5E STEM Hit the Target! Exploration of Projectile Motion

(5 class periods)

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SUBJECT/GRADE LEVEL

Subject Area: Physics, Physical Science

Grade Level: High School

Lesson Title: Hit the Target! An Exploration of Projectile Motion

Materials

Explore

- Access to Projectile Simulator
- Projectile motion worksheet.docx

Explain

- Teacher's Content Document

Elaborate

- PhET Lab Simulation
- Projectile Launcher Mission Worksheet

Evaluate

- Sample Outline Slideshow for Student Guidance

STANDARDS

Next Generation Science Standards

- HS-PS2-1: Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration
- HS-PS2-2: Use mathematical representations of phenomena to describe explanations for how the total momentum of a system of objects is conserved when there is no net force on the system.
- HS-ETS1-3: Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.
- HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity

Mathematics Standards | Common Core State Standards

- HSA.CED.A.2: Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

English Language Arts Standards | Common Core State

- SL.9-10.4 Present information, findings, and supporting evidence, concisely, and logically (using appropriate eye contact, adequate volume, and clear pronunciation) such that listeners can follow the line

of reasoning and the organization, development, substance, and style are appropriate to the purpose
- RST.9-10: Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

LESSON OBJECTIVE(S)

- Students will explore projectile motion through simulations.
- Students will manipulate variables (angle, velocity, gravity, mass) to observe their effect on a projectile's trajectory.
- Students will design, conduct, and analyze trials to determine the most effective method for hitting a target with precision.
- Students will communicate their process and findings using appropriate scientific terminology.

CAREER CONNECTION(S)

Mentor Background: Ashley Lochetto, Test Officer, Yuma Proving Ground (YPG)
Bio: Ashley is a mechanical engineer specializing in explosives engineering and has her Bachelor's from New Mexico Tech and a Master's in Systems and Program Management online at the Naval Postgraduate School based in Monterey, California.

Upon graduating from New Mexico Tech and before working at YPG, Ashley landed her first job with Lego Technologies, leveraging her engineering background and her previous work with kids in science, technology, engineering, and mathematics (STEM) outreach.

STEM Careers:

- Test Officer – e.g., Army Test and Evaluation Command – https://www.atec.army.mil/
- Physicist – https://www.careerexplorer.com/careers/physicist/
- Mechanical Engineer – https://www.careerexplorer.com/careers/mechanical-engineer/

ENGAGEMENT

Brief Description: Students begin by watching videos of projectiles—both real and simulated—to spark curiosity. Teachers guide a discussion with prompting questions to get students thinking about what affects how far and high a projectile travels.

Procedures:
Introduce the concept of projectile motion using a video -
Introduction to Projectile Motion (Approximately 5 minutes)
Kinematics Part 3: Projectile Motion (Approximately 7 minutes)

Engage Students with Questions:

- "What path do you think the object follows?"
- "What variables might determine how far or high it goes?"

EXPLORATION

Brief Description: Students use a virtual simulation to explore how angle, speed, and gravity affect projectile motion. They'll run trials, record data, and identify patterns.

Procedures:

Background Information:
Projectile motion involves two independent components: horizontal motion (constant velocity) and vertical motion (accelerated by gravity). This lab enables students to test predictions, collect data, and draw conclusions about the relationships between variables that affect projectile trajectories.

Teacher Actions:

1. **Set the Stage:**
    - Review terms: angle, initial velocity, range, and gravity.
    - Model how to use the simulation - https://www.physicsclassroom.com/Physics-Interactives/Vectors-and-Projectiles/Projectile-Simulator

2. **Guide Inquiry:**
    - Direct students to the Simulation.
    - Have students work in pairs or teams to:
        - Complete the **Projectile Motion Simulation** worksheet, including 'Setting up the Simulation,' 'Experimenting with Variables,' and 'Analyzing Projectile Motion.'
        - Predict what will happen.
        - Run multiple trials using the simulation.
        - Record results using the lab worksheet.
        - Groups identify one key finding to share during the Explain phase.

3. **Support Formative Assessment (Ongoing):**

    - Circulate to ask guiding questions:
        - "What trend are you noticing as you increase the angle?"
        - "Does mass affect the horizontal distance?"
        - "How do you know your data is reliable?"

    - Encourage the use of accurate vocabulary in student conversations.

EXPLANATION

Brief Description: Students make sense of their data by connecting simulation results to scientific concepts like Newton's laws and components of motion. They practice using vocabulary to explain why projectiles behave the way they do.

Procedures:

Background Content

In previous sections, students observed and explored projectile motion through videos and simulations. Now, they will dive into why certain outcomes occurred, linking them to scientific principles such as:

- Newton's Second Law (F = ma)
- Components of velocity (horizontal vs. vertical)
- Gravity's constant acceleration (9.8 m/s² on Earth)
- Optimal angle for maximum range (typically 45° in a vacuum)

Teacher Actions

1. **Introduce the Core Idea**
    - Display this question on the board: "Why does a projectile follow a curved path, and what determines how far it travels?"

2. **Facilitate Peer Teaching via "Think-Pair-Share"**

    - Show the video - Why 45° gives you max range? (Approximately 7:30 minutes)
    - Ask students to answer this question in pairs: "How would you explain why 45° gives the farthest distance to someone who missed class?"
    - Have several pairs share out. Prompt them to use terms like *range*, *gravity*, *horizontal velocity*, and *vertical acceleration*.

3. **Use a Whiteboard or Digital Space to Summarize Group Thinking**

    - Note to teacher: Refer to the Teacher's Content Document
    - Record key ideas and examples from student responses.
    - Reinforce with a teacher explanation and draw connections to NGSS standards and the upcoming Elaborate challenge.

