - What did you like most about this challenge?
- Required Calculations
    - Height of drop
    - Range from release to ground

- Time of drop
    - Horizontal velocity of object
    - Vertical velocity of object at different point throughout its trajectory
    - Diagram of the trajectory of the marble as it the leaves the cup and lands on the target, with velocities and distances labeled.

Report Requirements

In order to share your findings with the class, please create a report/presentation/video detailing the following:

- Design process, detailing initial design to final design
    - Include the reasoning behind any changes made from the initial prototype
    - Include a photo/diagram of your final design
    - *OPTIONAL* Include a video of your design in action
- Discussion questions
    - What was the most important piece of the design to allow the object to hit the target?
    - What were your redesigns, and why did they occur?
    - How did the object move after it left the release system?
    - Discuss the motion of the object as it leaves the cup and lands on the target.
    - What was the most difficult part of this challenge, and how did you overcome the obstacles?
    - What did you like most about this challenge?
- Required calculations
    - Height of drop
    - Range from release to ground
    - Time of drop
    - Horizontal velocity of object
    - Vertical velocity of object at different point throughout its trajectory
    - Diagram of the trajectory of the marble as it the leaves the cup and lands on the target, with velocities and distances labeled.

Your report may be completed in any way that allows you to share the above information. Be sure to include all the details of your design and results!

9) Report Rubric

Item	**Description**	**Points Assigned**	**Points Awarded**
Name	The name(s) of all group members has been included.	10	
Engineering Notebook	Information on all prototypes is included (descriptions/drawings).	10	
	Explanation for any changes needed is included.	20	
Discussion Questions	All questions have been considered and answered.	10	
	Each question has been answered in-depth, with evidence/details pulled from their designs/tests.	20	
Calculations	Each calculation has been completed.	10	
	Kinematic equations have been used accurately.	10	
	Trajectory of object has been drawn and clearly labeled.	10	
Report	Report is submitted by the due date and in the method as requested by the teacher.	10	
TOTAL		100	