

Energy Flow in Technological Systems

We are learning to identify and measure energy transformations in mechanical systems and to explain why energy conversions are never 100 percent efficient.



Figure 1: A bicycle leaning against a wall in a workshop or garage setting

Learning intentions

We are learning to:

- Recognize and describe evidence of energy in motion and position
- Distinguish between kinetic and potential energy in real systems
- Calculate work and energy using fundamental equations
- Explain why useful energy decreases through each stage of a technological system

Success criteria

I can:

- Identify kinetic and potential energy in everyday objects and machines
- Apply the equations $E_p = mgh$, $E_k = \frac{1}{2}mv^2$, and $W = Fd$ to solve problems
- Explain why energy transformations always produce heat loss
- Analyze the efficiency of an energy conversion device using real data

Curriculum alignment

- Explain and apply concepts used in theoretical and practical measures of energy in mechanical systems ([Outcome](#))
- Analyze and illustrate how technologies based on thermodynamic principles were developed ([Outcome](#))
- Apply the principles of energy conservation and thermodynamics to investigate efficiency ([Outcome](#))

Materials

- Metre stick or measuring tape
- Basketball or similar ball (mass approximately 0.6 kg)
- Stopwatch or smartphone timer
- Ramp made from a board propped at 20 to 30 degrees
- Toy car or wheeled object (mass approximately 0.2 kg)
- Thermometer
- Cup of water (250 mL)
- Ruler
- Printed data table (provided below)
- Whiteboard or chart paper
- Calculator (scientific or standard)

Lesson sequence

Stage 1: Hook (5 minutes)

Ask students: "When you drop a ball from the roof of the school, where does the energy come from that makes it hit the ground hard? And where does that energy go when the ball stops bouncing?"

Invite three students to predict answers aloud without discussion. Write their predictions on the board without comment.

Drop a basketball from waist height and let it bounce three times. Ask: "What changed in the ball's motion? What changed in the ball's shape? What changed in the temperature of the ball and the ground?" Pause for responses. Acknowledge that all three changes are evidence of energy being present and transferred.

Stage 2: Direct instruction (12 minutes)

Define kinetic energy as energy due to motion ([Outcome](#)). Write the equation on the board: $E_k = \frac{1}{2}mv^2$. Explain that the faster an object moves, the more kinetic energy it has, and that the relationship is not linear because velocity is squared.

Define potential energy as energy due to relative position or condition ([Outcome](#)). Explain gravitational potential energy specifically: the higher an object sits, the more potential energy it stores. Write the equation: $E_p = mgh$. Clarify that m is mass in kilograms, g is the acceleration due to gravity (9.8 m/s^2), and h is height in metres.

Introduce work as energy expended when an object is moved against an opposing force ([Outcome](#)). Write the equation: $W = Fd$. Explain that F is force in newtons and d is displacement in metres.

Work through one complete example:

A 0.6 kg basketball is held 2.0 metres above the ground.

Calculate its gravitational potential energy:

$$E_p = mgh$$

$$E_p = 0.6 \text{ kg} \times 9.8 \text{ m/s}^2 \times 2.0 \text{ m}$$

$$E_p = 11.76 \text{ J (joules)}$$

Explain: "This tells us that 11.76 joules of energy are stored in the ball because of its position. If we drop the ball from rest, all of that potential energy converts to kinetic energy as it falls."

Now calculate the velocity of the ball just before it hits the ground using energy conservation ([Outcome](#)):

$$mgh = \frac{1}{2} mv^2$$

$$11.76 \text{ J} = \frac{1}{2} \times 0.6 \text{ kg} \times v^2$$

$$11.76 = 0.3 v^2$$

$$v^2 = 39.2$$

$$v = 6.3 \text{ m/s}$$

Explain: "The ball reaches a speed of 6.3 metres per second. We can verify this makes sense because the kinetic energy at impact equals the potential energy we started with."

Introduce the concept of energy transformation. Explain that energy changes form constantly in technological systems ([Outcome](#)). In a car engine, chemical energy in gasoline transforms to thermal energy (heat), which transforms to mechanical energy (motion). In a solar panel, light energy transforms to electrical energy.

State the key principle: energy is conserved, but useful energy decreases with each transformation ([Outcome](#)). When a light bulb converts electrical energy to light, some electrical energy also converts to heat. That heat is not useful for lighting, so it represents lost useful energy.

Stage 3: Guided practice (10 minutes)

Set up the ramp. Place the toy car at the top of the ramp and release it. Ask students to predict whether the car will travel farther on a smooth floor or a carpeted floor. Record predictions.

Release the car on both surfaces and measure how far it travels each time. Record the distances.

