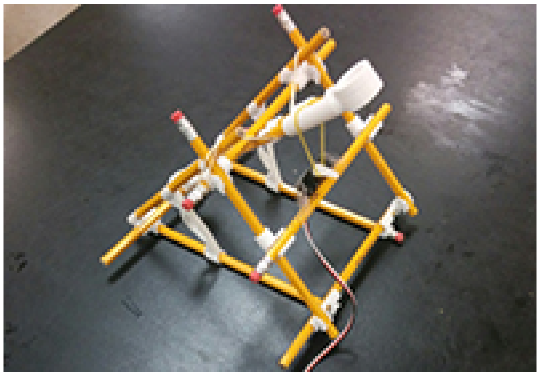
Ready, Aim, Launch!



Background/Context

Students will use this lesson to discover how the mass of a projectile affects the distance it will travel when launched. The students will also understand the difference between potential and kinetic (mechanical) energy.

At a Glance

- **Age Level**: 12-14
- **Subject**: Science
- **Time Needed**: 2, 50 minute lessons

Learning Objectives

Students will be able to describe the transformation of potential energy to kinetic energy, or vice versa, in systems with no external force applied.

Standards Alignment

Next Generation Science Standards
MS-PS3.B
When the motion energy of an object changes, there is inevitably some other change in energy at the same time.
Common Core State Standards CCSS.MATH.CONTENT.HSA.CED.A.1
Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational and exponential functions.
Asking Questions and Defining Problems

Asking questions and defining problems in grades 6-8 builds from grades K-5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models.

- Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles. (MS-PS2-3)

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 6-8 builds on K-5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

- Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. (MS-PS2-2)
- Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation. (MS-PS2-5)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6-8 builds on K-5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Apply scientific ideas or principles to design an object, tool, process or system. (MS-PS2-1)

Engaging in Argument from Evidence

Engaging in argument from evidence in 6-8 builds from K-5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world.

- Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (MS-PS2-4)

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS2-2), (MS-PS2-4)

Inquiry Process

Students will make a hypothesis to determine how the mass of an object will affect the distance the object will fly. They will build a standardized catapult and use it to launch different objects. The students will need to program a servo and attach it to the catapult to be the release mechanism for the catapult. The students will need to determine the mass and also measure how far the object travels. Then they will compare the data to determine the correlation between mass and distance. Then the students will finish their lab reports with a discussion of their findings and the applications of this new knowledge.

Prerequisite Skills

The analysis used in this activity uses the law of conservation of energy. The law states that energy can transform from one form to another. Determining the amount of energy the projectile has during its flight allows the energy supplied by the rubber band to be determined. The different types of energy used in the analysis are described below.

Gravitational Potential Energy
All objects on Earth are subject to a gravitational force, whether or not they are in contact with the Earth. This force has the potential to speed up falling objects. The higher the object is, the more speed it will gain when it falls. Potential energy is quantitatively determined as:
PE = (mass)(gravity)(height) = mgh
It is also important to note that SI uses the unit called the Joule, abbreviated with J, to dene energy. In order for this formula to be properly applied, the mass of the object must be recorded in kg. Also, the height must be recorded in meters.

Kinetic Energy
Gravity has the potential to speed up falling objects. As an object falls, it loses potential energy and gains energy related to its speed. This type of energy is referred to as kinetic energy. Kinetic energy is determined as the energy of motion. Kinetic energy is quantitatively determined as:
PE = (mass)(gravity)(height) = mgh
Just as mentioned earlier, the SI unit for energy is the Joule. In order for this formula to be properly applied, the mass of the object must be recorded in kg. Also, the velocity must be recorded in meters per second.

Elastic Potential Energy
Most of the energy supplied to the projectile comes from the elastic potential energy of the rubber band. This amount of energy depends on how far the rubber band is stretched.
Elastic potential energy is quantitatively determined as:
$EPE = \frac{1}{2}(\text{spring constant})(\text{distance stretched})^2 = \frac{1}{2}kx^2$
The spring constant is a value that depends on the strength of the rubber band. It will not be necessary to know the spring constant of the rubber band to complete this activity.

Mechanical Energy
The mechanical energy of an object is determined to be the sum of all of its energy. The projectile launched from the catapult will have both kinetic and potential energy during its flight. As it rises, some of its kinetic energy will be converted into potential energy. And as it falls, its potential energy will be converted to kinetic energy. But the amount of mechanical energy will always remain constant as it represents the total energy.

Modifications/Accommodations

Some students may need additional guiding to help them discover the new knowledge.

Technology and Resources

This catapult was made with 3D printed parts but any catapult can be built with popsicle sticks and rubber bands. The Arduino 101 servo will need to be programmed to be the release mechanism for the catapult.

Activity

Procedure

1. Measure the mass of the projectile and record it in Table 1.

- • Table 1: Launch Set Up
  - Mass of Projectile (g)
  - Launch Height (cm)
  - Launch Angle ()

2. Measure the launch height of the projectile and record in Table 1.

- • See Figure 2: Launch Height

3. Determine the launch angle and record it in Table 1.

- • Using right triangles, can be shown to be the complimentary angle of the angle on the bottom front of the catapult.

