5E STEM Unit: Investigating Forces and Motion: Understanding Mass and Acceleration

(12 class periods)

Authors

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SUBJECT/GRADE LEVEL

Subject Area:

Science

Grade Level:

Middle School 6-8

Student Learning Group Structure.

- Recorder: Responsible for taking notes during the experiment, documenting observations, and collecting data.
- Task Distributor: Ensures that each group member is assigned specific tasks and manages time for each part of the experiment.
- Conclusions Analyzer: Analyzes the collected data and discusses the implications of the findings with the group.
- Data Interpreter: Interprets the data collected, helping to create graphs or charts in the science notebook.
- Note: Students will change roles to ensure that all students are equitably participating in the lesson activity.

Materials

- **Science Investigation Notebooks.**
  - Notice-Wonder Template.docx
- **Day 1 Engagement activity:**
  - Unit Trailer
  - 5–10 popsicle/craft sticks
  - 1–2 extra sticks
  - 3–4 rubber bands
  - 1 plastic spoon (optional but typical)
  - Small projectile (e.g. pom-pom, foil ball, marshmallow)

- **Day 2 Exploration activity:**
  - Various balls of different masses (e.g., golf ball, tennis ball, baseball, possibly adding small weights like coins/washers with tape),
  - ramp (cardboard, textbook stack),
  - measuring tape/meter sticks,
  - stopwatches (optional),
  - data sheets.
- **Days 3-5 Explain**
  - Catapult mini lessons.pptx (part 1)
- **Day 6-7 Elaboration Activity:**
  - Two identical gallon or half-gallon milk jugs, with handles
  - Yardstick
  - 20-inch dowel rod
  - Two large rubber bands
  - Paper bowl or cup
  - Duct tape
  - Water balloons
  - Water
  - Pencils
  - Popsicle Sticks
  - Rubberbands
  - Red Solo Cups (cut off in half)
  - Masking tape
  - 12 in Dowel Rods/Skewers
  - Straws
  - Latex Tubing
  - Stopwatch (1 per group)
  - Meter Sticks (1 per group)
  - Scales (1 per group)
  - Catapult Launcher Data Sheets.xlsx
- **Days 8-10 Evaluation:**
  - Computer
  - Catapult Presentation Choice Board & …

STANDARDS

Next Generation Science Standards

- MS-PS3-1: Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.
- MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
- MS-PS2-2: Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Mathematics Standards | Common Core State Standards

- *CCSS.Math.Content.6.EE.B.6*
  Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set.
- *CCSS.Math.Content.6.EE.B.7*
  Solve real-world and mathematical problems by writing and solving equations of the form x + p = q and px = q for cases in which p, q and x are all nonnegative rational numbers.
- *CCSS.Math.Content.7.EE.B.4*
  Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.

English Language Arts Standards | Common Core State

- *CCSS.ELA-Literacy.RST.6-8.3*
  Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
- *CCSS.ELA-Literacy.RST.6-8.1*
  Cite specific textual evidence to support analysis of science and technical texts.

LESSON OBJECTIVE(S)

- Students will be able to describe how the change in an object's motion depends on the sum of the forces acting on the object and the mass of the object.
- Students will gather and analyze data to support their conclusions about motion and forces.
- Students will apply mathematical reasoning to calculate speed and kinetic energy.
- Students will explain the relationship between mass, speed, and kinetic energy.

CAREER CONNECTION(S)

Mentor Background:

Ashley Lochetto. Modernization Team I Test Officer Munitions and Weapons U.S. Army Yuma Test Center, KOFA Firing Range Ms. Ashley Lochetto started working for the Army in June of 2015 as a Test Officer for the Combat and Automotive Systems Division at Yuma Proving Ground. As a Test Officer, she worked on multiple evaluation programs in support of the direct fire mission and served as the test subject matter expert representative for the PM Maneuver Ammunition Systems XM1147 next generation tactical tank ammunition that replaced four individual munitions in one multipurpose projectile.

In April 2017, Ashley was given the opportunity to be a civilian test officer in Combat Systems Branch at Yuma Test Center where she continued working on multiple evaluations programs. Ashley continued to work as the Direct Fire SME ushering the XM1147 projectile through research and development testing into low-rate production testing. In addition to this role, Ashley planned, conducted and reported on several other high priority tank testing programs with safety and security at the forefront. Ashley supported the test and evaluation of tank ammunition and platforms for 4 years.

