Philadelphia Museum of Art

Physics at the Art Museum: Kinetic Energy, Potential Energy, and Work

This lesson plan explores kinetic and potential energy in relation to a tool familiar to knights and soldiers of the middle ages and early Renaissance: crossbows. What is kinetic energy? What is potential energy? At what point in a reaction does an object possess kinetic or potential energy? During the course of this lesson plan, students will also use the Physics in Art app

Grade Level

Grades 6–9

Common Core Academic State Standards

- CCSS. Mathematical Processes, Gr. 7
- CCSS. ELA-Literacy.L.6
- CCSS. ELA-Literacy.L.3

Pennsylvania Academic Standards

- 9.1.8.A.1.

Art Images Required

Click on the titles below to view high-resolution photographs on the Philadelphia Museum of Art website. Images that are also available in the Artstor Digital Library are indicated by an ID number or search phrase.

- *Crossbow*, c. 1470–1500, Austria
  Artstor: Conduct a simple search for "crossbows"

Etching and engraving

Image: 8 3/4 x 5 7/16 inches (22.3 x 13.8 cm)
Mount: 22 1/16 x 16 5/16 inches (56.1 x 41.5 cm)

The Muriel and Philip Berman Gift, acquired from the Pennsylvania Academy of the Fine Arts, 1985

1985-52-34312

Lesson Objectives/Essential Questions

1. What are examples of kinetic energy?
2. What are examples of potential energy?
3. What is happening to an object at the points where it has kinetic and/or potential energy?

Materials Needed

- iPad with projection capability (or several iPads for student use)
- Physics in Art app, available as a free download through the Apple store
- Ramp and marbles

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Lesson Process

PART 1: BEFORE APP USE — INTRODUCTION

1. Set up a ramp in the front of the classroom (use textbooks to build one if no ramp is available). Roll a marble down the ramp and push/roll it up the ramp. Describe what is happening to the marble:
    a. At the bottom of the ramp.
    b. At the top of the ramp.
    c. At the middle of the ramp.
    d. Why do you think this happens?
2. The marble is doing "work" as it moves across the ramp. Work equals force multiplied by distance. At each point on the ramp, the marble has a different amount and type of energy.
    a. At the top of the ramp, the marble has potential energy.
        i. What does potential mean?
        ii. The marble has potential energy at the top of the ramp because it is not moving, but has the potential to.
    b. While the marble is traveling down the ramp, it has kinetic energy.
        i. What does kinetic mean?
        ii. The marble has kinetic energy because it is in motion down the ramp.
    c. What type of energy does the marble have at the bottom of the ramp? Does it have more or less of this type of energy at the bottom or at the top?
    d. What would happen to the amount of kinetic energy if we made the ramp steeper or less steep?
3. Have the students stand with enough space to spread their arms. The students will explore the concepts of work, kinetic energy, and potential energy by doing jumping jacks.
    a. Have the students stand in an X position, with their arms above their shoulders in a wide V and legs apart in an inverted V.
    b. Have them hold this position and ask them: What type of energy do you have? What are you getting ready to do? (Answer: Storing potential energy that is waiting to be converted into kinetic energy to complete the jumping jack.)
    c. Ask them to complete the jumping jack.
        i. Remind them: As you move, you are creating kinetic energy. When you pause, you are holding potential energy that will be used when you move again.
        ii. Ask them: At what points in your jumping jack did you have potential energy? At what points in your jumping jack did you have kinetic energy?
        iii. Ask them: How does your potential and kinetic energy change when you make your jumping jack faster? Slower?

PART 2: USING THE *PHYSICS IN ART* APP

1. Students should complete Appendix 1 while exploring the app individually, or in small groups.
2. Check in with students as they are using the app to clarify the physics concepts and ask them for their observations about the colors of the paintings.
3. Discussion (suggested: think, pair, share):
    a. What is the benefit of a crossbow?
    b. What is the difference between the kinetic energy of a bow and arrow and the kinetic energy of a crossbow?
    c. What is the difference between the potential energy of a bow and arrow and the potential energy of a crossbow?
    d. How does the kinetic energy and potential energy of the bow and arrow and the crossbow affect the distance and speed in which the arrow or bolt travels?