4. Launch the projectile a couple of times to get used to how far it tends to go. To launch, load the projectile into the basket. Pull the lever arm back to the lever arm stopper and connect the servo to get ready to release.

5. Launch Projectile!

- • With a group of three people, have a group member stand back and watch for the highest point of the projectile over its trajectory. Then place a sticky note on the wall at the highest point.
  - Have the third member measure the time the projectile is in the air with a stop-watch. Record this in Table 2.

6. Measure the distance (where it lands) traveled by the projectile and record this value in Table 2.

7. Repeat Steps 5 and 6 for a total of three trials under the same conditions.

8. Calculate the average of time of flight, highest point reached, and distance traveled. Record in Table 2.

Calculations

1. Determine the Gravitational Potential Energy from the height the projectile is launched and record this value in the Calculations Table.

2. Determine the Gravitational Potential Energy at the average of the highest point reached during the flight and record this value in the Calculations Table.

3. Determine the velocity of the projectile at the highest point. This is possible because the projectile is not moving upwards or downwards at this instant. It is only moving sideways. Determine the velocity and record the velocity in Table 3.

4. Calculate the kinetic energy of the projectile and record it in Table 3.

5. Using the calculations, generate a formula to determine the amount of elastic potential energy contained in the rubber band. Write the formula below and use it to calculate the elastic potential energy and record this value below.

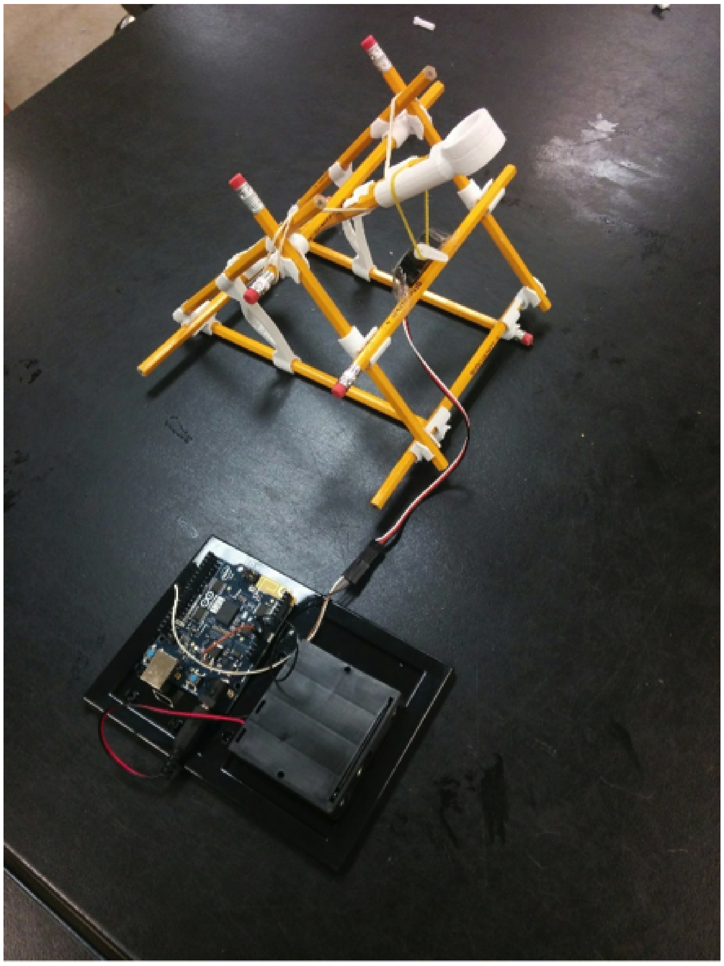
6. Draw two bar graphs. Draw one of the mechanical energy (ME), elastic potential energy (EPE), kinetic energy (KE), and gravitational potential energy (GPE) before launch and one showing ME, EPE, KE, and GPE after the catapult launch when the projectile is at the highest point of the launch. Use appropriate labels.
Figure 3: Projectile Path

7. Observe Figure 3 and then draw two bar graphs. Draw one for the ME, EPE, KE, and GPE for Point A (the instant after launch) and one for the ME, EPE, KE, and GPE for Point B (The instant just before it hits the ground). Use appropriate labels.

Assessment

Formative assessments will be made throughout the lesson. Teacher observations to effectively guide students to their learning through questioning. The teacher should have a checklist to determine if the students completed each step correctly. Another formative assessment will be a quick 5 question quiz relating to the lab. The summative assessment will be the lab report to determine the depth of each student's learning.

Additional Tips and Information



Source

Nicholas Peterson, Teacher, Richland 2 School District, South Carolina, USA
Students will discover how the mass of a projectile affects the distance it will travel when launched and understanding the difference between potential and kinetic (mechanical) energy.