She has since served 6 years on mostly research and development artillery programs as a test officer in the Munitions & Weapons Division, Modernization Branch. Ashley worked with the YTC test team to plan and complete testing on the mobile howitzer shoot-off program that supported four different artillery pieces from various countries. She has since served to be the SME on subsonic and hypersonic projectile testing along with a growing knowledge into propulsion and additional guidance and navigation efforts for munition performance. Ashley is an outgoing energetic personality, and she requested to take on more roles to better the community in serving on many STEM outreach programs to include GEMS and eCybermission each year, as well as she looks to better the test center in working with academia and industry to grow working relationships.

STEM Careers: Physicist, Mechanical Engineer, Test Pilot, Aerospace Engineer, Sports Scientist, STEM Teacher, Architect, Robotics Engineer, Military Specialist, Ballistics Test Engineer.

ENGAGEMENT

Brief Description: In this portion of the lesson, students will observe different forces acting on projectiles to produce ballistic motion. Students will also practice skills in hands-on investigation processes.
Students also have an opportunity to create their own ballistic projectile device.

Procedures:
Objective: Capture students' interest and stimulate their thinking about forces and motion.

- **Day 1-2: Engage & Introduction to Forces (Approx. 2-50 minute sessions)**
- **Objective:** Students will observe real-world examples of forces and motion, begin to identify factors affecting motion, and understand the concept of variables in scientific inquiry.
- **Materials:** Projector/Smart board, internet access, whiteboard/chart paper, markers.
- **Hands-on activity materials:**
    - 5–10 popsicle/craft sticks
    - 1–2 extra sticks
    - 3–4 rubber bands
    - 1 plastic spoon (optional but typical)
    - Small projectile (e.g. pom-pom, foil ball, marshmallow)
- **Engage (20 minutes): Observing Forces in Action**

    - Show the following videos to pique student interest and introduce the concept of force and motion:
        - Video 1: Precision Hit of Excalibur Round - Focus on the power and trajectory of the projectile.
        - Video 2: 2 Catapults out of Popsicle Sticks - Explores how mass affects acceleration
        - Video 3: Paper Rocket Launcher - Highlight the design and launch of a simple projectile.
        - Video 4: Pyramid Catapult - Additional type of catapult students can build.
    - **Discussion:**
        - "What caused the objects in these videos to move?" (Introduce the term "force").
        - "What do you think might make the projectile/rocket go farther or faster?" .
        - "In science, we often look at how one thing *changes* another(cause and effect). What kinds of *changes* did you see in the objects' motion?"
        - Introduce the idea of **variables**: "When we try to understand what causes a change, we look at different things that might *vary* or change. What are some things that *vary* in these videos?"
        - *Math Connection (CCSS.Math.Content.6.EE.B.6):* Explain that variables are like placeholders that represent quantities that can change. "We can use letters, like 'F' for force or 'm' for mass, to represent these quantities when we're thinking about them or writing about them."

- **Introduction to Inquiry (30 minutes): Planning for Investigation**
- **Student Team Structure:**
    - Recorder:
        - Responsible for taking notes during the experiment, documenting observations, and collecting data.
    - Task Distributor:
        - Ensures that each group member is assigned specific tasks and manages time for each part of the experiment.
    - Conclusions Analyzer:
        - Analyzes the collected data and discusses the implications of the findings with the group.
    - Data Interpreter:
        - Interprets the data collected, helping to create graphs or charts in the science notebook.
    - **Instructions:**
        - Students should change roles after each experiment to ensure equitable participation.
        - After building the catapult, students will launch their projectiles and observe the distance traveled.
        - Discuss how the mass of the projectile and the force applied affect the distance it travels.
    - **Reflection:**
        - Each student should reflect on their role and the group's performance after the task is complete.
        - Discuss what factors influenced the motion of the projectile and how they relate to the forces acting on it.
    - **Activity:** Brainstorm what makes objects move or stop. Create a class list of forces (push, pull, gravity, friction, air resistance).
    - **Concept Introduction:** Introduce the concepts of "net force" (the sum of all forces acting on an object) and "mass" (how much "stuff" an object has).
    - **Hands-on Activity Day 1:**
        - Have students build the simple catapult from the presented video
        - Materials required:
        - 5–10 popsicle/craft sticks
        - 1–2 extra sticks
        - 3–4 rubber bands
        - 1 plastic spoon (optional but typical)
        - Small projectile (e.g. pom-pom, foil ball, marshmallow)

Assembly Steps:

- Create the base stack
- Stack about 5 (or up to 7–10) popsicle sticks together and tightly bind both ends with rubber bands. This forms the weighted base.
- Make the arm assembly
- Take two sticks, align them, and secure one end together with a rubber band.
- Insert the base between the arm sticks
- Spread the two-stick pair slightly and wedge the base stack between them. Bind the other end of the two-stick pair to lock the base inside.
- Attach the spoon
- Lay the spoon on top of the free stick (the arm), scoop facing outward. Secure it with another rubber band around both spoon and stick.
- Load and fire
- Place your projectile in the spoon's bowl. Hold the base firmly and pull back the spoon arm. Release to launch.