ELABORATE

Brief Description: Students will extend their understanding of projectile motion by applying what they learned in the simulation to a real-world engineering challenge. They will take on the role of a Test Officer, like Ashley Lochetto, and design a launcher that hits a target at a given distance using the PhET Projectile Motion simulation. Students must calculate the correct launch angle and initial speed, justify their choices using relevant physics vocabulary, and present their testing strategy and the resulting outcome.

Procedures:

Teacher Actions:

- Review student findings from the Exploration phase.
- Introduce the Elaborate Challenge: "Hit the target with precision like a military test officer."
- Provide students with the target location and object to launch (e.g., 60 meters away at ground level, cannonball).
- PhET Lab Simulation
- Distribute the Projectile Launcher Mission Worksheet.
- Encourage students to work in teams to experiment with the simulation and aim for the target.
- Monitor student discussions, looking for the use of academic vocabulary such as *velocity, angle, range, acceleration, and gravity.*
- Ask probing questions like:
    - "Why did you choose that angle?"
    - "How does velocity impact your results?"
    - "Would this change if we were on the moon?"

Student Actions:

- Collaboratively analyze projectile motion variables in the simulation.
- Record trial data (angle, velocity, result) and optimize their design.
- Explain and justify their final selection.
- Prepare a 1-minute oral summary of their strategy and findings.
- Submit a completed worksheet and reflect on their process.

Formative Assessment Opportunities:

- Observation of student discussion and use of terminology.
- Completion of worksheet with justifications.
- Oral explanation of strategy to peers.

Differentiation/Adaptations:

- For learners who need more support, provide examples of angles and velocities with scaffolds.
- For advanced learners, introduce air resistance or uneven terrain in the simulation.
- Virtual learners can screen-record their attempts and submit a voice-over explanation.

EVALUATION

Brief Description: Students will demonstrate their understanding of projectile motion concepts through written and performance-based assessments. Emphasis will be placed on their ability to apply physics principles in a real-world context and communicate their reasoning.

Procedures:

Oral Summary Presentation (3–5 minutes per team)

This task is designed to assess students' understanding of:

- How angle, velocity, and gravity affect projectile trajectory
- How to design and optimize a projectile path to hit a specific target
- How to explain scientific reasoning using proper physics vocabulary
- How to apply trial-and-error data analysis and communicate results

Each team will:

- Create and deliver a 5-slide PowerPoint presentation summarizing and explaining their findings, strategies, and understanding of projectile motion concepts through the lens of a Test Officer (inspired by Ashley Lochetto).

Slide Requirements (5 Total Slides per Group):

Sample Outline Slideshow for Student Guidance (Student handout): Students can use this outline to create a 5-slide presentation that demonstrates their understanding of the key variables and physics concepts explored in the activity.

- Slide 1: Problem & Objective
  - State the challenge: Hit a target 60 meters away using a projectile launcher.
  - Briefly describe the goal of the task and how it connects to the real-world role of a Test Officer.
- Slide 2: Variables & Hypotheses
  - Identify and define key variables: angle, velocity, gravity, and mass (even if mass had no effect).
  - Share your initial predictions: What angle and velocity did you expect to work best and why?
- Slide 3: Experimental Process
  - Describe your team's approach in the PhET simulation.
  - Include screenshots or data tables of trials showing at least 3 different angle/velocity combinations. **Note:** (Students can use the data tables from the Projectile Launcher Mission Worksheet in the Elaborate)
  - Highlight what didn't work and what adjustments you made.
- Slide 4: Final Strategy & Explanation
  - What were your final values (angle and velocity) that hit the target?

    - Justify your choices using scientific vocabulary (e.g., range, horizontal velocity, gravity, optimal angle).
    - Reference Newton's laws or projectile motion principles if applicable.
- Slide 5: Reflection & Team Communication
    - What did your team learn through experimentation?
    - What challenges did you face and how did you overcome them?
    - How did your team collaborate and use evidence to make decisions?

Oral Presentation and Slideshow Rubric

Category	4 – Excellent	3 – Proficient	2 – Developing	1 – Needs Work
Understanding of Concepts	Clearly and accurately explains projectile motion concepts using vocabulary (range, angle, velocity, gravity, etc.)	Mostly accurate use of concepts and terminology	Partial understanding or misuse of vocabulary	Limited or incorrect explanations of concepts
Data Use & Experimentation	Includes data table/screenshots, multiple trials, thoughtful adjustments	Includes trials and some analysis	Few trials or unclear adjustments	Minimal or missing data
Strategy Justification	Strong, well-supported reasoning with connections to physics principles	Adequate reasoning, minor gaps in explanation	General explanation with weak connections	Little or no justification
Team Reflection & Communication	Thoughtful reflection on learning and teamwork dynamics	General reflection covers teamwork and learning	Vague or minimal reflection	No meaningful reflection provided

Presentation Quality	Visually clear, well-organized slides; group speaks confidently and shares roles	Organized slides; group presents with some confidence	Slides lack clarity or detail; uneven participation	Disorganized or missing slides; poor team delivery

REFERENCES

- Phet Motion Simulator - https://phet.colorado.edu/en/simulations/projectile-motion
- Projectiles - why 45° give you max range - https://www.youtube.com/watch?v=du7_itMwwT4

The authors acknowledge the utilization of ChatGPT, a language model developed by OpenAI, in the preparation of this lesson plan. ChatGPT was employed in the following manner(s) within this plan: brainstorming lesson objectives, revising instructional language for clarity, and aligning the lesson with relevant science and ELA standards.