Assessment

In pairs, have students review the section of the Physics in Art app that highlights Alexander Calder's mobile, *Ghost*. They should compare the kinetic and potential energies of *Ghost* using one of the systems from the list below, and following the guided questions in Appendix 2. The student pairs will present their findings to the class, including their conclusions of how kinetic and potential energies are present in the mobile and in the system they have selected.

- Pair 1: Roller coaster and car driving
- Pair 2: Ball and an arrow
- Pair 3: Air plane and yacht
- Pair 4: Train and bus
- Pair 5: Crossbow and bow and arrow

Enrichment

Review the equation in Step 2 of Part 1: "Work equals force multiplied by distance." Use this formula to experiment with values for work, understanding that information for "force" is limited.

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Appendix 1: Guided Notes

Physics in Art: Kinetic Energy, Potential Energy, and Work

DESCRIBE THE CROSSBOW:

_____

_____

_____

WHAT DO YOU SEE?

_____

_____

_____

WHAT ARE THE PRIMARY PARTS THAT YOU SEE?

_____

_____

_____

DESCRIBE THE PARTS OF THE CROSSBOW:

_____

_____

_____

WHAT WERE CROSSBOWS USED FOR?

_____

_____

_____

WHAT IS THE FUNCTION OF EACH PART OF THE CROSSBOW?

Bow:	**Trigger:**	**Bolt:**	**Stirrup:**
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Appendix 1: Guided Notes (cont.)

SHOOTING AN ARROW AND A CROSSBOW:

How do you do work when shooting an arrow?

_____

_____

What is the formula for work?

_____

_____

How do you give the bowstring potential energy?

_____

_____

How do you give the bowstring kinetic energy?

_____

_____

What is kinetic energy?

_____

_____

The more potential energy in the string, the more _____ in the arrow.

_____

_____

What does the crossbow allow us to do more of?

_____

_____

Which travels faster—an arrow show from a crossbow or an arrow shot from a bow?

_____

_____

DESCRIBE THE DIFFERENCES BETWEEN A CROSSBOW AND A TRADITIONAL BOW AND ARROW:

1. _____
   _____
   _____

2. _____
   _____
   _____

3. _____
   _____
   _____

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Appendix 2: Assignment

Physics in Art: Kinetic Energy, Potential Energy, and Work

Name: _____ Date: _____

DRAW A DIAGRAM OF BOTH OF YOUR SYSTEMS. MARK THE POINTS AT WHICH THE SYSTEM HAS KINETIC ENERGY (KE) AND POTENTIAL ENERGY (PE):

PICK A POINT AT WHICH BOTH OBJECTS HAVE POTENTIAL ENERGY. WHICH OBJECT HAS MORE POTENTIAL ENERGY? (NOTE: THE OBJECTS ARE NOT DOING THE SAME AMOUNT OF WORK. USE YOUR KNOWLEDGE OF THE OBJECT TO ANSWER THE QUESTION.):

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Appendix 2: Assignment (cont.)

PICK A POINT AT WHICH BOTH OBJECTS HAVE KINETIC ENERGY. WHICH OBJECT HAS MORE KINETIC ENERGY? (NOTE: THE OBJECTS ARE NOT DOING THE SAME AMOUNT OF WORK. USE YOUR KNOWLEDGE OF THE OBJECT TO ANSWER THE QUESTION.):

WHICH SYSTEM IS DOING MORE WORK? WHY?

WHY DO THE SYSTEMS HAVE DIFFERENT KINETIC AND POTENTIAL ENERGIES AT GIVEN POINTS?