- **Reading Activity:**
  - Students read a brief article on the different historical types of catapults:
  - Article webpage: https://www.real-world-physics-problems.com/catapult-physics.html
- **Pre-lab Discussion for Day 2:**
  - "Tomorrow, we're going to start an investigation to see how force and mass affect motion. What are some things we need to think about when planning an experiment?". Have Students write down in their journals what they can change.
  - *Math Connection (CCSS.Math.Content.6.EE.B.6):* Discuss how we will use variables to represent what we're changing (independent variable), what we're measuring (dependent variable), and what we're keeping the same (controlled variables). Briefly introduce the *mass* of an object 'm', the *distance* it travels 'd', and the *force* used on the object to make it move 'f'.
  - Notice-Wonder Template.docx

EXPLORATION

Brief Description: Students will explore aspects of the standard they are learning. They will interact with simulations based on their previous lesson interactions and activities. They will also conduct an experiment to enhance their understanding of the main variables of the standard as they explore how the lesson concepts are demonstrated in real life.

Procedures:

Day 3:

- **Explore - Simulation and Mass & Distance Investigation (Approx. 50 minutes)**
- **Objective:** Will engage in a simulation that represents a ballistic event. They will change conditions in the simulation and observe the results. Students will conduct an investigation to gather evidence on how the mass of an object affects its motion when a consistent force is applied.
- **Materials:**
    - Various balls of different masses (e.g., golf ball, tennis ball, baseball, possibly adding small weights like coins/washers with tape)
    - ramp (cardboard, textbook stack)
    - measuring tape/meter sticks
    - stopwatches (optional)
    - data sheets.
- **Review.**
    - Quick review of Day 1 concepts: force, mass, net force, and variables.
    - Ask students to give examples of each variable.
    - Stress the importance of units in their example.
- **Simulations. (15 Minutes)**
    - **Projectile Motion**
        - Students interact with the Phet Projectile Motion Simulator at https://phet.colorado.edu/en/simulations/projectile-motion
        - Students change variables such as mass of a projectile, the exit velocity, the force, angle, the elevation, and elevation of the cannon, gravity, and air resistance.
        - Students observe the changes in results of the experiment such as height and distance traveled by the projectile under the various experiential conditions.

    - **Projectile Data Lab:**
        - Student interact with the second simulation: https://phet.colorado.edu/en/simulations/projectile-data-lab
        - Students change the variables in the simulation such as the mechanism of launch,(spring, pressure, or combustion), launch angles, projectile types(mass), and distance traveled.
        - They formulate ideas and ask questions related to their previous learning.
        - Students complete a Know and Wonder Chart in their interactive science notebooks.
- **Experiment Set Up (15 minutes):**
    - Explain the experimental procedure for today: "How does the mass of an object affect the distance it travels when rolled down a ramp?"
    - **Hypothesis Formulation:** Students, in small groups, will write a hypothesis for the experiment. (e.g., "If the mass of the ball increases, then the distance it travels will decrease because...")
    - **Procedure Walkthrough:** Demonstrate proper technique for rolling the ball consistently from the same spot on the ramp. Emphasize consistent force.
    - Discuss controlled variables (e.g., starting height on ramp, type of ramp, surface the ball rolls on) and the independent variable (mass) and dependent variable (distance traveled)
- **Conducting the Investigation (20 minutes):**
- **Student Group Work Structure.**
    - Students will work in groups to investigate how different forces affect the motion of an object by designing an experiment that measures the effects of mass and force.
    - **Student Team Structure:**
        - Recorder: Responsible for taking notes during the experiment, documenting observations, and collecting data.
        - Task Distributor: Ensures that each group member is assigned specific tasks and manages time for each part of the experiment.
        - Conclusions Analyzer: Analyzes the collected data and discusses the implications of the findings with the group.
        - Data Interpreter: Interprets the data collected, helping to create graphs or charts in the science notebook.
    - Task Steps:
        - Students briefly discuss the relationship between mass, force, and motion. Introduce the concept of conducting an experiment to explore these relationships
        - As a group, students decide how to set up the ramp and how to measure the distance traveled by the toy car.
        - Students determine how you will vary the mass (adding weights) and the force applied (by pushing the car).