Ask: "Why did the car travel farther on the smooth floor? What happened to the kinetic energy it had when it left the ramp?"

Guide students to conclude that friction converted kinetic energy into thermal energy (heat in the carpet and the car's wheels). The useful energy (motion) was lost to heat.

Now work through a calculation as a class:

Suppose the car has a mass of 0.2 kg and leaves the ramp with a velocity of 3.0 m/s.

Calculate its kinetic energy:

$$E_k = \frac{1}{2} mv^2$$

$$E_k = \frac{1}{2} \times 0.2 \text{ kg} \times (3.0 \text{ m/s})^2$$

$$E_k = 0.1 \times 9.0$$

$$E_k = 0.9 \text{ J}$$

Ask: "If the car came to rest on the smooth floor after travelling 1.5 metres, how much work did friction do on the car?"

Guide students to use $W = Fd$. Rearrange to find F :

$$W = Fd$$

$$0.9 \text{ J} = F \times 1.5 \text{ m}$$

$$F = 0.6 \text{ N}$$

Explain: "Friction exerted a force of 0.6 newtons over a distance of 1.5 metres, doing 0.9 joules of work on the car and converting all its kinetic energy to heat."

Stage 4: Independent practice (10 minutes)

Distribute the data table and problem set below. Students work in pairs or individually.

Problem Set:

1. A 2.0 kg object is lifted 1.5 metres above the ground. Calculate its gravitational potential energy.
2. A 0.8 kg ball is dropped from a height of 3.0 metres. Assuming no air resistance, calculate:
 - a) Its potential energy at the top
 - b) Its velocity just before it hits the ground
 - c) Its kinetic energy just before it hits the ground
3. A force of 50 N is applied to push a box 4.0 metres across a floor. Calculate the work done on the box.
4. A car with a mass of 1500 kg accelerates from rest to 20 m/s. Calculate its kinetic energy at 20 m/s.
5. Explain why a car engine that converts chemical energy in gasoline to kinetic energy (motion) also produces heat. Where does the heat come from?

Circulate and check calculations. Ask follow-up questions: "What does this number tell you about the object?" "Why did you choose that equation?" "What would happen if the height were doubled?"

Stage 5: Consolidation (3 minutes)

Bring the class together. Ask three students to share one answer from the problem set. Address any calculation errors on the board.

Return to the opening question: "When you drop a ball from the roof, where does the energy come from?" Answer: from the gravitational potential energy stored in the ball's position. "Where does it go when the ball stops bouncing?" Answer: into heat in the ball, the ground, and the air. No energy is lost; it is transformed into forms that are no longer useful for motion.

State: "Next lesson we will measure the efficiency of real devices and see how much useful energy is actually captured in technological systems."

Differentiation

Extension

Challenge students to design a ramp-and-car experiment to test whether the height of the ramp affects the distance the car travels. Have them predict the relationship, collect data, and graph the results. Ask them to explain the relationship using energy concepts. They should recognize that doubling the height doubles the potential energy and therefore increases the velocity and distance proportionally.

Assign the problem: "A 70 kg student climbs a staircase that rises 4.0 metres. How much work does the student do against gravity? If the student climbs the stairs in 8.0 seconds, calculate the power (power = work ÷ time, measured in watts)." This introduces work as energy expended when the speed of an object is increased, or when an object is moved against the influence of an opposing force.

Support

Provide a worked example card that shows all steps for calculating E_p and E_k . Allow students to use this card during independent practice.

Reduce the problem set to three questions and focus on kinetic and potential energy only, omitting work calculations initially.

Pair students with a peer who is confident in algebra and rearranging equations. Have the confident peer explain each rearrangement step aloud before the student writes it.

Use a concrete demonstration: hold a ball at different heights and ask students to predict which height will produce the greatest bounce. Measure the bounce heights and relate them back to the potential energy equation.

Assessment

Formative checkpoint during Stage 4:

Observe students as they work through the problem set. Look for:

- Correct substitution of values into the equations $E_p = mgh$, $E_k = \frac{1}{2}mv^2$, and $W = Fd$
- Correct use of units (kg, m, m/s, N, J)
- Correct arithmetic and use of the order of operations (squaring velocity before multiplying by mass and 0.5)
- Ability to explain what the calculated number represents in physical terms

Ask individual students: "What does this joule value tell you about the object?" If a student cannot connect the number to a physical meaning (such as "the energy stored" or "the work done"), provide the sentence frame: "This number tells me that the object has ____ joules of ____ energy because ____."

Record which students need additional practice with equation selection and algebraic rearrangement. Plan a brief follow-up session before the next lesson for these students.