- **Conducting the Experiment**
  - The Task Distributor will assign roles and responsibilities.
  - The Recorder will document the setup and results in the science notebook.
  - The Data Interpreter will help in noting measurements and timing the car's travel.
  - Each group member will take turns applying different forces and changing the weights on the car.
- **Data Collection**
  - Measure and record the distance traveled and time taken for each trial in the science notebooks.
  - Repeat trials with different weights and forces as time allows.
  - Group Discussion (2 minutes):
  - Discuss the results as a group.
  - The Conclusions Analyzer will summarize the findings and suggest possible explanations for the results observed.
- **Wrap-Up:**
  - Each group should ensure that their science notebook is filled with notes that reflect their procedures and findings.
  - After completing the task, each student should reflect on their roles and contributions, considering how varying mass and force influenced the motion of the toy car.
  - Prepare to share key findings with the class in the next session.
- **Students, in small groups, perform the experiment.**
  - Measure and record the mass of each ball.
  - Roll each ball down the ramp 3-5 times, releasing from the *exact* same point each time.
  - Measure the distance each ball travels from the end of the ramp.
  - Calculate the average distance for each ball.
  - *Challenge:* If time allows, students can add small, consistent weights to one type of ball (e.g., taping coins) and re-test to see the effect of increased mass on the *same* object.
- **Data Collection (CCSS.Math.Content.6.EE.B.6):** Ensure students are clearly labeling their data tables with appropriate variables (e.g., "Mass of Ball (g)", "Trial 1 Distance (cm)", "Average Distance (cm)").

- **Clean Up & Initial Observations (5 minutes):**
  - Collect materials.
  - Ask students to summarize initial observations in their science journals/interactive notebooks: "What did you notice about the balls with different masses?"
  - Instruct students to continue to fill out their Notice-Wonder charts for future lessons
  - Ask students how they can connect the experiment to their observations in the simulations.

EXPLANATION

Brief Description: Students will receive a mini lesson on Potential and Kinetic Energy and how this energy is transferred from one to the other. They will then gain understanding of Newton's Second law of motion, its application of projectile motion and the relationships of the transfer of energy and motion. Students will solve mathematical equations to calculate Force, acceleration, and mass given the formula and specific variables. Students will receive a mini lesson on the Potential and Kinetic energy to solidify prior knowledge. Students will then receive a detailed explanation of Newton's Second Law of Motion including how to complete calculations to solve for different variables of the corresponding formula. Students will also explore the different aspects of projectile motion. Students will then synthesize these lessons into a complete understanding structure on how all these concepts interact and influence each other.

Procedures:

Day 4-6:

Explain: Mini Lesson on Potential, Kinetic, and Transfer of Energy: (15 Minutes)

Objective: Students will gain an understanding of energy and Newton's Second Law of Motion.

Materials:

Catapult mini lessons

- **Definition of Energy**
  - Energy is the ability of an object to move or do work
  - Energy can be transferred from one object to another.
  - There are several types of energy.
  - Our focus will be on Potential and Kinetic energy.
  - Energy is measured in joules.
- **Defining Kinetic Energy**
  - **Kinetic energy** is the energy of moving matter. Anything that is moving has kinetic energy—from atoms in matter to stars in outer space.
  - Things with kinetic energy can do work.
  - For example, when you throw a football, the moving football has Kinetic Energy.
  - The amount of kinetic energy in a moving object depends directly on its mass and velocity. An object with greater mass or greater velocity has more kinetic energy.
- **Defining Potential Energy**
  - **Potential Energy** is the amount of energy in an object that can be converted to Kinetic Energy.
  - **Gravitational Potential Energy** is the Potential energy in an object based on its position above a certain other position on the Earth.
    - For example, a skydiver in a plane has Gravitational Potential Energy because the skydiver is above the ground.
    - Gravitational Potential Energy is based on the Earth's gravitational pull on objects.
    - Gravitational Potential is transformed into Kinetic Energy when the object falls.
    - The farther from the Earth the greater the greater an object's Gravitational Potential Energy

- **Elastic Potential Energy**
  - Potential Energy due to an object's shape is called Elastic Potential Energy.
  - This energy results when an elastic object is stretched or compressed by a force.
  - The farther the object is stretched or compressed, the greater its Potential Energy is. (for example, when the arm of the popsicle stick catapult is bent back.)
  - A point will be reached when the object can't be stretched or compressed anymore.
  - When the external force is removed, it will forcefully return to its original shape.
  - When an object returns to its original shape, The Elastic Potential Will be transferred from the compressed object into another object resulting in Kinetic Energy (This happens when the catapult launches the object. The object moves from the catapult to the target.)

- **Main Lesson:**
  - Students will use Cornell Notes to record pertinent information from the lesson.
- **Newton's Second Law of Motion.**
  - **Academic Vocabulary.** Students are first introduced to the academic vocabulary they will be using for this lesson unit.
    - Mass: The Amount of Material in an object measured in Kilograms(kg.)
    - Acceleration: The change over an object's speed over a unit of time usually measured in meters per second squared. (m/s^2)
    - Force: An action that changes or maintains the motion of a body or object measured in Newtons(N).
      - 1 Newton = $1kgm/s^2$
  - **Newton's Second Law.**
    - Students are introduced to Newton's second law of motion and its application on their previous lesson scenarios.
    - Brief lesson video. Newton's Second Law of Motion.
    - Newton's second law of motion describes how force and mass affect acceleration. The law states that the acceleration of an object equals the net force acting on the object divided by the object's mass. This can be represented by the equation: ***F=ma***
  - **Calculation of Force, Velocity, Mass.**
    - Students are provided the definition of Newton's second Law of motion and the corresponding formula of Force = mass x acceleration or F= ma.
    - Students understand how the application of a force to an object can cause motion based on their observations in their previous lesson experiments.
    - Students are also presented with the relationships of all three variables

    - **Force and Acceleration (Direct Relationship):**
        - Newton's second law states that the acceleration of an object is directly proportional to the net force acting on it.
        - This means a greater force leads to greater acceleration.
        - If you double the force applied to an object with constant mass, its acceleration will also double.
        - Expressed by the equation F = ma, where if 'm' is constant, 'F' is directly proportional to 'a'.
    - **Mass and Acceleration (Inverse Relationship):**
        - The acceleration of an object is inversely proportional to its mass.
        - This means a greater mass leads to smaller acceleration for the same applied force.
        - If you apply the same force to an object with twice the mass, it will experience half the acceleration.
        - This highlights inertia: greater mass means greater resistance to changes in motion and harder to accelerate.
        - Expressed by the equation F = ma (or a = F/m), where if 'F' is constant, 'm' is inversely proportional to 'a'.
- **Calculation of Force, mass, and acceleration.**
    - Students use the online Force calculation tool to practice solving related variables.
    - f=ma calculator
- **Ballistic or Projectile Motion**
    - Students interact with the Projectile motion simulator.
    - Archery simulation
    - Students receive an explanation of ballistic or projectile motion that describes the motion of the object launched from their catapult.
        - Projectile motion describes the curved path an object takes when thrown at an angle, due to gravity.
        - An object moving at an angle has both horizontal and vertical velocity components.
        - Gravity only affects the vertical component of velocity; the horizontal component remains constant.
        - The path of a projectile is parabolic.
        - The vertical velocity decreases as the object ascends, becomes zero at the maximum height, and then increases as it descends.
        - When a cannon fires a ball, the maximum range is achieved at a 45-degree angle.
        - This is because at 45 degrees, both the time the ball is in the air and its horizontal velocity are optimized for maximum range.
        - The initial vertical velocity of both stones in the cliff scenario is zero, so they fall at the same rate and land simultaneously, regardless of horizontal speed.
- **Summation and Student Understanding.**
    - Students analyze the concepts of energy transfer, Newton's Second law of Motion, and Projectile Motion.

- They come to the conclusion that:
  - Potential Energy in their catapult is being transferred from the catapult to Kinetic energy in the projectile.
  - The Energy transfer creates a Force (F) on their projectile (m).
  - The amount of the Force (F) on their projectile (m) determines how fast (a) their projectile will travel.
  - External factors such as the Earth's Gravity and the angle of launch, combined with the acceleration of the projectile will determine the distance the projectile will travel.

- **Formative Assessment.**
  - Students will take a four question formative assessment to gauge understanding of concept and algebraic thinking skills.
  - An extension question will be provided as well
    - Question one: Mass of an object is 25kg, Acceleration is $10m/s^2$. Calculate the Force on the object in Newtons.
    - Question two: A projectile is accelerating at $30m/s^2$ with a force of 270N. What is the mass of the projectile?
    - Question 3: How much Force is needed to accelerate the projectile to $50ms^2$?
    - Question 4: A second projectile is launched with the same Force in question 3 but with a mass of 5kg. What is its acceleration?
    - Extension Question. The projectile encounters some wind that increases its acceleration to $120ms^2$. How much force did the projectile gain?





ELABORATE

Brief Description:

- **Elaborate:** Students choose the catapult they wish to create, gather materials, create the launcher, and collect data.
- **Objective:** TSW engage in the creation of a catapult themselves.
- **Materials:**
  - Two identical gallon or half-gallon milk jugs, with handles
  - Yardstick
  - 20-inch dowel rod
  - Two large rubber bands
  - Paper bowl or cup
  - Duct tape
  - Water balloons
  - Water
  - Pencils
  - Popsicle Sticks
  - Rubberbands
  - Red Solo Cups (cut off in half)
  - Masking tape
  - 12 in Dowel Rods/Skewers
  - Straws
  - Latex Tubing
  - Catapult Launcher Data Sheets.xlsx

Procedures:

Days 7-8 :
Catapult Launcher Engineering

- **Introduce Catapult Options for Engineering:** On Day 6, clearly explain the options students have for engineering.
  - Students will work in groups to view various catapult options to decide which catapult to build. Advanced students could potentially use their own design as long as it only needs the materials we have available AND will be finished by day 7.
    - Water Balloon Catapult
    - https://www.msichicago.org/science-at-home/hands-on-science/water-balloon-catapult
    - Science Max Catapult
    - https://www.youtube.com/watch?v=gOFWm4xbSro
    - Young Engineers: Pyramid Catapult
    - https://www.youtube.com/watch?v=Zg1Pz0WUMW4
    - Water Balloon Sling Shot
    - https://www.instructables.com/Water-Balloon-Slingshot-in-3-minutes/

    - Students will have one day to decide which catapult launcher to build and one day to build their catapult.
    - Groups should test their catapult to ensure it can handle the weight of a water balloon before launch day.
- **Requirements:**
    - Catapult must include a way to launch a small water balloon.
    - Catapult must be launched 3 times.
        - Students will record the mass of the water balloon, the distance launched measured each time, as well as the time it took for the water balloon to land.
        - Students will use the basic formulas to determine the speed, kinetic energy, Acceleration, and Force:
          Speed= Distance/Time,
          Kinetic Energy= 1/2mass*velocity^2
          Acceleration= velocity^2-initial velocity^2/ 2*distance
          Force= mass* acceleration

Day 9: Launch Day: Catapult Testing

- **Elaborate Continued:** Students will test their catapults and record data on the data sheet linked above.
- **Objective:** Groups will test their engineered catapults to look at the net forces that act on the water balloon as it flies through the air, how much time it takes to land, how far the water balloon launches, if mass affects that, etc.
- **Materials:**
    - Group Engineered Catapults
    - Waterballoons
    - Scales
    - Meter Sticks
    - Stopwatches
- **Introduce Set Up:**
    - Show students the line where catapults can be shot from and the direction they are to be shot.
    - Students will launch the catapults three times.
- **Data Recording:**
    - Groups will record their data: the mass of the water balloon, the distance launched measured each time, as well as the time it took for the water balloon to land.

- **Learning Group Structure**
    - **Recorder:**
        - Responsible for taking notes during the experiment, documenting observations, and collecting data.
    - **Task Distributor:**
        - Ensures that each group member is assigned specific tasks and manages time for each part of the experiment.
    - **Conclusions Analyzer:**
        - Analyzes the collected data and discusses the implications of the findings with the group.
    - **Data Interpreter:**
        - Interprets the data collected, helping to create graphs or charts in the science notebook.
- **Calculations of Speed, Kinetic Energy, Acceleration, and Force:**
  Groups will use the basic formulas in Google Sheets when data is recorded to determine the speed, kinetic energy, acceleration, and force. These figures will automatically be calculated for them once distance, mass, and time are entered into the sheet.
    - Speed= Distance/Time,
    - Kinetic Energy= = 1/2mass*velocity^2
    - Acceleration= velocity^2-initial velocity^2/ 2*distance
    - Force= mass* acceleration
- **Summation and Student Understanding:**
    - Groups will analyze their data to answer the CER questions: “How are speed, mass, and acceleration related?” & “How are force, mass, and acceleration related?”

EVALUATION

Brief Description:

- **Evaluation:** Students choose options from a choice board to give them direction on how to prepare their overall presentation of which catapult they chose to create and how it performed.
- **Objective:** TSW present their overall findings by choosing a presentation method from a choice board.
- **Materials:**
  - Catapult Presentation Choice Board & Rubric.docx
  - **Choice Board:** A document outlining various presentation options
  - **Rubric:** A scoring guide detailing the specific criteria and performance levels for evaluating the overall presentation, regardless of the chosen method. This will cover aspects like:
    - **Catapult Design & Construction:** Explanation of the chosen design, materials, and build process.
    - **Data Analysis:** Presentation and analysis of quantitative and qualitative data gathered during testing.
    - **Conclusions:** Interpretation of results, identification of variables affecting performance, and conclusions drawn.
    - **Presentation Quality:** How well the information is presented, logical flow, and ease of understanding.
    - **Clarity & Cohesion:** How clear the presentation is and how it flows.
  - **Computers:** For accessing digital resources, creating presentations, and potentially editing videos.

Procedures:

Days 10-12:

Over these three days, students will dedicate their time to compiling their comprehensive findings into a final presentation.

1. **Introduce Choice Board:** On Day 8, clearly explain the choice board options, review examples (if available), and clarify any questions students might have about each method.
2. **Review Rubric:** Thoroughly go over the rubric, explaining how each criterion will be assessed. Emphasize that the content requirements are consistent across all presentation options, even if the format differs.
3. **Student Selection:** Students will choose their preferred presentation method from the choice board. You might consider having them briefly justify their choice to ensure they've thought it through.

4. **Work Session:** Students will use the remainder of Days 8-10 to work individually or in pre-assigned groups (depending on your project structure) on their chosen presentation. Provide ample time for research, data compilation, content creation, and refinement.
    a. Learning Group structure
        i. **Recorder:**
            1. Responsible for reporting notes taken during the experiment: observations and collected data.
        ii. **Task Distributor:**
            1. Ensures that each group member is assigned specific tasks and manages time for each part of the presentation creation.
        iii. **Conclusions Analyzer:**
            1. Analyzes the collected data and discusses the implications of the findings with the group.
        iv. **Data Interpreter:**
            1. Places the created graphs or charts in the presentation.

***All students will share in the reporting process.**

Students should practice sharing parts of the presentation before presenting.*

5. **Teacher Support:** During these work sessions, circulate among students to provide guidance, answer questions, and offer constructive feedback. This is a good time to check for understanding and ensure students are on track with their chosen method and the rubric requirements.

CATAPULT PRESENTATION CHOICE BOARD

PRESENTATION FORMAT: CHOOSE 1 THE "LAUNCH & LEARN" STYLE	Create a physical or digital display board. Include sections for design, hypothesis, experimental setup, data (with charts), results, and conclusion. Prepare to explain each section verbally.	If feasible, demonstrate your catapult. Use a digital presentation (e.g., Google Slides) for data charts, design explanation, and conclusions. Include photos/videos of launches.	Create a 3-5 minute video. Include footage of design, construction, and launches. Integrate data charts and a clear voice-over explaining design, data, and conclusions.
NECESSARY INFO: PART 1 CHOOSE 1 THE "DATA DEEP DIVE"	Present at least three distinct data charts comparing mass and distance and charts explaining the relatioinship between kinetic energy, mass, and speed and the relationship between force, mass, and acceleration(e.g., bar graph, scatter plot, line graph). Explain trends, outliers, and what each chart reveals.	Present data charts. Explain how these statistics support your conclusions about mass and distance, kinetic energy, mass, and speed, and force, mass, and acceleration.	State a hypothesis about mass vs. distance and a hypotheesis about kinetic energy, mass, and speed as well as a hypothesis about force, mass, and acceleration before presenting results. Compare actual results to your prediction. Discuss why predictions were accurate or inaccurate, linking to design/experimental conditions.
NECESSARY INFO: PART 2 CHOOSE 1 THE "DESIGN & DISCOVERY" SPOTLIGHT	Provide detailed diagrams or schematics of your catapult, labeling components and materials. Explain the function of each part and how they work together. Discuss design choices and their intended impact.	Share your design process, including initial sketches, prototypes, and modifications. Discuss construction challenges and how you overcame them. Explain how design changes impacted performance.	Focus on the materials you chose and why (strength, flexibility, cost). Explain the physics principles at play (leverage, potential energy, projectile motion) in student-friendly terms.
NECESSARY INFO: PART 3 CHOOSE 1 THE "CONCLUSION & BEYOND" REFLECTION	Summarize key findings. Discuss major successes and challenges. Propose at least two specific improvements to your catapult or experiment for the future.	State your main conclusion. Discuss any unanswered questions or new hypotheses that arose. Suggest future experiments that could build upon your findings.	Summarize findings. Discuss how the principles learned apply to real-world engineering or physics concepts (e.g., trebuchets, sports equipment, space launches).

PRESENTATION RUBRIC

Category	4: Exemplary	3: Proficient	2: Developing	1: Beginning	0: Not Evident
Catapult Design	Provides a comprehensive, clear, and highly engaging explanation of the catapult's materials, features, and mechanism. Design choices are thoroughly justified with scientific principles.	Clearly explains the catapult's materials, features, and mechanism. Design choices are generally justified.	Describes most materials and some features, but the mechanism or rationale for design choices is unclear or incomplete.	Lists some materials but provides little to no explanation of design, features, or mechanism.	No description or explanation of the catapult design is provided.
Data Analysis	Presents data (mass, distance for 3 balloons) clearly and accurately using appropriate and highly effective visuals/methods for the chosen format. Data is thoroughly analyzed, interpreted, and trends are explicitly and insightfully discussed.	Presents all needed data clearly and accurately using appropriate visuals/methods for the chosen format. Data is analyzed, interpreted, and trends are discussed.	Presents some data, but either didn't include some needed data or visuals/methods may be unclear or inaccurate, or not fully appropriate for the format. Analysis and interpretation of trends are superficial or incomplete.	Data is presented in a disorganized or inaccurate manner, or is incomplete. Little to no analysis or interpretation is provided.	No data is presented or analyzed.
Conclusion	Offers a profound and insightful summary of findings, challenges, successes, and highly creative/feasible future improvements directly supported by evidence.	Provides a clear summary of findings, challenges, and successes. Offers relevant and feasible suggestions for future improvements.	Summarizes some findings, challenges, or successes but lacks depth or clarity. Future improvements are vague or impractical.	Attempts a conclusion, but it is unclear, incomplete, or does not address findings, challenges, or improvements adequately.	No conclusion is provided.
Presentation Quality	Chosen format is executed with exceptional professionalism, creativity, and attention to detail. All content is well-organized, easy to follow, and highly engaging. Meets all specific requirements of the chosen format (e.g., time limits, word counts, visual clarity).	Chosen format is executed professionally and clearly. Content is well-organized and easy to follow. Meets most specific requirements of the chosen format (e.g., time limits, word counts, visual clarity).	Chosen format shows some effort, but organization is lacking, clarity is sometimes an issue, or key requirements of the chosen format are not met.	Chosen format is disorganized, unclear, or incomplete. Many specific requirements of the chosen format are missing or poorly addressed.	Presentation is incomplete, unintelligible, or not submitted in the chosen format.
Clarity & Cohesion	The entire presentation is exceptionally clear, logical, and flows seamlessly. All parts are connected, demonstrating a deep understanding of the project as a whole and the interrelationships between design, data, and conclusions.	The presentation is clear, logical, and generally cohesive. Most parts are connected, showing a good understanding of the project and its components.	The presentation has some clear sections but lacks overall logical flow or cohesion. Connections between parts of the project are weak or not fully evident.	The presentation is difficult to follow, illogical, or fragmented. Connections between project parts are largely absent, making it hard to understand the overall purpose.	The presentation lacks any discernible structure or coherence.

REFERENCES

- Provide links to resources that you used in the creation of this unit.
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- Water Balloon Catapult
- https://www.msichicago.org/science-at-home/hands-on-science/water-balloon-catapult
- Science Max Catapult
- https://www.youtube.com/watch?v=gOFWm4xbSro
- Young Engineers: Pyramid Catapult
- https://www.youtube.com/watch?v=Zg1Pz0WUMW4
- Water Balloon Sling Shot
- https://www.instructables.com/Water-Balloon-Slingshot-in-3-minutes/

- The author(s) acknowledge the utilization of Gemini, a language model developed by Google, in the preparation of this lesson plan. Gemini was employed in the following manner(s) within this plan: brainstorming & grammatical correction for the Elaboration and Explanation portion of the lesson plan.
- The author(s) acknowledge the utilization of inVideo, an AI-powered video creation platform developed by a company of the same name, in the preparation of this lesson plan. inVideo was employed in the following manner(s) within this plan: to create the trailer based on a script. The author then edited the trailer, script, images, and clips to fit the needs of the unit.

ADDITIONAL RESOURCES

- Unit Trailer
- Unit Trailer Option 2
- Water Balloon Ballistics Challenge
- Gifted and Talented Extensions
- Additional Readings Specifically for Elementary Level